MANUAL

OF

OPIUM HUSBANDRY,

FOR THE USE OF OFFICERS IN THE GOVERNMENT AGENCIES

BEHAR AND BENARES.

JOHN SCOTT, F.L.S.,

Honorary Member of the Agri-Horticultural Society of India, Curator of the Royal Botanic Gardens, Calcutta, (on special duty) attached to the Opium Department.

Published by Authority of the Board of Revenue, L. P.

Calcutta:

PRINTED AT THE BENGAL SECRETARIAT PRESS.

1877.

PREFACE.

THIS manual has been drawn up at the request of A. Money, Esq., C.B., Member of the Board of Revenue, who is desirous to have, in a concise and readily consultable form, the general results of my experiments and observations on the opium poppy, with a view to their circulation amongst the officers of the department.

Those for whom this treatise is chiefly intended are well aware of the facilities which have been afforded me for the study of the poppy plant, I having been for the past four years attached to the Opium Department, by order of the Government of India, with a special view to the field-study of the plant in its various stages of growth, so as to ascertain, if possible, the nature and cause of the more serious diseases which affect it, and also to make suggestions as to its general improvement as a drug-producer.

In passing this work from my hands, I wish it to be distinctly understood that it is issued with no pretensions on the writer's part to teach the more experienced officers of the department anything new in the ordinary husbandry of the plant. It may, however, prove an useful initiatory treatise for the junior officers, and on a few special points it may even convey hints and illustrations not unuseful to those of a senior grade. I here allude to the mode of seed selection, the microscopic structure of the capsule, the phenomena of drug-secretion and circulation, and the nature and modes of treating the different diseases and injuries to which the plant is subject in the various stages of its growth; all subjects, I need scarcely remark, of much practical and scientific interest.

To these few explanatory remarks then, I will but add that, in case I may some day be called upon to draw up a new edition of this manual, I shall feel grateful to any officers of the department who will favour me with any original observations or opinions—adverse or otherwise—bearing on those recorded in this little treatise.

JOHN SCOTT.

BANKIPORE,
July 1876.

TABLE OF CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

APPENDIX.

TABLE G. PAGE.

TABLES H, I, AND J.

TABLE K.

TABLE L.

MANUAL

OF

OPIUM HUSBANDRY.

CHAPTER I.

THE SOILS OF CULTIVATION.

1—*Introductory remarks.* 2—*Humus soils or vegetable moulds.* 3—*Loamy soils.* 4—*Marly and calcareous or limy soils* 5—*Argillaceous or clayey soils.* 6—*Siliceous or sandy soils.* 7—*Gravelly or drift soils.*

In considering the conditions under which the opium poppy may be most successfully cultivated, it is of prime import to have regard to the soil; its physical properties, and the more predominant of its chemical ingredients. We may thus with some degree of certainty select a soil suited to the known requirements of the poppy, which, though none of the nicest or most fastidious of feeders, has nevertheless its likes and dislikes. It is indeed, pronouncedly a *potasso-lime* lover, requiring also as other essential auxiliaries, *carbon*, *nitric acid*, and the organic alkalies—*ammonia*, *&c.* It is thus that soils with a fair proportion of the above mineral and organic constituents, though of the most diverse basic character, may, and will produce a vigorous crop, of copious drug-yielding poppy. Let us now, briefly describe the more characteristic of our Indian poppy soils.

2. *Humus soils* of a loamy, marly, or calcareous character are those perhaps, on which the poppy thrives best. They vary in colour from a dark, almost blackish-brown, to a light greyish-brown, according as the humus (vegetable mould), or the earthy admixtures preponderate. Soils however with a preponderance of vegetable mould are anything but common in our poppy districts. Indeed, they are chiefly found in the immediate vicinity of the villages, and have thus been converted from their natural earthy character by the continued addition of vegetable refuse, the excrements of man and animals, &c. The most highly productive plots are, as might be expected, those so located and conditioned.—I would obviate this want of organic matters in the generality of the poppy soils (and also supplement the inefficient supply of other manures),—really the failing quality, by the culture of green crops on the poppy lands during the rains, which I would have cut

and dug into the soil in time to have all thoroughly decayed ere the poppy sowing time. ...... I may observe here that the relative proportions of organic and earthy matters in such soils may be readily ascertained by drying a sample upon paper, in an earthenware or other vessel over the fire (care being taken that the heat is not sufficient to char the paper), until it forms a dry powder and ceases to lose weight to further exposure at the same temperature. A weighed sample of this being then taken and thoroughly burned in the open air. The loss by burning—allowing a small percentage for water—indicates the amount of organic matter in the soil.

3. *Loamy soils* are also well suited for poppy cropping. They are variously characterised according to their proportionate admixture with clay, lime, and sand. We have thus the so-called clayey or sandy loams, &c., indicating in the first an excess of clay, the latter of sand, and correspondingly a *cold* and *moist*, and a *hot* and *dry soil*. Such soils, as I have remarked, meet well the wants of the poppy, as they indeed do, those of the generality of agricultural products. Named and arranged as they are according to the quantity of clay, sand, and lime they may happen to contain, the practical cultivator may determine with sufficient accuracy the relative proportion of their components by the following simple plan suggested by Professor Johnston in his excellent treatise on agricultural chemistry and geology. Thus "if an ounce of soil be intimately mixed with a pint of water till it is perfectly softened and diffused through it, and if after shaking, the heavy parts be allowed to settle for a few minutes the *sand* will subside, while the *clay*, which is in finer particles, will still remain floating. If the water and fine floating clay be now poured into another vessel, and be allowed to stand till the water has become clear, the *sandy* part of the soil will be found on the bottom of the first vessel, and the clayey part on that of the second, and they may be dried and weighed separately." It may be remarked here that the clayey portion of our Indian soils is very generally in such an impalpable state, that when well diffused in water, the latter after standing for days will still be dull or cloudy. It is thus tedious to wait until the water becomes clear, but a sufficiently accurate result for all practical purposes may be attained by allowing a slight excess above the weight of the portion deposited for that still held in suspension. To resume.—Professor Johnston continues, "if 100 grains of dry soil (not peaty or unusually rich in vegetable matter) leave no more than 10 of clay when treated in this manner, it is called a *sandy soil*; if from 10 to 40, a *sandy loam*; if from 40 to 70, a *loamy soil*; if from 70 to 85, a *clay loam*; from 88 to 95, a *strong clay soil*; and when *no sand* is separated at all by this process, it is a pure agricultural clay." The *strong clay soils* are those used for making *tiles* and *bricks*, while the pure *agricultural clay* is commonly used in the manufacture of pipes, and is well known as *pipe clay*. ...... *Soils* of pure clay, however, rarely occur, it being well known to all practical men that the strong clays (*tile clays*), which contain from 5 to 15 per cent. of sand, are brought into arable cultivation with the greatest possible difficulty. It will rarely, almost never, happen, therefore, that arable land will contain more than 30 to 35 per cent.

of alumina."—As regards the poppy lands in the Government agencies those of the south Gangetic plain would appear to be very generally a *sandy clay* or *loam*, as above defined. Thus, I have had before me analytic results of these soils from various parts of the south Gangetic plain, and I find them varying in composition from 2 to about 10 *per cent.* of *clay* and from 75 to 90 and upwards of *sand* or siliceous matter. Again, in that part of the north Gangetic plain over which poppy culture extends the soils are very frequently of a more clayey nature, and in many places sufficiently retentive of moisture to enable the cultivator to dispense with artificial irrigation in the culture of the poppy. Even here, however, and especially in the flat alluvial tracts in the vicinity of the Ganges and its tributaries, the soil not unfrequently is of a light and sandy character, and the poppy must be regularly irrigated.

4. *Marly soils* and *calcareous* or *limy soils.*—A *marly soil* is such as contains from 5 to 20 per cent. of lime, while those containing above 20 per cent. of lime are called *calcareous*, and may of course either be *sandy* or *clayey*, according as one or other forms the basic constituent. To estimate the proportion of lime in such soils "a sample should be heated in the air till the organic matter is burned away. A weighed portion (200 or 300 grains) should then be diffused through half a pint of cold water mixed with half a wineglassful of spirit of salt (*muriatic acid*), and allowed to stand for a few hours with occasional stirring. When minute bubbles of gas cease to rise from the soil the water is poured off, the soil dried, heated to redness as before, and weighed: the loss is nearly all lime, unless the soil happen to contain a large quantity of magnesia, or of oxide of iron in combination with carbonic acid, or with some organic acid, which is not often the case." (*Johnston's Agricultural Chemistry and Geology*, p. 92.)—Such soils are confined to the limestone and chalk formations, and in the latter case, when largely mixed with clay, become extremely difficult to work. They are also cold and moist, unfavourable to the germination of the seed, and tend to retard the ripening of the crop. On the other hand. lime with loam or a sandy clay, as a base, affords a highly favourable soil to many of our most important agricultural plants: included amongst which is the opium poppy. It is indeed highly probable that the comparatively high drug-produce of certain parts of the Gya division, as also the adjoining portions of that of Shahabad—which lie over or in the vicinity of the limestone formation, and its outcrops—may be thus explained. Anyhow, Shahabad and Gya, are two divisions which, as a rule, give the highest average return of drug, and both lie largely in a limestone region. Analyses of poppy soils from the Gya district have also afforded from $5\frac{1}{4}$ to $7\frac{1}{2}$ per cent. of lime. As regards poppy then, I am strongly disposed to attribute the higher general fertility of those divisions to the relative richness of their soils in lime.

5. *Argillaceous* or *clayey soils* are so called as having as a basic component *argil* or *oxide of alumina.* The purer clay soils, as we have seen, are of no agricultural value whatever; they are inert, cold, wet, and tenacious or sticky, soaking large quantities of water when it falls or is poured upon them, though possessing comparatively low powers of absorbing moisture from the atmosphere. They thus in dry weather, sooner than many other kinds of soil, form a hard crust on the

surface, alike unfavourable to the absorption of heat from the atmosphere or evaporation from their soddened under-layers. In small portions, however, clay is an essential component of all the more valuable agricultural soils: highly fertile ones, contain from 5 to 15 per cent., while those containing 20 and upwards become increasingly barren and utterly sterile to the agriculturist when abounding to the extent of 80 or 85 per cent., though of course long ere that worthless for arable operations. In the north Gangetic divisions of the Behar Agency clay abounds sufficiently in the soil to retain, as has been remarked, a sufficiency of moisture (in all but exceptionally dry seasons) for the growth and maturation of the poppy, thus saving the cultivator all the labour and expense of the oft-to-be-repeated, artificial irrigations. Fairly fertile soils from the experimental gardens at *Deegah*, contain from 5½ to 8 per cent. of clay, and a series of samples from the most fertile of the irrigated plots in the Hajeepore division afforded from 2½ to 6¼ only.

6. *Siliceous or sandy soils* comprehend those containing upwards of 80 per cent. of siliceous and micaceous matters. Such soils are loose and friable, readily absorbing atmospheric heat, and thus valuable as affording the earliest crops, while they are also much less difficult to till, than those of a clayey or marly nature. "In fertile soils," remarks Donaldson, "it—*sand*—averages 50 to 80 per cent.; it absorbs one-fourth of its weight of water without dropping, and evaporates twice as fast as chalk and three times faster than clay. It forms the chief constituent in most soils, forming upwards of nine-tenths of their whole weight." In limestone districts, however, it is frequently largely mixed with lime, and then, as Solly remarks, "these differences in the proportion of the earthy components give rise to the varieties of light or free, and stiff or clayey soils, which are also modified by a greater or less quantity of organic matters."—Samples of soils from the Deegah experimental gardens, as shown by Mr. Pedler's analysis, contain from 78 to about 80 per cent. of siliceous sand; while four samples collected by myself from the most highly fertile plots in the Hajeepore division were found by Mr. Pedler to contain from 83¾ to upwards of 87: the average being about 86 per cent. In the case of one very poorly productive plot from which I brought a sample, it was found to contain 90½ per cent. of silica with 2⅓ of clay, 2¼ of iron oxide, and only 0·449 of lime. The majority of the poppy soils in both agencies, I believe, have as their predominant component silica, and thus present themselves as sandy clays, loams and the like. Such soils in homely phraseology are termed "*hungry soils*," as speedily decomposing manurial applications. This is due to their loose and incohesive texture and their low powers of retaining moisture: thus readily permeable by air and moisture, organic matters rapidly decay in them, and from their open nature, manurial matters are carried down by rains beyond the range of the roots of most of the green and cereal crops. To sustain any high degree of fertility in such soils, frequent applications of manure are thus more than in other kinds necessary.

7. *Gravelly or drift soils* consist of water-worn detritus and fragments of rock, and are thus more local than those of a fine sandy or

argillaceous character. They vary in texture from a simple admixture of sand and small stones to a gravelly loam or clay. The former class are of course barren and unproductive, the latter, as having, in addition to sand and pebbles, or the like, an admixture of loam, clay, or calcareous matter, are not unfrequently susceptible of profitable arable culture. Indeed, when iron is not in excess (as very generally occurs in gravelly soils), and a sufficient quantity of loam or vegetable mould mixed with the gravel, an excellent soil is afforded for early cropping purposes: when loam and vegetable matters predominate, next to light or moderately light loams, they are considered the very best for garden purposes. In tropical countries they are, as a rule, however, difficultly manageable, and expensive to maintain in arable culture. This is due to their loose texture and consequent rapidity of giving off moisture, or allowing it to pass down beyond the range of the roots (unless bedded on an impervious subsoil): the absorption of heat from the sum being also more rapid, they soon acquire a temperature scorchingly destructive to all cereal or green crops.

CHAPTER II.

ARTIFICIALLY IRRIGATED AND NATURALLY IRRIGUOUS LANDS.

1—*The relative extent of those lands under poppy in the two agencies.* 2—*Poppy as a rule more productive on the irrigated, than the unirrigated lands.* 3—*The general characters of the soil in the poppy district.* 4—*The comparative influence of variety and climate on the hygroscopic condition of the soil.*

THE relative extent of the artificially irrigated and naturally irriguous lands in the two agencies (Behar and Benares) is widely different. Thus, in the season of 1871-72 while there were only about $2\frac{1}{4}$ times more of the former than the latter class of lands in the Behar Agency, the proportion in the Benares Agency was as 56 to 1. In the latter agency the irriguous lands pertain chiefly to the Goruckpore and Bustee divisions, and small portions to those of Fyzabad and Lucknow. In the Behar Agency they are wholly confined to the six divisions north of the Ganges, the relative proportion of the two being as $1\frac{1}{8}$ to 1 in favour of the irriguous, the major portion of which extends along the older alluvial deposits to the east of the Gunduck river. It is also to be observed that in the Benares Agency the irriguous lands pertain to the same deposits. Thus, in the Goruckpore division they lie along the central tract between the Raptee and Gunduck rivers, in Bustee to the west of the latter river, and in Fyzabad between the Gogra and Goomtee rivers. It is to be observed that the central shed of all these Gangetic tributaries consists largely of the later tertiary beds, superposed on a stiff and, less or more impervious bed of variously coloured clay; whilst towards and along their banks we have a deposit of more recent and lighter alluvium. On the latter tract the poppy requires artificial irrigation, whereas on the former the crop attains maturity by the natural moisture of the soil.

2. Under such conditions, however, the poppy thus treated would appear to be altogether less productive than that on the regularly irrigated lands. Thus, by referring to the Agent's annual report for 1871-72, I find that while the irrigated lands on the south Gangetic plains, afford an average of *four seers eight and a half chittacks*, those on the four largely irriguous north Gangetic divisions yield only, some *three seers and six chittacks* per beegha. These relatively low returns, however, of the latter class of lands is, as I am disposed to believe, rather the result of a lower system of husbandry (their having no complement of irrigative water: *a prime manurial agent*), than any real disparity in their agricultural capabilities. I will not dwell upon this point here, however, as it will be discussed subsequently. For the present we have simply to do with the physical properties of the soil, and especially those facilitating or otherwise the absorption and retention of water.

3. With regard to the nature of the poppy soils throughout both agencies, it may be remarked that, with some trifling local exceptions, natural and artificial, there is considerable uniformity; the later tertiary deposits extending very generally over the north or upper Gangetic tracts, with the exception of the river valleys and their streamlets, on which we very generally find deposits of a more recent alluvium. The south Gangetic districts are somewhat more varied, though here again we find by far the major part of the cultivation confined to the sandstones and shales of the coal measures, these being interposed very generally with layers of "kunker" (a nodular, concretionary, argillaceous limestone), less or more impregnated with iron, and all overlaid to a varying depth, with a sandy clay or loam of a pale, dirty brown or reddish colour. This is somewhat broken on the left bank of the Soane by a strip of limestone, while the Gya division in part and Monghyr wholly, lie among trappean and granitic rocks with the schists, slates, and grits of the metamorphic series. The soil is very generally a light sandy clay, becoming stiffer in the vicinity of the felspathic rocks. Again, in the Chota Nagpore division the older rock systems are principally developed, notably Palamow (the finest poppy district of the division), where there is a large development of micaceous slates and trap-rocks, with the coarse conglomerates of the coal measures. These form a broad irregular swatch, surrounding the district like an atoll or lagoon island, and opening to the south-east. The overlying soil is generally of a stiffish nature, forming a hard crust in the hot weather, though under irrigation producing excellent poppy and other crops in the cold weather.

4. Now, throughout this Gangetic division of the poppy area, comprising upwards of 220,000 beeghas; irrigation is everywhere necessary for the maturation of the crop. This, it may be remarked, is not wholly due to the mere physical properties of the soil, being deficient (as compared with the naturally irriguous lands on the north Gangetic plain), of the qualities of absorbing and retaining moisture, but on the other hand, largely to the reduced rainfall, the prevalence during the cold season of dry westerly winds, and an altogether less humid atmosphere. As regards the mere physical properties of the soil, I know from personal observations that plots of less

or more extent in the southern districts are quite as retentive, and highly absorptive of moisture, as many of those in the opposite Gangetic districts which require no artificial irrigation. There can thus, as it appears to me, be no question, that the different hygroscopic conditions of the soils are rather due to climatic differences than in their properties for retaining and absorbing moisture from the atmosphere. Again, as showing that the hygrometric condition of the atmosphere during the cold season is not sufficient in all cases to afford the supplemental moisture necessary for the wants of the poppy, we not unfrequently find in proximity to each other—I would especially mention the Hajeepore district—plots of insufficiently retentive soil, due mayhap, to a gravelly or very pervious subsoil, requiring frequent irrigation, while others are irriguous enough for the maturation of the crop. I have thought it worth while to draw attention to these reciprocal relations of soil and climate on the irrigation or non-irrigation of the poppy in different districts, as showing how slightly the actual hygrometric condition of the districts referred to, is in excess of the necessary requirements of the poppy. It is important to note this, as I have not unfrequently heard it remarked on with surprise that the opium culture should be so largely confined to tracts where artificial irrigation is necessary, while many other parts of India could afford a sufficiently moist soil and atmosphere for all its wants. Now, in so far as relates to the mere growth of the plant, or its culture as an oil-producer only, I do not doubt that the transposition would be successful, but I am strongly of opinion that any opium produced under such conditions would be of very inferior quality. This, I think, is shown by the fact that even in Behar, with prevalent easterly winds—always less or more humid—the opium, relatively to that under westerly winds, is of very inferior quality. What then could we expect from crops grown and matured under such high conditions of humidity? I would anticipate a drug of passewah-like colour and consistency, and even that in small quantity, for reasons to be explained in a subsequent chapter of this little treatise.

CHAPTER III.

TILLAGE, OR THE MECHANICAL TREATMENT OF THE SOIL.

1—*The native husbandry of the poppy lands.* 2—*The native plough and hingah or clod-breaker.* 3—*Pulverization of the soil: its fertilising influence.*

The tillage, or mechanical treatment of the poppy lands, is an important branch of the plant's husbandry. After the maturation of the poppy, the lands are, as a rule, fallowed for some two and a half months only, *i.e.*, until the commencement of the rainy season, during which period all the more assiduous cultivators endeavour to have cattle folded on them. The earliest fall of rain is taken advantage of: the surface is broken up by the plough, and Indian-corn, one or other of the millets, &c., sown thereon. These crops are harvested by the middle of September or earlier, when flocks of sheep or cattle, if available, are again folded upon the lands. Ploughing is also commenced and repeated at short intervals until the middle of October or later, when the land must be bedded for seed sowing. Such is briefly the annual routine treatment of the land between the harvesting of the one season's poppy, and the sowing of that of the consecutive season.

2. The plough in use by the natives, however, is a most inefficient implement,—breaking up but the mere crust of the soil. A great advantage would doubtless accrue from deeper tilth, as in exceptional cases only would there be any danger of opening up any fresh soil, containing matters noxious to vegetation. The soil is very generally of an alluvial character and of a very uniform quality for more than the depth to which it would be desirable to have it stirred up. Now, it is obvious that the few inches of soil in tilth, and consecutively cropped for centuries (with but scant, and in many cases, no manurial application at all), would be greatly benefited by having some two or three inches of the fresh under soil (rich in all those plant food-stuffs of which the overlying crop-bearing layer had been exhausted), broken up and mixed with it.—As regards the use of the plough in thus deepening the tilth, it must be admitted that there are serious difficulties in the way; the poor ryot not having means to incur additional outlay on the preparation of his land, and the cattle at his command being simply unfit for the draught of the most shallow cutting of English or American ploughs. The only way of obviating this difficulty would thus be to use the kodalee, by which the soil could easily be turned over to a depth of from nine to twelve inches. This should be done immediately after the harvesting of the poppy, so as to expose the larger surface, as long as possible to the action of the atmosphere. Its proper pulverization could then be effected by the ordinary native implements —the *plough* and *hingah*—and an enriched bed thus prepared for the future crop. Soils thus treated might be cropped with advantage also during the rains, the crop being harvested at latest by the middle of September, so that the land might again be ploughed, reploughed, and thoroughly pulverised by the middle of October, when the sowing of the poppy crops should be commenced.

3. The repeated breaking up and exposure to sun and air of the soil surface has a most important fertilising influence. In the first place, it has an effect similar to that of frost in higher latitudes: the sun in this case withdrawing the moisture, separating the particles, and thus tending to its ready pulverisation. Besides this merely mechanical effect, there are also important chemical changes promoted; thus, as being freely and uniformly permeable by air and water, the former is decomposed, and, as Sir H. Davy observes, "ammonia is formed by the union of the hydrogen of the water with the nitrogen of the air, and nitric acid by the union of the oxygen and nitrogen. The oxygen may also unite with the carbon contained in the soil and form carbonic acid and carburetted hydrogen." The importance of the pulverization of the soil indeed cannot be too strongly impressed on

the native agriculturist. "If a field," remarks Liebig, "is to produce a crop corresponding to the full amount of food present in it, the first and most important condition for its accomplishment is, that its physical state be such as to permit even the finest rootlets to reach the spot where the food is to be found They must not be obstructed by the cohesion of the soil. Plants with their delicate roots cannot grow on a tenacious heavy soil, even with abundance of mineral food." One of the earliest writers on improved husbandry—Jethro Tull—indeed estimated the process of pulverization so highly, that he fancied the soil's virgin fertility might be thus sustained for ever! The beneficial effects of the process were early recognised. Virgil in his Georgics, with the modern agriculturist, insists that "a soil to be fertile, must, above all things, be light and friable, and this condition we seek to bring about by the operation of ploughing." Cato asks—"Wherein does a good system of agriculture consist? In the *first* place, in thorough ploughing; in the *second* place, in thorough ploughing; and in the *third* place, in manuring;" and again, "ploughing the land simply means rendering the earth porous and friable, which tends to increase its productiveness." This opening up or loosening of the surface soil should also be carefully attended to in the earlier stages of the poppy crops, and indeed continued regularly after each watering (as the soil otherwise soon forms a hard, impermeable crust, unfavourable to healthy growth), until the foliage of the crops has quite covered the soil, so as to check any rapid evaporation and subsequent crusting of the surface.

CHAPTER IV.

THE SOIL: ITS EXHAUSTION AND RENOVATION.

1—*The effects of mixed cropping on the soil.* 2—*The comparative tilth of the poppy lands, and those of the cereal and pulse crops.* 3—*The early American agricultural practices.* 4—*Special and general exhaustion of the soil.* 5—*The renovation of the fertility of the soil.* 6—*The alternation of crops.*

It need scarcely be remarked that all soils under an unconservative system of husbandry will sooner or later be exhausted, in so far as regards the purposes of a remunerative cultivation. The general modes of husbandry as practised by the natives of this country must inevitably lead to the exhaustion of the soil in the above sense. They, as a rule, practise the most superficial tilth, take from two to three crops from their land annually, affording the soil little or no extraneous returns in the way of manure. Moreover, they adopt no regular system of rotation, but repeat from season to season the particular cold and rainy season crops which they find most remunerative, until the soil becomes as it were sickened of them, and then only do they adopt that mixed system of cropping (*i.e.*, sowing together various kinds of cereal and green crops) which, though doubtless temporarily successful, is of all the others the most exhaustive to the soil, when unrecouped by extraneous manurial applications. Such mixed crops, of the most varied kinds, drawing as they do on all the different mineral food-stuffs that the soil contains, do thus correspondingly accelerate the ultimate and complete exhaustion of the soil. "The constituents of the soil," remarks Liebig, "are the farmer's capital; the element of food supplied by the atmosphere, the interest of the capital; and by means of the former he produces the latter. In selling the produce of his land, he thus alienates a portion of his capital and the interest; while in returning to the land the constituents of the soil removed in the crops, he simply restores his capital to the field. In altogether alienating the crops of his fields, he deprives the land of the conditions of their reproductiveness, and a system of farming based upon such principles justly deserves to be branded as a "system of spoliation."

2. The poppy lands, though poorly tilled, scantily, if at all, manured, and over-cropped from season to season incessantly, with little or no alternation, do nevertheless, as a rule (with those of indigo), receive the most of the native agriculturist's care. The poppy, indeed, more than indigo, is a labour-requiring, and precarious plant. The latter being a rainy season crop, and its growth wholly dependant on the natural moisture of the soil and humidity of the atmosphere, thus requiring little care after the plants overshadow the soil and check the growth of weeds; whereas in the case of the poppy, from the seed sowing to the harvesting, it is a continued care, with oft recurrent labour.—To return, however, to the soil, its mechanical treatment and cropping characteristics, as bearing on the question of soil exhaustion. As regards the mere mechanical treatment of the soil, there can be no question that at least a large portion of the poppy lands are subjected to a very effective *surface tilth*. Generally from the beginning or the middle of September to the middle or close of October the lands are run over with the native plough and hingah, at intervals of from ten days to a fortnight. This, so far as it goes, effects a very fair pulverization, but the depth of tilth being only some three or four inches, of course the development of the roots of the crop must necessarily be checked, and consequently the whole parts of the plant. This evil is intensified from year to year, the restricted and superficial root range of the crops tending to the undue diminution of all the more important mineral food-stuffs of the plant, induces a less vigorous habit, and renders it altogether more precarious: the ultimate evil effects being further accelerated by the withdrawal of the whole crop from the soil, with little or no compensation in the way of extraneous matters. The culture of the crop thus, generally speaking, tends to a low ebb, and it has been remarked by one of the most experienced and observant officers in the department—Mr. King, Shahabad—that old poppy cropped lands within his knowledge produce now a very much less vigorous crop than they did in former years, and this he attributes wholly to impoverishment of the soil. That this has not as yet been more generally felt may be due to the fact that, the poppy, less than any other of our green or cereal crops, depends on the natural humidity of the soil or atmosphere, having a regular artificial supply, and the productiveness of the soil may thus be prolonged by the beneficial chemical actions and reactions thereby induced. The ultimate evil, however, under such conditions can only

be retarded for periods varying with the original composition of the soils; the inevitable result is at last the same. Under such modes the soil must needs be reduced to a state of absolute exhaustion.

3. "Rational agriculture," remarks Liebig, "in contradistinction to the spoliation system of farming, is based upon the principle of restitution; by giving back to his fields the conditions of their fertility, the farmer insures the permanence of the latter...... The deplorable effects of the spoliation system of farming has been nowhere more strikingly illustrated than in America, where the early colonists in Canada, as in the states of New York, Pennsylvania, Virginia, Maryland, &c., found tracts of land which for many years by simple ploughing and sowing yielded a succession of abundant wheat and tobacco harvests; no falling off reminded the farmer of the necessity of restoring to the soil the constituents carried away in the produce. We all know what has become of these fields! In less than two generations, though originally teeming with fertility, they were turned into deserts, and in many districts brought to a state of such absolute exhaustion that even now, after having lain for more than a hundred years, they will not yield a remunerative crop of a cereal plant. The American farmer despoils his field without the least attempt at method in the process. When it ceases to yield him sufficiently abundant crops, he simply quits it, and with his seeds and plants betakes himself to a fresh field; for there is plenty of good land to be had in America, and it would not be worth his while to work the same field to absolute exhaustion."—*Modern Agriculture, pp.* 180 *et seq.* A very similar practice to that of the American backwoods-men is still carried on in the valleys and on the flanks of the Himalayas (as elsewhere in the less densely populated parts of India), by the hill tribes, who will laboriously cut and burn a mass of heavy jungle over a more or less extensive area, dig it roughly as the rainy season sets in, and at once sow it with Indian corn, murwa, or some of the other millets, &c. They continue cropping it thus for some three or four seasons (longer in the valleys), when it is abandoned for its infertility, and the labour of clearing another plot of jungle land undertaken. Thus in recurrent quadrennial or septennial periods do those rude agriculturists, shift from their failingly fertile lands, until they are naturally recouped. Even this, however, seems to be limited, and we find many of the hill flanks which have been thus successively cropped by man and nature, now altogether abandoned by the former as unworthy of his labour, and but sparely utilized by the latter, so utterly unpropitious have they become for even their, *quondam* natural vegetation.

4. Lands in such a state as the above—*i.e.*, deprived of not one, but of most of the mineral ingredients essential to vegetable life—could only be renovated at an expense far exceeding any probable return. In other cases, where the exhaustion is not general—*i.e.*, of many different minerals—but of one or more of those substances peculiar to the particular crops long cultivated thereon, the renovation of the soil may be in general profitably effected. Let us illustrate this in the case of a poppy-field brought to a state of exhaustion by successive crops for a long series of years: assuming that the crops were Indian-corn in th-

rainy season, and poppy in the cold season. The more important of the ash-constituents of the two plants, in the absence of any special analysis of the soils, may be regarded as safe indicators of the substances required for the restoration of the fertility of the soil, *i.e.*, presuming that the soil after a series of years of cultivation under known crops has gradually declined from a state of high fertility to absolute sterility. Now, in the first place, as regards the poppy, we know that the primary ash-constituents are potash and lime (forming upwards of 55 per cent., the several others of a secondary class ranging from 5½ to 10½ per cent.) In the Indian-corn, as in all other grasses, *silica* forms the basic portion of the ash of the nutritive organs, *i.e.* the root, the stem, and the leaves, while the seeds containing but a decimal centage: *potash* and *soda*, with phosphoric acid and magnesia, are the next important, while as of secondary import we may note *sulphuric acid*, *lime*, and *chlorine*. Having regard, then, to the special food-stuffs of the poppy and Indian-corn, there can be no question that the failing soil constituents are in the first place the salts of potash and lime, phosphoric acid and magnesia, while as of secondary note we may specify sulphuric acid and chlorine: *silica*, though forming the major portion of the ash of the Indian-corn, may be safely overlooked here, as being always present in sufficient quantities in our poppy soils, for all that crop's requirements and any that may alternate with it. As regards the crops now under consideration, therefore, there can be no question of the silicates having anything to do with the failing crop-producing qualities of the soil.

5. I would thus then, set about the restitution of the soil's fertility; commencing operations as soon as possible after the poppy harvest.—The land in the first place would be roughly turned over with the kodali to a depth of from 9 to 12 inches, and thus exposed to atmospheric action during the hot season. With the earliest fall of rain in June, I would have it again broken up with the native plough, following this, when sufficiently moist and friable, with the hingah, for the purpose of pulverising the soil and preparing for a green manurial crop. The plot under treatment, we may assume to be no less wanting in organic than in mineral matters. Now, as a rule in India, the only really practical means of restoring to a soil the former is by growing special green crops for direct application to the soil. The plant which I consider the best for such a purpose during the rainy season is the common "soni," *Crotolaria juncea*. Seeds of this plant are everywhere available at a very cheap rate; it is of free growth and a copious leaf-producer, while requiring little or no attention or labour from the seed-sowing until it is sufficiently advanced for cutting. The seed should be sown by about the middle of June, allowing, say, from six to eight seers per beegha, as it is of importance to have a densely set crop. By the close of August the crop, as a rule, will be coming into flower; it may then be cut or uprooted, and *at once buried in the soil*. When cut and allowed to lie, even for a short period, it not only decays less rapidly, but it also loses much of its natural fertilising virtues. The process of burying the plant is simple. I prefer burying it whole, that is, without cutting it into small pieces, as the plant is thus secured in a much fresher state. A furrow then,

from 18 to 24 inches broad and about a foot in depth, is opened along one side of the plot, the bottom of this being now bedded with the plant and all covered by trenching over the adjoining two feet or so of soil, and leaving again an open furrow for bedding the *soni*. The processes of trenching, bedding, and burying the plant are thus successively repeated until all is finished, and the green plant thus forms a uniform layer at a depth of, say, ten or twelve inches. Assuming the crop to have been buried by the end of August, it will in ordinary moist seasons be sufficiently decayed by the middle of September to permit its being ploughed over. *Lime* should be applied immediately after this first ploughing at the rate of from *ten* to *fifteen* maunds per beegha. Ploughing should be frequently repeated, and on each occasion crossing the land at different angles, so as to thoroughly and uniformly mix the decaying matters with the soil. The hingah should also occasionally be used. By this treatment the soil will be well pulverized by the middle of October. Finally, and immediately before the soil is prepared for the seeds, something like the following mixture of mineral substances should be applied:—400lb. *superphosphate of lime*; 360lb. *shorah* (*Potassium nitrate*); 360lb. *sujeemattee* (*Sodium carbonate*); 240lb. *khareenoon* (*Sodium sulphate*); 80lb. *crude magnesia*, and (as a fixer of those nascent gaseous matters resulting from the mutual actions and reactions of the various mineral and organic substances in the soil) 400lb. of *charcoal* dust. In all I would thus apply 1840lb., which is equal to 473 grains per square foot, to the beegha of 27,225 square feet. The above application, I should state, is with the view of restituting the fertility of the lands for both rainy and cold seasons' cropping:—the crops *Indian-corn* and *poppy* respectively. I should also observe that Indian-corn, as drawing largely on one of the most important mineral constituents of the poppy—*potash*—tends to accelerate the exhaustion of the soil for opium produce. Again, *lime*, though an important constituent of the poppy, is but sparingly utilised by Indian-corn, while with magnesia the obverse is the case; so also with the soda salts, which are of high import to the Indian-corn in its vegetative period, being largely present in the roots, stem, and leaves; while in the poppy they have but minute decimal values, if present at all.

6. The above application of mineral substances will meet the wants of both crops, *i.e.*, poppy and Indian-corn. It will also do this without prejudice to either, each assimilating those substances that are necessary to its organisation. Plants, I need scarcely remark, possess a more or less definite physical constitution, dependent on that selective quality by which they imbibe and assimilate in due proportions the inorganic components peculiar to their living structure. It is thus that plants of different kinds, when grown alternately (or together, if their respective habits favour it), tend to prolong the soil's fertility, the roots of each imbibing unequal quantities or special kinds of inorganic matters, and they thus, so to speak, live on one another's *rejectamenta*.

CHAPTER V.

MANURES; THEIR APPLICATION TO THE SOIL.

1—*Introductory remarks.* 2—*Division of manures, as organic and inorganic.* 3—*Green vegetable manures.* 4—*Jute or soni water.* 5—*Dry vegetable manures.* 6—*The relative manurial value of different vegetable substances.* 7—*Animal manures.*

THE application of manurial substances to the soil, though but little practised in tropical agriculture, is no less necessary to sustain any high degree of fertility, than in that of extra-tropical or temperate latitudes. It has indeed been remarked that within the tropical zones no high tillage is necessary, the luxuriance of vegetation being so great that most of the products of the soil will grow indiscriminately in their particular seasons, and the only care of the husbandman, after the first preparation of the soil, is to keep down the vast growth of weeds which would otherwise overgrow the crops. This is a great mistake; especially has it fallacy been shown, as we have seen, in many of the American States, where in the course of a few years virgin soils of the highest fertility were hopelessly impoverished by the continued extraction of the whole crop, without extraneous returns. Practically or theoretically, there can thus be no question that the soil in tropical countries will as bounteously reciprocate to high tillage as it does in the extra-tropical zones. The highest farming, assuming it to be skilfully and prudently conducted, will everywhere prove the most remunerative.

2. Manures naturally divide themselves into two classes, viz., *organic* and *inorganic*. We need here notice those only that are more especially useful in opium husbandry. First for the organic manures, or those of a vegetable and animal origin. The dissolized parts of living and dead plants contribute largely to the fertility of our best soils. They may be applied with special advantage to clayey soils poor in organic matter, as tending to render, them more friable and lighter, as also affording a supply of organic food. "Again they also," remarks Johnston, "yield to the root those saline and earthy matters which it is their duty to find in the soil, and which exist in decaying plants in a state more peculiarly fitted to enter readily into the circulating system of new races."

3. *Green manures.*—Vegetable matters in the green state, as a manurial agent, have an immemorial usage in Chinese agriculture, and are still largely used in that country. Green manuring was also practised by the ancient Romans. Columella writes—"lupins, beans, peas, lentils, and vetches are said to manure the land." Of lupins and vetches I believe this to be truly the case, *provided they be cut down green and ploughed in before they are dry.* Varro also says – "there are many plants which, when cut down and left on the land, improve the soil. Thus lupins for instance are ploughed into a poor soil in lieu of manure." The practice is still continued by the modern Italians.

It is indeed not unfrequently practised throughout the continent of Europe, as also in the British islands, and that by the most advanced agriculturists. Strangely enough, it is nowhere, as far as I can learn, practised by the native agriculturists in this country, though from the general paucity of organic manures it is specially applicable. .... In North America, Indian corn is sown upon poor lands at the rate of 4 to 6 bushels per acre, and two and even three crops are cut and ploughed in during the summer, and in some parts the clover is never cut, but ploughed in as the only manure. As green manurial applications to our poppy-fields, I know no better plant for rainy season growth than the soni—*Crotolaria juncea.* It should be sown in the commencement of the rains; say by the middle of June, and cut when the flowers have just begun to open, which will be about the end of August. It should be buried in a fresh state, as previously described: ploughing may be commenced by the close of September and regularly continued with occasional draughts of the hingah, for the thorough pulverization of all, until about the middle of October, when poppy-seed sowing should be commenced.

a.—Various other, of the rainy season annuals might of course be used for the above purpose. I need not, however, particularise any here, as I have found *soni* to serve this purpose well. I would only recommend as a substitute for *soni* on the *clayey* or more *tenacious class* of soils, a green crop of Indian-corn or one or other of the common millets,—cheena, jowar, chujura, and the like—which, more than soni, tend to *lighten and loosen the soil.*

b.—Another important manurial agent of the above class is not unfrequently available in large quantities in our poppy districts, viz., tank-weeds, the various *jhanjis*, and the *singara*, &c., of the natives. These form most valuable manurial agents and may either be applied in the fresh state as taken from the tank, or collected as the tanks dry up in the hot weather, and heaped in some convenient place for application to the soil, burying all with the plough in October. If the heap is turned occasionally all will be thoroughly well decayed by that period.

4. Under this head also I would particularly draw attention to the *jute* or *soni water* (*i.e.*, the water in which those plants are steeped for maceration), which is a most excellent fertiliser. I have had experience of its value as a poppy fertiliser, and there can be no question that it would similarly increase the fertility of the soil for the majority of our agricultural products. It appears, however, to be nowhere utilised, though largely available in many districts. The period when the *soni* is mature and undergoing maceration is the close of the rainy season, which, as immediately preceding the period for the final preparation of the lands for poppy, suits well for a first irrigation. As many of those *soni-steeping* tanks however, dry up soon after the close of the rains, it might be necessary to irrigate the lands in the intervals of ploughing, or failing this, should the water get dried up, the surface soil of the tank or jheel may be applied with advantage...... Professor Johnston thus summarises the fertilising influence of green manurial applications—"Their fertilising properties will be understood when we remark that three-fourths of the

whole organic matter we bury has been derived from the air; that by this process of ploughing in the vegetable matter is more equally diffused through the whole soil than it could ever be by any mechanical means; and that by the natural decay of this vegetable matter ammonia and nitric acid are to a greater extent produced in the soil, and its agricultural capabilities in consequence materially increased."

5. *Dry vegetable manures.*—Dry vegetable matter generally decays very slowly, and as compared with that in a fresh or less or more fermented state, when applied to the soil, its efficacy is more gradual and prolonged. Though the immediate action is not so perceptible, yet, as Johnston remarks, "the ultimate benefit to the soil and the crops may be even greater than when fully fermented, supposing them to be such as require no special forcing at one period of the year. This is easily understood. While undergoing fermentation the straw loses part of its substance, either in the state of gaseous matter which escapes into the air, or of saline matter which is washed out in the liquid form. Thus after complete fermentation the quantity of matter really present is less, and consequently when added to the soil, though the *immediate* effect upon the crop be greater, the *whole* effect may also be very considerably less." Of matters in the above state the following only need be noticed here:—

(*a.*)—*Leaves of trees.*—In the agricultural tracts of this country, where these substances might be applied with advantage to the soil, from the general paucity of fuel, they are for that purpose the perquisites of the poor classes. When fermented and decayed, leaves form what is called vegetable mould—a substance indispensable to the horticulturist, and a valuable application to stiff, clayey soils, as rendering them of looser texture, &c.

(*b.*)—*Poppy stalks.*—These have a highly fertilising action, as having a rich mineral ash, and are especially applicable to poppy soils. Unfortunately the assamees return neither those nor their leaves to the soil, the latter being very generally collected and sent to the factory as a packing substance for the opium, while the stalks are all used for fuel. The ash, however, it should be stated, is largely returned to the soil along with that of other fuel matters, and this is of a high value, as affording upwards of 45 per cent. of the plant's mineral food-stuffs. I have under experiment this season two beeghas of land treated with poppy refuse—one on which the stalks, &c., were simply broken down and applied to the soil; another on which previous to application they were mixed with lime, heaped and fermented. The latter, as might be expected, has been the more stimulative: the crop of more rapid growth and gross habit, though in the other case also the advantage is obvious, as compared with adjoining and untreated crops.

(*c.*)—*Oil cakes.*—The oil expressed, seed-refuse of the *poppy*, *rape*, *tesee*, and *castor-oil* plants, &c., are all of high efficiency as manurial agents. The latter, castor-oil cake, is perhaps of more immediate action than the others, accelerating vegetation in a marked way, but we have yet to learn as to their relative efficacy on the opium-producing qualities of the poppy. As regards their application to the soil, they should in the first instance be thoroughly pulverised and then spread equally over the land at the rate of from 5 to 8 maunds per beegha. They may be indifferently applied when the seed is being sown, or immediately before it, when the land is last ploughed.

(*d.*)—*Charcoal powder, ashes, &c.*—These substances, though less or more wholly of a mineral character, as being of vegetable origin, may be noticed under the above head. Charcoal is produced by "*stifle-burning*," (*i.e.*, heating in a closed vessel, or with the least possible access to air) wood, and other vegetable matters. Charcoal-powder possesses the remarkable properties of absorbing noxious vapours from the air and from the soil, and of extracting unpleasant impurities as well as saline substances from water, and of decomposing many saline compounds. It also sucks into its pores much oxygen and other gases from the air. Owing to these and other properties it forms a valuable mixture with liquid manure, night-soil, farmyard manure, ammoniacal liquor, or other rich applications to the soil. It is even capable itself of yielding *slow* supplies of nourishment to living plants. (*Johnston.*) It is an excellent vehicle for the diffusion of urine in the soil. I have thus applied it with marked advantage to the poppy, as also ammoniacal liquor, *i.e.* water rich in ammonia, distilled in the manufacture of coal gas.

(*e.*)—*Straw-ashes.*—In this country straw is never burned for the ash, all being used up as cattle food-stuff, while the stubble is collected for fuel.

(*h.*)—*Ash of the husk of rice, wheat, and barley.*—The rice husk is generally burned by the natives of this country, while that of wheat and barley is mixed up with the dry and cut stalks of the various pulses and cereals and forms the staple food-stuff of cattle in the cold and hot seasons. It is the *bhoosa* of the natives.

Ashes—*rakh* or *rhakistar* of the natives.—This is a valuable manurial compound, consisting of the mineral matters of cattle excrements, and a variety of vegetable substances. The value of this *rakh* is well known by the native agriculturists, and they are careful to collect it for application to the lands. It indeed in general is the only manurial return which they make to their lands. The manurial value of these ashes would be greatly enhanced if they were kept dry, and not left as they usually are, fully exposed to the weather : rain washing out the whole of the soluble portion of the salts and leaving only the insoluble and earthy matters behind. The real active ingredients, *i.e.*, those immediately serviceable as a vegetable food-stuff, are thus lost, and amongst those *one* specially suited to the poppy. This is *potash*, which, as is well known, is largely obtained for commercial purposes by washing common wood ashes. The ashes, then, as applied by the natives to their fields are generally in what is called a *lixiviated* state; that is, the *washed refuse* of the original ash.

6. The relative manurial value of those different vegetable substances is estimated by the quantity and kind of *mineral matters* they respectively contain, and the proportion of nitrogen. "Some writers," remarks Johnston, "ascribe the entire action of these manures to the nitrogen they contain. This, however, is taking a one-sided view of their natural operation. The nitrogen during their decay is liberated chiefly in the form of ammonia—a comparatively evanescent substance, producing an immediate effect in hastening or carrying forward the growth of the plant, but not remaining permanently in the

soil. The reader therefore will form an opinion consistent alike with theory and with practice if he concludes that the *immediate* effect of vegetable manures in hastening the growth of plants is dependent in a great degree upon the quantity of nitrogen they contain and give off during their decay in the soil; but that their *permanent* effect and value is to be estimated chiefly by the quantity and quality of the inorganic matter they contain, of the ash they leave when burned. The effect of the nitrogen may be nearly expended in a single season; that of the earthy and saline matters may not be exhausted for several years."—*Agricultural Chemistry and Geology.*

7. Animal manures, in general, have a more energetic action than those of a vegetable nature. They consist of the parts of animal bodies and of their solid and liquid excrements. Of the former the *bones* need alone be noticed here, as being really the only parts available in the opium-producing districts. Caste prejudices, however, stand in the way of their use, and of course only the very lowest class will apply them to the land. I have experienced this difficulty; and in trying crushed bones on a few of the plots in the experimental poppy gardens under me, I could not get one of my own work people to touch them, so that to get them spread on the soil I had to engage a few of the *Dome caste.* Those trammels of caste, of old customs, methods, and prejudices, are ever in the way of innovations on the time-honoured modes and notions of the Hindoos.

(*a.*)—*Bones* are applied to the soil in various states, and according as they have been less or more finely crushed do they correspondingly exercise a less or more immediate and prolonged action on vegetation. As regards their manurial efficacy, it is sufficient to know that they are alike rich in organic and inorganic matters, affording of the former about 33 per cent. and of the latter 67 per cent., consisting of lime, magnesia, salt, and phosphoric acid, as phosphates in part of the proceeding bases. These, it need scarcely be remarked, are all highly essential to the fertility of the soil.—First then as to *crushed bones* and *bone dust.* As bone-mills are not to be had in our poppy districts, the common soorkee mill affords an excellent substitute. By this, bones may be prepared for the soil in either of the above conditions; the latter, as of more immediate action, is generally preferred. Coarsely broken bones may also be rendered actively efficient fertilisers by the following fermentive process, as explained by Mr. Stephens in his *Book of the Farm*:—"Mix in equal parts bones, with sand, mould or saw-dust, in a flat-topped heap. The bones and other materials should be well drenched with water. In a few days such a heat will be generated in the heap as to render it unbearable by the hand. The heat may or may not be allowed to die out before the heap is used. A large heap makes better manure than a small one Large bones may be reduced by fermentation in this way, by turning the heap over at the end of a fortnight and watering it afresh, and at the end of a month very few whole bones will remain."

(*b.*)—*Dissolved bones.*—The most readily available form in which bones can be applied to the soil for vegetative effect is by reducing them in sulphuric acid. "For this purpose the bone-dust is mixed with one-half its weight, and sometimes with its own weight, of sulphuric acid (the oil of vitriol of the shops), previously diluted with from one to three times its bulk of water. Considerable effervescence takes place at first, from the action of the acid upon the carbonate of lime in the bones; but after two or three days, with occasional stirring, the bones are entirely dissolved or reduced. The solution or paste may now be dried with charcoal dust, fine vegetable soil, or other matters, and applied with the hand to the soil."—*Superphosphate of bones* is a most active and efficient fertiliser. The preparation of it is thus described by Mr. Johnston:—"When *burned bones* are digested with sulphuric acid diluted with three times its bulk of water, gypsum (*sulphate of lime*) is produced, and falls to the bottom of the solution, while the phosphoric acid and a portion of the lime remains in the sour liquid above it. When this liquid is boiled down or evaporated by dryness it leaves a white powder, which is known by the name of acid or superphosphate of lime. As the ordinary burned bones are difficult to dissolve in the soil, and as the acid superphosphate is more easy of solution, it is likely to be taken off more readily by the roots, and thus more rapidly to aid the growth of plants.—(*Agricultural Chemistry and Geology*, p. 275.)

(*c.*)—The rate at which bones in the different states above noticed may be applied to the soil is about the following: first, *crushed bones*, say from 10 to 20 maunds per beegha; second, *dissolved* or *sulphuretted bones*, from 8 to 10 maunds; and third, the *superphosphate of bones*, from 6 to 8 maunds per beegha, *i.e.* the Behar beegha of 27,225 square feet. In regard to the season and mode of application, it may be observed that the *crushed bones*, as being in the least soluble state, and thus of less immediate though more permanent action than either of the others, may be applied about the close of September, when the soil is being ploughed, so as to have them thoroughly mixed and aërified with the soil by the time it is prepared for the seed. Thus treated, the first crop will derive a more immediate effect than if applied later.—*Dissolved bones* and the *superphosphate*, as being in a very soluble condition and readily available to the crops, should be sown along with the seeds, or, perhaps better, after the first irrigation and immediately before the soil is loosened, pulverized, and levelled to promote the germination of the seed. There will thus be less risk of the more soluble components being washed down beyond the reach of the plant's roots, as in the case of its application with the seed and the immediate irrigation of the soil. To effect a more equable diffusion of these substances over the soil, they may be advantageously mixed in about equal quantities with charcoal dust, or, where available, *kunker dust*. Both will tend not only to promote the efficiency, but prolong the action of the bones.

(*d.*)—*Farm-yard manure.*—This consists of the straw and other materials used as food or litter to such animals as the horse, cow, sow, &c., and of course increases in value with the quantity of their excrements mixed with it. That so-called in India, as compared with that of British home-farms, is indeed a sorry product, chiefly consisting of the solid excrements of the cow and buffalo. The manurial value of the product is also greatly decreased by the lower feeding of the animals, mainly grass—dry or fresh—and the dried stalks of the pulses and cereals. The seeds and grains of these are rarely given them, and thus, as compared with the mixed manure of the English home-farm, it must be largely deficient in those phosphatic salts which so much enhance the value of the latter. It may also be observed that the grain and seed produce of the native agriculturist, as compared with that of an English farm, will afford an inferior food-stuff, as being deficient in phosphates. We thus cannot say of the Indian farm manure what Mackintosh correctly says of that product from the British farm-yard, "that it is the most effective fertiliser yet known; that although others may be equally quick in their effects, yet none of them are so lasting. Compared with inorganic fertilisers, it may be set down as the substantial food of plants—they are stimulants, producing a sudden and ephemeral effect, leaving the plant much in the condition of an animal pampered with rich food in youth and left to shift for itself before it has arrived at a state of puberty."

(*e.*)—As regards the state in which farm-yard manure should be applied to the soil, there can be no question that the fresher it is applied the better. In the dried or decayed state its fertilising qualities are greatly deteriorated. Thus, direct experiments have shown that "100 *cwt.* of *fresh farm-yard manure* are reduced to 80 *cwt.* if allowed to lie till the straw is half rotten; to 60 *cwt.* if allowed to ferment until it becomes fat and cheesy; and again if completely decomposed it is reduced to 40 or 50 *cwt.* Now chemical analyses have shown that 100 *cwt.* of fresh farm-yard manure contains about 40lb. of nitrogen, and that by fermentation during the first period 5lb. of this is dissipated in the form of volatile ammonia; in the second 10lb.; in the third 20lb. Completely decomposed manure has thus lost about one-half of its most valuable constituents. The practical deduction which appears to be warranted by these experiments is, where it is possible, to apply farm-yard manure in a fresh state to the land." (*Morton.*)

(*f.*)—Johnston makes the following remarks on the relative fertilising value of the *dung* of the *cow, horse,* and *pig* :—"So much of the saline and soluble organic matters in the excretions of the cow pass off in the liquid form that its dung is correctly called *cold,* since it does not readily heat and run into fermentation. Mixed with other manures, however, or well diffused through the soil, it aids materially in promoting vegetation. The horse, being fed generally on less liquid food and discharging less urine, yields a hotter and richer dung, which is admirably fitted for bringing substances into a state of fermentation, but answers best for the land when mixed with other varieties of manure. The dung of the pig is *soft* and *cold* like that of the cow, containing like it at least 75 *per cent.* of water: applied alone as manure to roots it is said to give them an unpleasant taste, and to injure the flavour even of the tobacco plant."—(*Agricultural Chemistry and Geology.*)

(*g.*)—*Night-soil* is the most energetic manurial agent of all the solid excrements of animals. In the principal cities and large towns of Britain, as on the continent of Europe, it is now sedulously collected and prepared in various ways so as to destroy its offensive smell, while retaining its high fertilising qualities. In China it is kneaded into cakes with clay, dried in the air, just as the natives here prepare and dry their cakes of cow dung, and under the name of *taffo* is extensively exported to the agricultural districts from all the large towns of the empire. In Persia also it is largely used by the agriculturists after being dried in the sun and powdered. Caste prejudices and old customs, however, debar its use in any of the above forms by the native agriculturists of this country. They are, however, not the less alive to its eminent fertilising qualities, and thus though its manipulation in any form is religiously avoided, they encourage *stooling* on their lands, and as rendering them haunts for such purposes, those in the vicinity of villages at intervals of from three to four or more years are sown with *arhur*, and such rank-growing plants as afford the necessary cover.

(*h.*) *Droppings of birds.*—The droppings of domesticated and wild birds are also highly energetic, and most powerful promoters of vegetation. They possess the united virtues of both the liquid and solid excrements of other animals. They contain every part of the food of the bird, with the exception of what is absolutely necessary for the support and for the right discharge of the functions of its own body. It is thus fitted to return to the plant a greater number of those substances on which plants live than either the solid or liquid excrements of other animals; in other words, it is the most propititious of all to vegetable growth. (*Johnston.*) Of these we need only notice here the well known *guano*, as the droppings of certain fish-feeding birds (so massively deposited on the rocky shores and isles of the Peruvian coast) have been called by the natives of Peru. It has been immemorially used in the agriculture of that country, and was first introduced to European agriculture by Humboldt in 1804, though it was fully thirty years later ere it was at all appreciated by the agriculturists of Europe. It is now admittedly one of the most powerful of manurial agents. As containing, however, but a very small quantity of *potash*—an essential food-stuff of the poppy—it is necessary to supplement it with a light application of *shorah* or crude nitrate of potash, should there be a natural deficiency of that alkali in the soil. As regards its application to the poppy, it may be either applied when the seed is sown, or afterwards as a top-dressing to the young crop. As a top-dressing it should be applied cautiously, say at the rate of *one* to *three maunds* per beegha. If applied when the seed is sown, it may be applied more freely, (its more energetic qualities being absorbed and stored by the soil for the future use of the crop); say at the rate of from *three* to *six* maunds per beegha. In addition to this, however, and especially in lands poor in potash, the fertilising effects will be greatly enhanced by an admixture of from two to four maunds of *shorah*, and as an absorbent or storer of the more volatile matters, an equal quantity of charcoal powder or gypsum.

(*i.*) *Urine of animals.*—The liquid excretions of animals, though less generally used in this country—all but wholly lost—are equally as valuable manurial agents as the solid matters. They are rich in nitrogen, ammonia, and other organic alkalies, and contain in solution all the more valuable growth—promoting salts. As compared with the solid excretions, they thus act more powerfully on vegetation in the first instance; their action, however is less prolonged. The fertilising properties of animal urine are now obtained by various methods in a solid and concentrated form. Thus burned gypsum in a powdery state is mixed with urine in the proportion of seven gallons of the latter to ten pounds of the former. The mixture is allowed to stand some time, being occasionally stirred; the liquid is then poured off, and the gypsum, now enriched with a considerable percentage of the urine salts, is dried, and then known as *urate*. Again, by another method we have a preparation known as *sulphated urine*. This, as containing all the saline matters of the *urine*, with the addition of sulphuric acid, possesses more powerful fertilising properties than the *urate*. It is largely prepared by manure manufacturers, thus—"They mix as much sulphuric acid with the urine as is sufficient to combine with and fix the whole of the ammonia which may be produced during the decomposition of the urine. The mixture is then evaporated to dryness, and is sold and applied in the state of a dry powder." (*Johnston.*) This, mixed with equal quantities of *ashes* or *soni-water*, would form an excellent top-dressing for poppy.

(*j.*)—An excellent method of enriching the land, and which as being practised by the natives, may be noticed here. This is by folding cattle on them, and especially by eating off stubble, &c., with sheep. The practice deserves every encouragement, the mixed excrements of the sheep having much more powerful fertilising properties than those of the cow or the buffalo. Thus, with reference to the relative quantities of nitrogen, it has been shown that 28¾℔. of the mixed excrements of sheep will produce the same fertilising effect on the soil as 100℔. of the solid excrements of the cow, while with mixed excrements of the latter the relative values are as 37 to 100. In both forms the excrements of the cow are thus very inferior to those of sheep.

CHAPTER VI.

MANURES; THEIR APPLICATION TO THE SOIL.

1—*Introductory remarks on inorganic manures.* 2—*Lime and its salts.* 3—*The potash salts.* 4—*The soda salts.* 5—*The magnesia salts.* 6—*Iron and its salts.* 7—*The ammoniac compounds and salts.*

INORGANIC OR MINERAL MANURES.—A most important class of manurial agents is presented by certain mineral bases and their saline compounds. Of the former, lime is the most generally important, and of the latter the phosphates, sulphates, and nitrates are preeminent fertilisers. They constitute the essential food-stuffs of plants, and if deficient or absent in our lands crops will languish and die. Hence the whole art of manuring, as Johnston remarks, consists in adding to the soil those matters in which it is deficient, in a proper chemical condition and in the requisite proportions.

2. *Lime.*—This mineral is applied in various states, the following of which may be briefly noticed here, viz. the *sulphate*, the *phosphate*, and the *carbonate*.

(*a.*)—*Sulphate of lime, or gypsum.*—Water thoroughly saturated with lime and mixed with a few drops of oil of vitriol of the shops—*sulphuric acid*—will render it milky and cause a white powdery deposit. This is *gypsum* or sulphate of lime, and consists of lime in combination with sulphuric acid. It is an extremely useful application, specially so of course, to lands deficient in lime and sulphur, while, besides its specific fertilising qualities, it is a powerful absorber or fixer of ammonia. It is an excellent poppy fertiliser, and may be either sown with the seed, or applied as a top-dressing to the young crops.

(*b.*)—*Phosphate of lime.*—This excellent manure is largely prepared from bones: their white earthy residue burned in the open air consisting of upwards of 55 per cent. of phosphate of lime. It is also found as a native mineral in many countries; and has thus been applied with advantage to the soil, without any artificial preparations.—The *acid* or *superphosphate of lime* is also a powerful fertiliser. It is largely manufactured in England from a deposit in the tertiary strata, occurring on the eastern shores of Norfolk and Suffolk, and known as the *Crag.* It consists largely of rounded flinty nodules, frequently called *coprolites*, and containing as much as 50 per cent. of phosphate of lime. This mineral phosphate is prepared for agricultural purposes by mixing the ground product of the *crag* nodules with about an equal weight of strong sulphuric acid, and then drying the whole. As containing the two basic mineral constituents of the poppy, it will doubtless prove an eminent fertiliser for that plant.

(*c.*)—*Carbonate of lime.*—This is by far the most common of the lime compounds and most generally used by the agriculturist. The limestones when of a pure variety consist almost wholly of carbonate of lime. In this natural state, however, the lime is of low agricultural value, and cannot be reduced by any mechanical means to a state of comminution in which it is available to plants. It is thus necessary to subject it, in the first instance to the *kiln*, and thereby dissipate the whole of the carbonic acid and watery matters; leaving as a residue the pure mineral lime. "In this state," remarks Johnston, "it is known as burned lime, lime-shells, caustic lime, and quicklime, and possesses properties very different from those of the unburned limestone. It has a hot alkaline taste, absorbs water with great rapidity, falls to powder or slakes, and finally dissolves in 732 times its weight of cold water . . . When quicklime is left exposed to the air, even in dry weather, it gradually absorbs moisture from the atmosphere and falls to powder without the artificial addition of water. . . . It then absorbs carbonic acid, and is thus reconverted into the dry carbonate of lime . . . . Now, it may be asked—as the lime thus returns to its original state of the carbonate, what is the use of burning it?

The benefits are partly mechanical and partly chemical. By slaking, the burned lime falls to an exceedingly fine bulky powder, and may thus be equally distributed over a large area and intimately mixed with the soil. Now, neither limestones nor chalk could be economically so comminuted by any available mechanical means. Again, by burning the lime is brought into a caustic state, which it retains for a longer or shorter period, till it again absorbs carbonic acid from the air or from the soil. In this caustic state its action upon the soil and upon organic matter is more energetic than in the state of mild lime; and thus it is fitted to produce effects which mere powdered limestone or chalk could not bring about at all. The following are the four distinct states of chemical combination in which lime after being burned may be artificially applied to the soil:—

Quicklime or lime shells, in which the lime as it comes from the kiln is uncombined either with water or carbonic acid.

Slaked lime or hydrate of lime, in which by the direct application of water it has been made to combine with about one-fourth of its weight of water. *In both the above states the lime is caustic*, and may be properly spoken of as *caustic lime.*

Spontaneously slaked lime, i.e. by absorption of moisture from the atmosphere, in which one-half of the lime is combined with water and the other half with carbonic acid. In this state it is only half caustic.

Carbonate of lime, the state in which it occurs in nature, and into which burned lime, after long exposure to the air, is more or less perfectly converted. In this state lime possesses no caustic or alkaline properties, and is properly called *mild* lime—*Lime in Agriculture.*

(*d.*)—The rate at which it is applied to the land varies with the natural condition of the soil: the stronger clays and such as contain much vegetable matters requiring most, say from 10 to 20 maunds per beegha. Of course very much larger quantities may be applied with increased advantage. Thus we find lands naturally poor in lime under high-farming in Britain getting doses of from 10 to 40 tons and upwards per imperial acre, which is equal to about 262 and 1,150 maunds per beegha. To the lighter and poorer class of our poppy lands it may be applied at the rate of from 5 to 10 maunds per beegha. There would be further advantages by an additional application of animal manure, or say from 5 to 8 maunds of oil-cake. The lime might be applied after the close of the rains, during the ploughing routine; the oil-cakes immediately before the sowing of the seed.

3. *Potash.*—By dissolving the common pearl-ash of the shops (*a carbonate of potash*) with water and boiling with quicklime, the carbonic acid is dissipated and *potash* alone is obtained. It forms a basic component in the ash of the poppy, and may be applied with advantage to that plant, either in the form of a *sulphate, nitrate, phosphate, carbonate, or silicate.*

(*a.*)—*Sulphate of Potash.*—This salt would doubtless be an excellent manure for the poppy, as affording with the potash sulphuric acid; an eminent promoter of vegetation.

(*b.*)—*Nitrate of Potash.*—Nitre or saltpetre is the potassium nitrate of the chemists, and a compound of nitric acid and potasso. The *shorah* of the natives is a crude saltpetre and an abundant product in many of the poppy districts as elsewhere in India. It is an excellent application for the poppy, and may either be applied as a top-dressing at different stages of the crop, or sown after the sowing and first watering of the seed, when the land is finally pulverised and levelled for its germination. It may be applied to the soil at the rate of from *one* to *four* maunds per beegha.

(*c.*)—*Phosphate of Potash.*—This salt is known in two forms,—one in which the potash is in excess of the phosphoric acid, the other in which there is an excess of the latter. They are prepared by heating burned bones with sulphuric acid. The gypsum which forms, being separated; carbonate of potash is applied, in quantity sufficient to neutralise the acid; in other words, until it does not redden litmus. The clear solution is then concentrated by evaporation, and the phosphate separates in crystals as the liquid cools. If the solution is thoroughly evaporated we have a compound consisting of 56·94 *potash* and 43·06 *phosphoric acid;* while if it be only concentrated, and then set aside to cool, the *potash* forms 34·40, the *phosphoric acid* 52·48, there being also present 13·12 water. Both are readily soluble in water, though permanent in the air. They are likely to be specially useful to the poppy, if applied as a top-dressing to the plant in the later stages of its development.

(*d.*)—*Carbonate of Potash.*—The carbonate of potash, the dry pearl-ash of the shops, consists of 68·2 of potash and 31·8 carbonic acid. Unlike the phosphate, it rapidly absorbs moisture from the air and deliquesces or becomes liquid: it is thus readily distinguished from the carbonate of soda, which at ordinary temperatures gives off water and ultimately forms a dry white powder. Pearl-ash is likely to prove a useful top-dressing for the young poppy; its value would doubtless be further increased if mixed with lime. *Ashes*—the *rakh* of the natives—as consisting largely of crude *pearl ash*, with a varying percentage of the sulphate and silicate of potash, also forms a valuable application to either the soil or the plant. In combination with lime its fertilising value would be much increased.

(*e.*)—*Silicate of Potash.*—The silicate of potash is prepared in two forms, first by melting one part by weight of carbonate of potash with three of silica, then consisting of about 82 of *silica* and 18 *potash;* again by melting one part of carbonate of potash with two of silica, it consists of 75 of silica and 25 of potash. As regards the functions of this salt, as also of the silicate of soda, Johnston remarks that it may be either to supply to the soil with the soluble silicates of potash or soda in which it may be deficient, or, if they are decomposed in the soil, with soluble silica and with the carbonate of potash and soda. The silicate of potash may probably prove less useful to the poppy than the other forms noticed above (silica being one of its less important food stuffs), though from its ready solubility in water, and as being decomposed by the carbonic and other acids in the soil, it cannot but directly or indirectly promote the growth of the poppy. In concluding these notes on the potash salts, it may be observed that from their great solubility, they will prove most beneficial to the poppy if applied at the later stages of its growth; say with the appearance of the flower-buds, as being then more likely to increase the alkalies in the drug.

4. Soda.—Sóda in any of its forms appears to be but little utilised by the poppy; it has, however, in no instance been found really prejudicial to the plant, and the acids in combination with it are all eminent fertilisers. I may thus briefly notice a few of its compounds:—

(*a.*)—***Sulphate of Soda.***—Salt cake, the Glauber's salt of the shop, whence the "*globber*" or "*glouber*" of the natives, by whom it is also called *khareenoon*, consists of sulphuric acid and soda. It is a common educt of the soil in many parts of the plains of India during the dry season, appearing as a snow-like efflorescence. In the northern poppy districts it is very abundant, rendering tracts of land utterly worthless for arable purposes. Though thus in excess, utterly sterilising the soil, it is an excellent vegetable stimulant, and is largely applied to lands naturally deficient of it for the growth of clover, the various agricultural grasses, and other green crops.

(*b*.)—*Carbonate of Soda.*—This is the common soda of the shops; it consists of soda 21·8, carbonic acid 15·4, and water 62·8. It is a basic ingredient of the evil-famed reh, which has so extensively overrun tracts of land in the canal ranges of the Punjab and North-West Provinces. The *sajeematee* of the bazaars contains a considerable percentage of the carbonate, with usual small quantities of the sulphate and chloride of soda. The carbonate has as yet been but little used in agriculture. Johnston thus notices the fertilising qualities of this and the carbonate of potash:—"they possess the property of dissolving vegetable matter in the soil, and of disposing it to decompose and become soluble in water. They also dissolve silica, decompose mineral substances, and dispose the sulphur of the soil to form sulphuric acid and combine with them. They thus form soluble silicates, sulphates, &c., which they convey into the plant."

(*c*.)—*Chloride of Sodium.*—This is common salt—a compound of chlorine and sodium: it readily becomes moist in a damp atmosphere. Common salt has been applied to the land in various ways, for various purposes, and with various degrees of success. It has been used alone, dug or ploughed into the land, harrowed in with the seed, and laid on as a top-dressing on grass, on young corn, and on root crops. . . . In dry climates salt will rarely do anything but injury. In such climates the saline matter, natural to the soil, is brought to the surface by waters which rise from beneath, and accumulates there so as often to be a chief cause of the destruction of the crops on natural herbage. (*Johnston's "Experimental Agriculture."*) This evil in the case of the poppy, I may observe, is greatly obviated by the regular irrigation of the plant, though I should only recommend its use in the culture of that plant in combination with lime. "The salt," remarks Johnston, "being then decomposed in whole or in part, and the soda of the salt is brought into the caustic state, while the lime is converted into chloride of calcium." Both of these are very soluble in water, and can therefore readily act upon the soil and upon the plant. Wherever common salt is useful to the soil, this mode of applying it in connection with the lime may be safely recommended. Lime with salt may thus be used as a top-dressing for poppy in the proportion of 40 seers of the latter to 120 seers of the former. If sown with the seed it may be applied more freely, say two maunds of salt to six maunds of lime.

(*d*.)—*Nitrate of Soda.*—Cubic-petre, as this salt is sometimes called, consists of 36·7 soda and 63·3 nitric acid. It is a native salt purified by crystallisation from water. It is distinguished from nitre by crystallising in rhomboids instead of long prisms, in attracting moisture and readily deliquescing in moist air. A favourite fertilising agent of the assamees, called *noni-mattee*, consists, I believe, largely of this and the nitrate of potash. When applied as a top-dressing to the young poppy, it has an effect very similar to that of the salts of ammonia, imparting a deeper colour to the foliage, increasing the size and accelerating the growth of the whole plant. In moist weather its effects are apparent in a few days after application, sickly looking plants with foliage of a pale yellowish-green then assuming a deep healthy green. Its efficacy is increased by applying it in combination with lime, in the proportion of *one* of the latter to *three* of the former.

5. *Magnesia.*—Magnesia is not one of the least important of the mineral food-stuffs of the poppy; it forms from 6 to 7 *per cent.* of the vegetative organs, and upwards of 9 per cent. of the seed. As there is frequently but a very small quantity of this mineral naturally present in our poppy soils, it may generally be applied with advantage in any of the following forms, viz., as the *sulphate*, the *carbonate* or *nitrate.*

(*a.*)—*Sulphate of Magnesia.*—This is the Epsom salts of the shops. The impure salt can be had at a cheap rate, and if applied as a top-dressing with lime or nonimattee to the young poppy, it may be expected to promote its growth. It may be safely applied with the above, at the rate of one maund per beegha.

(*b.*)—*Carbonate of Magnesia.*—The magnesian limestones which extend over a narrow tract from Durham to Nottingham are throughout less or more rich in carbonate of magnesia, containing as a maximum about 45 per cent. of their whole weight. They also occur in some of the low hill ranges in India, and some years ago were exported in considerable quantities to England. "The calcined or burned magnesia," remarks Johnston, "whether in the pure state or when mixed with quicklime, as it is in the magnesian limes, absorbs carbonic acid more slowly than lime does, and by mere exposure to the air may perhaps never return to its original condition of carbonate of magnesia. When allowed to slake spontaneously it forms a compound of hydrate and carbonate, which is identical with the common calcined magnesia of the shops. Again, if slaked by the direct application of water, magnesia like lime, forms a hydrate only, without absorbing any sensible quantity of carbonic acid. Thus, when magnesian limes are slaked by water, the magnesia they contain may remain in whole or in part in the caustic state (that of hydrate), and may change very slowly even when exposed to the air. When mixed with a soil containing vegetable matter, it is brought more constantly in contact with carbonic and other acids, and thus more speedily loses its caustic state, but the prolonged presence of this caustic magnesia is one of the causes of the injurious action which magnesia limes exercise upon the land."—"*Lime in agriculture.*" In the non-caustic state of carbonate there can be no doubt that magnesia promotes vegetation, and might prove especially useful to the poppy, as being naturally a considerable utiliser of that mineral. To poppy lands naturally deficient in magnesia it might be safely applied, with or prior to the sowing of the seed, at the rate of from 40 to 60 seers per beegha.

(*c.*)—*Nitrate of Magnesia.*—This salt consists of 27·6 magnesia and 72·4 nitric acid. As being very deliquescent when exposed to the air, and in being very soluble in water, this salt is likely to prove highly useful as a top-dressing to the advancing crops. It is considerably richer than any of the other agricultural nitrates,—potash, soda, and lime—in nitric acid, and also the most highly soluble, so that its special qualities are more readily available to the plant. As having a larger proportion of nitric acid than any of the other salts above noted, and assuming that the special fertilising action of salts generally is due more to the acid than the base, it should relatively prove the most useful in promoting growth...... With regard to the functions of these nitrates in the soil and in the plant, Johnston remarks "that they may supply oxygen to the organic and mineral matters of the soil, and thus promote their passage to a state of combination more suited to the plant's growth. The nitrogen they contain may also enter into new states of combination; and such may be the case likewise with their potash, soda, lime, and magnesia, in the presence of the other mineral and vegetable matters with which they come in contact in the soil. Again, their function in the plant is probably threefold: first, to supply nitrogen, which we know to be so necessary a part of the plant's substance; second, to supply alkaline and earthy matters; and thirdly, to act chemically on the sap: producing or inducing those chemical changes, on the rapid succession of which the more speedy growth of plants depend." (*Experimental Agriculture, p.* 171.) The above salt should only be used as a top-dressing to the growing plant, and probably it will prove the more useful if applied shortly before the flower-buds appear; it may be safely applied at the rate of from one to one and a half maunds per beegha.

6. *Iron.*—The salts of iron have been applied as a top-dressing in small doses with marked advantage to certain crops. From the fact, however, that a mere trace of it at most is present in the ash of the poppy, it is evidently of little import in that plant's economy. Indeed, I chiefly allude to it here as accelerating germination and apparently imparting vigor to the young progeny. Curiously enough, however, though a trace of it is only found in the vegetative organs of the plant, it was found by Dr. Duncan (when officiating as Principal Assistant to the Behar Opium Agent) in upwards of fifty different samples of opium grown in the experimental gardens here and in quantities varying from two to three per cent. I am strongly of opinion, however, that this comparatively high percentage of iron in the drug is not due to its existence as a normal constituent. I am of opinion that it is introduced in cleaning the iron trowels on which the drug is collected and the scrapings of the earthenware jars in which it is first prepared. I need not dwell on this here, however, as it will be fully treated under the head of impurities and adulterations of the drug. I will here notice only the sulphate, the ammonic-sulphate, and the carbonate of iron, as having tried their effects on the seeds of poppy.

(*a.*)—*Sulphate of Iron.*—The sulphate of iron has been applied with decided advantage as a top-dressing to various green crops. In one instance I applied it to an experimental plot of poppy along with the seed at the rate of 25 seers per beegha, mixed with 10 maunds of lime and 10 maunds of charcoal. The seed prior to sowing was also steeped or 12 hours in a solution of the iron sulphate. The germination was decidedly retarded and but very sparing, though the seed-beds were irrigated immediately after the seed was sown, and an ample supply of moisture thus afforded them. They germinated sparingly and weakly 20 days later. The presence of the iron in the steep and in its application to the soil had evidently an injurious action, as a portion of the seeds (*similarly* steeped and dried with lime) sown on *soil* untreated with iron, though again not germinating before the 14th day, did then do so, freely and vigorously. The action of the lime, however, or the sulphate would appear to have been the chief cause of the injury; as seeds in all respects similarly treated and sown on soil to which a similar quantity (25 seers of iron sulphate in solution), dried up with charcoal dust only, was applied germinated freely and vigorously by the 14th day.

(*b.*)—*Ammonic-sulphate of Iron.*—A solution of the ammonic-sulphate of iron—the ordinary crystallised form being used at the rate of 20 seers per beegha, dried up with 10 maunds of charcoal dust—was applied to a plot of land immediately prior to the sowing of the seed. A few days after the seeds had been sown the germination was very profuse. As compared, however, with those on plots treated with animal and vegetable manure only, though they were somewhat more forward and vigorous in the early, I might say initial stage, the fugitive action of the salt was soon evident: the plants grew up with slender stems and spare foliage, wanting altogether in the vigor of those treated with organic manures.—I made a similar experiment with the *precipitated carbonate of iron*, and the results were very similar. The germination profuse, the seedling plants vigorous, but there was a decided falling off as the crop grew up, and the ultimate returns were poor, as compared with those treated with the organic manures.

7. *Ammonic salts.*—Nitrogen in its different states of combination is essential to the healthy development of plants, and in nature is largely afforded them, directly or indirectly, by the ammonic compounds. Johnston, in discussing the functions of the salts of ammonia in the plant, remarks that "they may enter directly into the roots of plants and perform certain functions important to their healthy and rapid growth. Thus, they supply nitrogen in a form in which it is immediately available for the production of those nitrogeneous—*protein*—compounds, which not only form an important part of the substance of the plant, but appear also to preside over those chemical changes constantly taking place in its sap, and upon which the health and rapidity of growth depend. Among the intelligible chemical uses of ammonia in the sap, I may mention that when it enters the roots in the state of carbonate it has the power of decomposing the alkaline sulphates and chlorides and converting them into carbonates, and thus preparing them to combine with the organic *acids* formed in the sap, with which we find them so generally united." (*Experimental Agriculture.*) Their application to the poppy is thus likely to promote the development of the principal constituents of opium. As applied to opium husbandry, I have as yet only tried ammoniacal liquor, the sulphate and the muriate of ammonia. These with the phosphate and nitrate I may briefly notice here:—

(*a.*)—*Ammoniacal Liquor.*—I had an opportunity of trying the effects of this on the opium poppy through the kindness of Dr. Waldie, who was good enough to send me a quantity from the Calcutta gas works. In one of my experimental plots I applied it at the rate of 100 gallons (dried up with charcoal dust) per beegha. This had a distinct effect in promoting the growth of the plant, but the opium return was very poor indeed. This, however, was due to know deteriorating or failing influence in the manure, but wholly to the inferior drug-producing qualities of the variety grown. It might be used, I believe, with great advantage as a top-dressing for the young poppy, say shortly after the first thinning and weeding. The rate of application need not exceed 100 gallons (drunk up by charcoal dust) per beegha.

(*b.*)—*Sulphate of Ammonia.*—This salt in the state of dry crystals consists of *sulphuric acid* 60·6, *ammonia* 25·8, and *water* 13·6 per cent. It is more extensively used in agriculture than any other of the ammonic salts, and as compared with the mineral sulphates, it has been observed, in its applications to the cereals, that while affording an equal quantity of grain, it considerably increases the produce of straw. As regards the opium poppy, it may also be used advantageously. In one case I applied it at the rate of four maunds per beegha, mixed with eight maunds of charcoal dust, as well with the view to diffuse the salt more equally in the soil; as also to absorb and store for the future wants of the plant its more volatile constituents. The application was made immediately before the seed was sown. In this I think I erred, and doubtless if applied as a top-dressing to the young crops its powerful fertilising virtues would be more fully utilised by the plants. I remarked that the germination was free and rapid, and later, as compared with the crops on adjoining plots treated with superphosphate of lime and guano-phosphate, was of much more vigorous and forward growth. The drug produce was also good, considering the high percentage of scanty drug-producing plants, the opium at 75° consistence weighing 5 seers 3 chittacks, which is equal to 10 seers, 6 chittacks per beegha.

(*c.*)—*Muriate of Ammonia.*—This salt, the *sal ammoniac* of the shop, consists of *muriatic acid* 68·2, *ammonia* 31·8. It slowly deliquesces when exposed to moist air. As regards the poppy, this salt acts somewhat less powerfully than the preceding. Mixed with charcoal dust I applied it at the rate of 200lb. per beegha with the poppy seed. The plants were generally vigorous throughout, and very similar in habit to those on an adjoining plot, which had been treated with muriate of lime, though readily distinguished by the deep, lustreless green of the foliage: those on the latter plot being of a glaucous green. In repeating an experiment with this salt on the poppy, I would recommend its application as a top-dressing to the young plant. Mixed in about equal proportions with charcoal dust, it might be thus applied at the rate of 80lb. to 100lb. per beegha.

(*d.*)—*Nitrate of Ammonia.*—This salt readily deliquesces in moist air; it consists in 100 parts of *nitric acid* 67·5, *ammonia* 21·2, and of *water* 11·3. I have had no experience with this salt on the poppy. The following remarks on its general properties and functions, however, show that it is likely to prove one of the most effective of the ammonic salts in its application to the poppy also. Thus "the fact that both the ammonia and the acid with which it is combined in this salt contain nitrogen in a form in which plants are accustomed to take up and appropriate it, has rendered it probable that, weight for weight, the nitrate of ammonia would more largely promote the growth of plants than any other salt of ammonia" (*Experimental Agriculture.*)

CHAPTER VII.

MANURING THE SEED AND THE PLANT.

1—*Seed-steeping.* 2—*The beneficial effects of the process.* 3—*Experiments with poppy seeds.* 4—*Manuring the plants.* 5—*Correlation of the ash constituents of the poppy and the alkaloids in its drug.* 6—*Special manurial top-dressing for the poppy.*

Manurial seed-steeping is an ancient practice. The Chinese appear to have immemorially practised the soaking of their cereal and other seeds in liquid manure before sowing them. In addition to this, they also very generally cover their seeds with a mixture of ashes and charred vegetable matter, which greatly invigorates the young plants. In the early Roman agriculture the selection and manurial steeping of seeds were practised. Virgil, for example, recommends in his Georgics, that seeds intended for sowing should be picked out by hand, and that those of the *pulses* should be previously *soaked in saltpetre water.* In the Punjab the sal-ammoniac prepared from the excrements of camels has been of old used, as now, in water solution as a steep for seeds previous to their being sown. In Persia also seed wheat is steeped in a ley of wood ashes before sowing, as are the seeds of the melon there, and in Cabool....... Mr. E. Solly, in an interesting paper on seed-steeping in the Transactions of the Horticultural Society of London, thus concludes:—"It is evident that the value of any steep or process of preparing seed will in great part depend on the nature of the soil where the seed is sown, and the weather or peculiar conditions of the season when it is used. It must always be remembered that no process of steeping can possibly replace the use of manure. If by steeping the seed we are enabled to obtain from the soil a larger crop than we should otherwise have had, it is certain that the crop of the next year will suffer in proportion. The only chemical effect of seed-steeping must be to cause germination to proceed more rapidly and give increased vigour to the young plant, and consequently to require a larger supply of earthy matters from the soil."

2. The seeds of the poppy, as we all know, are very small, though, as compared with the minute embryo, the oily albumen is large. This can afford the germ, however, but an initial nourishment, and it must thus early draw on extraneous stores. It is thus easy to see that such minute seeds must be largely benefited by being enveloped or impregnated, so to speak, with readily available food-stuffs. The manurial seed-steeps and coating of the poppy seeds may thus be expected to promote and invigorate the germinal plants, inasmuch as, though they have a relatively copious albumen, the tiny radical which they exsert can but sparingly draw on the ordinary extraneous supply of the soil. They are thus altogether more precarious in their primal stages than those with a gross embryo and copious albumen........ Again, besides the anticipated fertilising action of the steeping process, it also in some cases mitigates or prevents the attack of mould. Thus, rust which is common on our cereal and grass crops may be greatly mitigated, if not wholly prevented, by steeping the seed grains immediately before sowing in a solution of the sulphates of copper (blue vitriol), of soda, or of lime. These different steeps all act by destroying the vegetative powers of the mould spores. The late Professor Henslow long ago observed that by simply immersing grains of wheat in water, those infected with *bunt* float, and may thus be readily separated from the sound grains which sink. In the process of thrashing wheat however the minute spores of the bunt mould attach themselves to perfectly sound grains and cannot thus be separated, so that it has been found necessary to add some alkaline ley—lime, potash, or soda—to the water, which uniting with the oily coating of the spores admits of their being readily separated by the simple process of washing. The double purposes then of mitigating or preventing blights and invigorating the germinal plant may thus be secured by the process of steeping. I will here confine myself to their influence on the poppy, as illustrative of which I append the following experiments which I made in the gardens here.

3. In the first case it may be well to describe the general process adopted in carrying out those experiments. In the first instance 2oz. of seeds in each case were taken from a sample retained on a sieve with 900 meshes to the square inch; *i.e.*, 1-30th of an inch on the side of the square. The weighed sample was then immersed in water, decanted in a few minutes, so that all the light seeds might be thus separated from the denser. The latter were alone used in the experiments, and, with a few exceptions half a fluid ounce of the saturated solution was used: this being diluted with water, enough was taken to cover the 2oz. sample of seeds, these in each case being allowed to remain until they had wholly soaked up the solution. They were then dried with quicklime, gypsum, superphosphate of lime, guano-phosphate or charcoal dust, and immediately sown in moist soil.......For the sake of comparison I had best arrange them under the heads of ammonia salts, carbonates, sulphates, nitrates, phosphates, and miscellanea. In the first column the name of the solution is given, in the second the degree of concentration, in the third the dates of germination,—including under separate columns from the 4th to the 12th day; while the degree of germination is thus indicated—(*a*) very sparing; (*a*1) moderate or fair; (*a*2)

free; (*a*3) very free. The last column remarks on the health of the young plant:—

I.—Ammoniac Compounds and Salts.

1	2	3	4	5	6	7	8	9	10	11	12	
		Concentration of steep.	Degree of germination up to the 12th day.									REMARKS.
1	Common hartshorn ...	Diluted 1 to 4.	...	...	...	*a*	...	...	*a*2	...	...	Pale green.
2	Ammoniacal liquor. ...	Undiluted ...	...	*a*	...	...	*a*	...	*a*3	...	...	Dark ditto.
3	Carbonate of ammonia .	Sat. sol. 1 Wat. 8	..	...	*a*	..	...	*a*3	...	...	...	Ditto ditto.
4	Muriate of ammonia ...	Ditto ...	...	...	.	...	*a*	...	*a*3	...	..	Ditto ditto.
5	Sulphate of ammonia ...	Ditto ...	...	...	...	...	...	*a*	..	..	*a*3	Pale ditto.
6	Phosphate of ammonia...	Ditto ...	..	...	..	*a*	...	...	...	*a*3	...	Dark ditto.
7	Nitrate of ammonia ...	Ditto ...	...	*a*	...	...	*a*3	...	...	...	...	Ditto ditto.

The seeds in the above experiments, as soon as they had soaked up their steep, were mixed (to dry up adherent moisture) with finely-powdered charcoal and gypsum, and at once sown. Those treated with the ammoniacal liquor and nitrate of ammonia germinated most rapidly, though in subsequent vigor they did not exceed the more tardy, *e.g.*, the muriate and sulphate of ammonia. The hartshorn steep appears to be unfavourable, as the plants were throughout sickly.

II.—Sulphuric Acid, and the Sulphates.

1	2	3	4	5	6	7	8	9	10	11	12	REMARKS.
		Concentration of steep.	Degree of germination up to the 12th day.									
1	Sulphuric acid ...	Diluted 1 to 20...	...	...	...	...	..	...	*a*	...	a^1	Very pale.
2	Sulphate of potash ...	Sat. sol. 1 to 8 ...	...	...	...	..	*a*	...	...	a^3	..	Dark-green.
3	Ditto of soda ...	Ditto ...	...	...	...	...	*a*	...	...	a^1	...	Pale green.
4	Ditto of lime ...	Clear solution ...	...	...	...	...	...	...	*a*	...	a^2	Ditto.
5	Ditto of magnesia ...	Sat. sol. 1 to 8 ...	...	...	...	...	...	...	...	*a*	...	Ditto.
6	Ditto of iron ...	Ditto 1 to 12...	...	*a*	...	...	a^2	...	a^3	...	...	Very healthy
7	Ammoniac sulphate of iron.	Ditto 1 to 10...	...	...	...	*a*	...	a^3	...	...	...	Ditto.
8	Sulphate of copper ...	Ditto 1 to 20...	...	...	...	...	...	...	*a*	...	a^2	Pale green.

The sulphate steeped seeds were all cleared of adherent moisture with the superphosphate of lime and at once sown. The germination was somewhat irregular, those in iron sulphates being the most rapid and certainly the most healthy germs. Ultimately, however, they did not perceptibly differ from those of potash, lime, or soda. The acid steep, as also those of magnesia and copper, had a decidedly retarding effect, and the young plants had a pale and sickly look for some time.

III.—Carbonic Acid, and the Carbonates.

1	2	3	4	5	6	7	8	9	10	11	12	REMARKS.
		Concentration of steep.	Degree of germination up to the 12th day.									
1	Carbonic acid ...	Water solution	...	..	...	a^1	...	...	a^3	...	...	Very healthy.
2	Carbonate of potash ...	Sat. sol. 1, Wat. 4.	...	...	..	a	...	a^3	...	...	.	Ditto.
3	Carbonate of soda ...	Ditto ...	...	...	...	...	...	a	..	a^1	...	Pale green.
4	Bicarbonate of lime .	Ditto ...	...	...	...	a^1	...	...	a^3	...	...	Healthy.
5	Carbonate of magnesia, (magnesia water).	Fl. Mag. 1, Wat. 4.	...	...	...	...	...	a	..	a^1	...	Pale green.
6	Carbonate of lithia ...	Sat. sol. 1, Wat. 4.	...	..	a^1	...	a^3	...	...	...	..	Very healthy.

The steeped seeds in this instance were dried with guano-phosphate. The germination was upon the whole regular, those treated with the lithia salt being slightly the earliest. The most backward were those treated with soda and magnesia salts, and in the early stage of growth, the plants were the least vigorous, and in colour a very pale-green.

IV.—Nitric Acid, and the Nitrates.

1	2	3	4	5	6	7	8	9	10	11	12	REMARKS.
		Concentration of steep.	Degree of germination up to the 12th day.									
1	Dilute nitric acid ...	Sol. 1, Wat. 8	...	...	..	...	*a*	...	...	*a*2	...	Pale green.
2	Nitrate of potash ...	Sat. sol. 1, Wat. 8.	...	..	*a*1	...	*a*3	...	...	...	...	Very healthy.
3	Ditto of soda ...	Ditto ...	...	...	...	...	...	*a*1	...	*a*3	...	Healthy.
4	Ditto of lime ...	Ditto ...	...	...	...	*a*1	...	*a*3	..	...	...	Very healthy.
5	Ditto of magnesia ...	Ditto ...	...	...	...	...	...	*a*	...	*a*1	...	Pale green.

The nitrate-treated seeds were dried with a mixture of guano-phosphate and gypsum previous to their being sown. The germination was less regular and upon the whole tardy, as compared with those from the carbonate steeps. The potash salt proved the most active, and the least active was that of magnesia. The young plants also, as in the case of those from the acid steeps, were of a pale-green colour and altogether less healthy than any of the others.

V.—Phosphoric Acid, and the Phosphates.

1	2	3	4	5	6	7	8	9	10	11	12	REMARKS.
		Concentration of steep.	Degree of germination up to the 12th day.									
1	Dilute phosphoric acid...	Sol. 1, Wat. 8	...	...	...	...	...	*a*	...	*a*1	...	Rather sickly.
2	Phosphate of potash ...	Sat. sol. 1, Wat. 8.	...	...	...	*a*1	...	*a*3	...	...	...	Very healthy.
3	Ditto of soda ...	Ditto ...	...	...	...	*a*	...	...	*a*3	...	...	Healthy.
4	Dissolved phosphate of lime	Sol. 1, Wat. 8	...	...	...	...	*a*1	...	...	*a*3		Very healthy.
5	Phosphate of guano ...	Sat. sol. 1, Wat. 8.	...	...	...	*a*1	...	*a*3	...	...	...	Ditto.
6	Dissolved superphosphate (bones) ..	Sol. 1, Wat. 8	...	...	...	...	*a*1	...	...	*a*3	...	Ditto.

The phosphate steeped seeds were dried with a mixture of lime and charcoal powder. The germination was very regular, and the young plants all of a dark-green colour and very healthy, with the exception of those treated with the dilute acid; those for some time were easily distinguished by the pale-green colour of their foliage.

VI.—Miscellaneous Steeps.

1	2	3	4	5	6	7	8	9	10	11	12	Remarks.
		Concentration of steep.	Degree of germination up to the 12th day.									
1	Camphorated water ..	Sat. sol. ...	a1	..	a3	..	...	..	..	..	...	Very healthy.
2	Alcohol and camphor .	Ditto ...	...	..	...	..	..	..	.	a	...	Sickly pale-green.
3	Common salt	Sat. sol. 1, Wat. 8.	...	...	..	..	a	..	..	a3	...	Healthy.
4	Chloride of calcium ...	Ditto ...	...	...	a	...	...	a3	...	...	...	Very healthy.
5	Slaked lime and soap seed	Ordinary lime water with seeds.	...	...	...	...	a	..	..	a3	...	Healthy.
6	Water	Common well water.	...	...	a1	.	a3	...	. .	...	...	Ditto.
7	Dry seed	Untreated ...	...	...	...	a	..	...	a3	.	...	Ditto.

The steeped seeds were all dried with a mixture of charcoal dust and guano-phosphate. The camphorated water proved singularly active: germination commencing on the *fourth* day, and very free by the *sixth*, when it had but commenced with the earliest of the others viz, water and calcium. The spirit of camphor steep on the other hand retarded germination and proved altogether unfavourable (no doubt from the steep being too concentrated); the young plants were pale and sickly, and nearly all died in the cotyledonery stage. The water-soaked seeds, as compared with the untreated seeds, germinated earlier and much more regularly, though they certainly showed no subsequent superiority.

It is worth while to briefly summarise the general results of the above process. In the first place it is to be observed that the seeds, in addition to the liquid used and absorbed, had a further advantage in the coating of manurial powders, by which their surface was dried prior to their being sown. By the processes of sifting and washing also, all the small and light seeds where separated, and those of the greatest density only used. This general mode of treating the seeds has of course a great advantage over that more commonly adopted of simply steeping them for a longer or shorter period in a considerable quantity of the manurial liquid and draining off the excess, then partially drying the seeds either by simple exposure to the sun or mixing them with dry soil or sand. It is to be observed, however, that the value of one and all steeps are transient, and will not by any means enable the plant to dispense with fertilising applications to the soil. At most it but gives their germs an initial vigor, which to permanently advantage the crop must needs be reciprocated by a fitly fertilised soil. It is absurd to suppose that we may thus render unnecessary any manurial applications to the soil, as was broadly asserted in two German pamphlets published some thirty years ago, one entitled an "*Account of the discovery of a method of cultivating the soil without manure*," by Franz Hunrich Bickes; the other "*The manuring of seeds, or a simple and cheap cultivation of the soil by the artificial manuring of the seeds, by which at the same time the rust and other diseases of corn crops are prevented; 'practically tried for five years and proved on a large scale*," by C. L. Victor (vide *Journal Agri-Hort. Society of India, Vol.* 1½, *Correspondence and Selections, p.* 552). The alchymists of old were wont to dream, to work, and search with a life's devotion, for that *virgin earth* coveted as the means of preparing that mysterious substance, the philosopher's stone, which as they fainly believed changed every '*base metal*' to gold, or according to a later creed, "cures all diseases, restores youth to the exhausted frame of age, and indefinitely prolongs life." So Messrs. Bickes and Victor sought, and would have us believe, found modes of preparing that alchymical or miraculous seed by means of which, on the most sterile of soils, a plant will develop itself spontaneously, grow with a luxuriance hitherto unknown, and yield returns of a hundredfold. *Sic: es-to perpetua!* is the exclamation of the agriculturist's friend.

To resume, however, our notice of the effects of the above treatment on the poppy seed. It will be observed from the tables that the ammoniacal liquor, and iron sulphate steeps proved the most active stimulants. The camphorated water is singularly active, the germination commencing on the fourth day, and copious on the sixth. The young plants were also extremely healthy and of a darker colour than the generality of those otherwise treated. Seeds steeped in the saturated solution of alcohol and camphor germinated, as we have seen, tardily and sparely, the plantlets being all of a pale, sickly green colour, and in very few cases survived the colytedonary stage. Less concentrated (twenty grains camphor to one fluid ounce of alcohol) the steep promoted germination, and the plants were very healthy, as were those also from seeds steeped in spirit of camphor and mixed with charcoal dust to dry up the adherent moisture. Besides accelerating germination and invigorating the young plant, those camphor steeps appear to be a very effective antidote to the mould-blight, which periodically causes so much damage to the poppy. During the past season I have at least had indications of this in my experiments with camphor steeps, but they are on far too small a scale to speak with any degree of confidence. The poppy crops this season (as indeed I anticipated from its extensive and peculiarly vegetative development last season, 1874 and 1875), however, have been remarkably free from the poppy mould, and the immunity observed in the above experiments may be after all casual. Anyhow, it deserves and requires extensive experimental illustration.......I was much struck on first observing this apparent blight immunity of the plants from camphor and alcohol steeped seeds, which *à priori* (considering the composition of the two substances) I should have thought more likely to promote than prevent the mould disease. In specially treating poppy seeds with various acid and alkaline matters, I in no other instance observed them to have the slightest effect on the mould, the treated seeds giving rise to a progeny quite as subject to the infection as those from the untreated. As compared with the wholly untreated seeds, and even those steeped in water only, it will be observed in several instances that the germination was accelerated. This was especially the case with the ammoniacal liquor, nitrate of ammonia, and sulphate of iron, and of many of the others, while rather retarding than accelerating germination, they nevertheless had a decidedly invigorating effect on the young plants. To take advantage of this and to sustain their pristine vigor, it is absolutely necessary, as I have already asserted, that the soil should be properly tilled and manured. These are the real conditional mainstays of any high produce.

4. The top-dressing or application of manures to the growing crop is an excellent practice, and may be expected to be of special advantage to those plants in which the art of the cultivator is directed to an increased production of the acid or alkaline qualities of the crop. Of that class are nearly all our officinal plants, peculiarly so, those of a herbaceous and annual character, with acid or alkaline qualities, and of the latter, perhaps, there is none more so than the opium poppy, the generator of a substance (*sui generis,* the most potent of narcotics, and valuable of medicines) so entirely dependent on its chemical character, its alkaline qualities.

(*a.*)—The manurial top-dressing of the plant is a high farming and horticultural practice, and but rarely adopted in the less advanced stages of the agricultural art. Even the ancient Roman agriculturists, though less or more attentive to the manuring of the soil and the seed, and even the selection of the latter, appear to have but rarely applied manurial matters to the plant. Columella says that *mossy meadows* may be improved by a fresh sowing or by manuring, but *neither* of these operations will answer so well as frequent strewing over with ash, which destroys the moss. With Cato and Varro, he also observes that the Romans sowed pulverized pigeon's dung and the like over their crops, and mixed it with the surface soil by means of the hoe. The manurial top-dressing of the plant is but little practised by the native agriculturists of India, and limited to a few crops; such as the poppy, the tobacco, the onion, and the sugarcane: the substances used being oil-cake, ashes, and nonimattee. In a mixed or separate state the two latter are frequently applied to the poppy. They have both a wonderfully invigorating influence on the plant when of a slender habit, with foliage of a pale yellowish green. The nonimattee is indeed a specially active stimulant, changing rapidly the pale and sickly hue of the foliage to that of a light healthy green, and altogether increasing the vigor of the plant. This is probably due to its so readily affording the plant a supply of ammonia, with nitric and sulphuric acid. Nonimattee being further eminently rich in the nitrates and sulphates of potash, with a varying percentage of lime and soda salts. This might indeed be anticipated by consideration of its origin. This, as is well known, is due to the action of the atmosphere on the alkaline matters contained in the sun-dried bricks or clay-walls of the native houses, whereby the surface loses its coherence and falls off in a dry powdery form—the *maur-frass* of the Germans, *i.e.* wall corrosions. It is also to be observed that these wall crumblings are further enriched by the absorption of various organic and inorganic matters from the cakes of cowdung regularly dried thereon for fuel, and furthermore by the addition of village sweepings tinctured less or more with the liquid excrements of man and animals. We have thus in the nonimattee, an excellent fertilising compound, and that, from the high solubility of its more valuable components, readily available to the wants of the plant. Though an active, it is however, but a fugitive stimulant, so that on the poorer class of lands the poppy requires two, three, or more doses during its period of growth to sustain its vigor. As compared with pure saline and mineral top dressings, the nonimattee, as consisting largely of insoluble or slowly soluble matters, must be on each occasion applied in comparatively large quantities. Thus the natives apply it at the rate of from 20 to 25 maunds per beegha, while with increasing benefit it may be applied to the poppy during its season of growth at intervals, say, of three weeks, beginning from the final thinning of the crop, in doses of from 30 to 50 maunds per beegha. Ashes are also useful applications to the soil, the seed, or the plant. In applying them to the latter, however, it is desirable to apply them in quantity in the early stages of the plant's growth, as, though equally efficient in their fertilising qualities as the nonimattee, they are less active, though more permanent. I may here notice another excellent top-dressing for the poppy crops: this is the scrapings of efflorescent salts from lime and brick walls, which is to be found more or less abundantly on damp sites. Those saline efflorescences consist of sulphates and carbonates with alkaline bases, and, as remarked by Liebig the influence of lime in their production is manifested by their appearing first at the place where the mortar and brick are in contact. Again, the crystalline salts, remarks Liebig, which often effloresce on the walls of stables and cowhouses, and in places moistened with the liquid of sewers, are *nitrates*, usually *nitrates of lime*, a salt which deliquesces in moist air, and by the presence of which the wall becomes continually moist and damp. Those lime salts form excellent top-dressings for the poppy, and may be applied at the rate of about two maunds per beegha. With nonimattee their efficiency is greatly increased, allowing, say, two maunds of the former to twenty maunds of the latter per beegha, care being taken that they are well mixed together before application.

(b.)—It is to be observed that the main object in view in the manurial top-dressing of the opium plant is to supply direct to the leaves certain compounds which under atmospheric action may be induced to afford in a readily available form, materials likely to promote the secretion and enrich the quality of the drug in the plant. Now, *it is* clear that the leaves in the natural performance of their functions of absorption and respiration (normally imbibing ammonia, carbonic acid, water, and various aqueous solutions from the atmosphere, and again giving off oxygen, carbonic acid, and according to some vegetable physiologists, nitrogen in small quantities), will also absorb and assimilate any readily soluble food-stuffs applied to their surface. It is thus by increasing the supply, let us say, of a few of the more important mineral food-stuffs of the poppy, that we will may greatly exalt its powers of absorbing and assimilating those organic matters (carbonic acid, water, and ammonia) from the air or the soil from which opium and its alkaline constituents are elaborated. The capacity, the pliability, or plasticity of the plant, to be thus artificially

enriched is, I think, shown by the variability in the ash constituents of the poppy in different soils, and also of its alkaloids. Thus I have before me analyses by Mr. Redler of three samples of opium, of the ash of the plants, of the soils on which they were grown, and of their irrigating waters, in which the percentage difference in *morphia* is 3·91, *narcotine* 4·50. It should be stated that the opium was the produce of one variety: different varieties varying considerably in their relative richness in alkaloids. I should state that when these experimental analyses were made I had not then observed the remarkable differences in the drug-producing functions of different individuals—capsules of certain plants producing scarcely *one grain* of drug, while others produce from 18 *to* 30 *grains*,—and I had not thus adopted any selective system with a view to the elimination of the scanty drug-yielding plants and the multiplication of the most copious drug-producers only. With such individual differences then it is easy to see that the relative drug produce of the respective plots can afford us no criterion of the comparative fertilities of the soil, as being largely, indeed wholly, dependent on the proportion of scanty and copious drug-producing plants on each plot. The general results of the analyses are, however, of use, in so far as indicating with fair accuracy those constituents of the soils and waters most essential to the healthy development of the plants, and thereby tending to promote the development of alkaloids in the drug. On consulting the analyses, then, we find that the ash of the plants yielding opium richest in *morphia* contains a higher percentage of potash, phosphoric acid, and chlorine—the latter eminently so—viz. 1·04 than that, of either of the other samples of opium. Now, it is noteworthy that the waters of D contain less chlorine than those of C and B; the soil of the former contains more; viz., 0·126 per cent. Again, the soil of D is the richest, 0·022 per cent., in phosphoric acid, while the waters in each present but traces of it. As regards the potash salt, we find that the soil and waters of D contain more than those of C and B. The analytic results of the lime salt are somewhat conflictive. Thus C, with the maximum of 0·0853 in the water and the maximum 0·629 in the soil, gives a plant-ash richer in lime, by 2·48 and 3·68 per cent. respectively than that of D and B. Sulphuric acid—an important vegetative agent—would also appear, from the analyses under review, to exercise certain special functions in the development of alkaloids in the drug. As to the rationale of its action, I have little to say. It is of course evident that it can but indirectly promote vegetative development, as not of that class of nitrogenous or azotised products containing sulphur. It is present, however, in the ash of the haulm and in the seed, and it may, indeed does, produce important chemical changes—analytic and synthetic—with the organic acids, &c., naturally formed in the sap, without itself forming a constituent of any part of the plant or of its special products. This appears to have been the case in the three series of analyses under consideration. Thus we find, taking the respective results of the plant ash and the opium, that the ash D contains only 5·93 per cent. of sulphuric acid, while the opium gives 8·66 of morphia; the ash C, with 7·64 of sulphuric acid, gives 6·47 of morphia in its opium, while that of B yields the low percentage of 4·65, and the high percentage of 10·08 in the plant's ash. Again, as regards narcotine, B yields 8·56, C 13·06, and D 10·59. Considering then the fact that on all the three plots seeds of the same variety (and indeed sample) were used, and that the soils of each contained but mere traces of sulphuric acid, while the waters used in the plants irrigation varied but very slightly—0·0106 *per mille* being the maximum, D with most in the water having least in the plant, while B, with a maximun in the water, has an ash richer than D in sulphuric acid by 4·15 per cent., there would thus appear to be certain correlations between the alkaline richness of the drug and the quantity of sulphuric acid present in the plant.

5. We may now briefly discuss the apparent functional relations of the more important saline and acid constituents of the plant's ash in the development of the alkaloids—*morphine* and *narcotine*—in the drug. Now, in the three samples of opium, B, C, and D, we have seen that there is a variation of 4·01 per cent. in *morphine* and of 4·50 in *narcotine*, the maximum of each being presented by the same samples of opium, viz. B. The latter is thus the poorer in total alkaloids by 6·32 per cent. This is a very marked discrepancy. It must nevertheless be confessed that the relative differences in the constituents of the ash of the three samples is not by any means sufficient to afford a satisfactory explanation for the scanty development of alkaloids in the opium sample B. More satisfactory indications will thus be afforded by a comparison of the more important ash constituents of the two samples, C and D, relatively to the proportionate development of the alkaloids, *morphine* and *narcotine*. Thus we find in the ash D that the potash is in excess of the lime by 5·44 per cent., whereas in sample C the difference (still in favour of the potash) is only 2·73, that is, nearly half less. Again, sample D is the richer in phosphoric acid, chlorine, and carbonic acid; C in sulphuric acid, by 1·71 per cent. Starting then from the fact that we have on each plot the same variety of seed, similarly treated throughout, grown on very similar soils and irrigated by but slightly different waters, we may assume that the salts of lime and potash—the sulphates, phosphates and carbonates, and doubtless also the nitrates—are eminently calculated to promote the development of the opium alkaloids. Important auxiliary agents will also be doubtless afforded by the soda salts in their analytic and synthetic reactions.

6. With a view to the satisfactory illustration of the influence of manurial top-dressing on the amount and quality of the drug, I have this season instituted a series of experiments with saline and mineral manures, applying them to the plant in one series, just as the flower-bud began to make its appearance, and another in a more advanced stage, viz. when the first flowers were about to expand The results, I hope, will be valuable and interesting. In the meantime, for those disposed to try experiments on the manurial top-dressing of the poppy, I would recommend such applications as the following:—

1*st.*—Oilcakes—castor-oil, poppy, rape or teesee—with lime, say four maunds of each per beegha. This might be applied as a first top-dressing when the plants have been finally thinned. Cowdung in a fresh state, dried up with nonimattee or ashes, and all broken to a fine powder, makes an excellent top-dressing also.

2nd.—Shorah 40 seers, lime 160 seers, with 20 maunds nonimattee, to be applied (of course after all is properly mixed) before the flower-buds make their appearance.

3rd.—Khareenoon 40 seers, lime 160 seers, mixed with 20 maunds nonimattee, and applied as in No. 2.

4th.—Lime 6 maunds, mixed with 3 maunds charcoal dust, to be applied at an early stage of growth, as in No. 1.

5th.—Shorah 4 maunds, with 4 maunds charcoal dust, all well pulverized and mixed: to be applied in a more advanced stage, say with the first appearance of the flower-buds.

6th.—Common salt 20 seers, shorah 40 seers, mixed with 160 seers of lime: to be applied as in No. 5.

CHAPTER VIII.

THE OPIUM POPPY: VARIETIES CULTIVATED IN INDIA.

1—*Introductory remarks.* 2—*Specific characters of the wild plant.* 3—*Descriptive notices of its cultivated varieties.* 4—*Notes on the Malwa varieties.*

THE opium poppy (*Papaver somniferum*) is a native of Asia Minor, but having been so long and generally cultivated in Europe and parts of Asia it is now naturalised, less or more, in many different countries. It appears to have been cultivated for its seeds in Europe from the most remote ages, and the medicinal virtues of the juice had not altogether escaped the early Greek physicians. It seems probable, according to Dr. Royle, that it first came into extensive use in Egypt. When it was first cultivated in India is not known, but it had attained considerable importance in 1786, as there is a memorial of the Marquis of Cornwallis of that date respecting the best mode of deriving a revenue from opium. It has now been long extensively cultivated in the upper Gangetic plain, in Behar, Bundelkhund, and Malwa; and on a small scale in the temperate and tropical zones of the western Himalayas, in Assam, and other parts of India. It is also, as is well known, extensively cultivated in Asia Minor, Egypt, Persia, and though a comparatively late introduction to the Chinese empire, it is now largely cultivated and annually being extended. The Chinese, however—experts as they are in the agri-horticultural art—have altogether failed in producing a drug at all comparable, either commercially or officinally, with the poorest of the Indian sorts. Commercially the opium of the Behar and Benares Agencies is the best, as being the most approved by the Chinese, though, as a *purely officinal* article, it is inferior to the Smyrna and Constantinople drug, as also the pure and carefully prepared Malwa drug.

2. *Papaver somniferum*, the opium poppy, is an annual herb from two to four feet high, and distinguished from its allies by its smooth, simple, or divided stem, less or more closely embraced with oblong or ovate-oblong, irregularly, often deeply, lobed leaves, with toothed and unequally serrated margins. The flowers large; white or red, rose, purple, or lilac; variegated and edged with the same colours, and with very frequently a purply blotch at the base of each petal. The sepals smooth and cast off by the unfolding of the four crump petals (the "*patta*" or leaves of the assamees, of which the shell or covering of the opium for the China trade is composed), these have generally a more or less ovate outline, the margins entire, jagged or prettily fringed; the capsule—the "*dherri*" of the assamees—smooth, roundish, or oblong, of a dull green or glaucous, and containing numerous white, grey, or dark purply coloured seeds.

I shall now pass in descriptive review the several varieties which are found in our Indian poppy fields, beginning with those degenerate or wild forms which are so often seen under a neglected husbandry.

(*a.*)—*P. Somniferum Nigrum.*—Stem much divided and bearing many flowers (10 to 25); the leaves of a dull glaucous green, oblong to ovate, irregularly—but rarely deeply—lobed, and toothed from 5 to 10 inches long by 2½ to 4 inches broad. The flowers red, usually with a dark purply blotch at the bottom of each petal; the latter have entire margins, and are from 2½ to 3 inches long by 2 to 3½ inches broad. Capsules globose (opening by holes under the broad peltate stigma, or crown for the discharge of the seeds), glaucous, and from 1 to 1½ inch long by about the same in diameter. The seeds are greyish purple, and commonly known as *maw-seed*, in countries where this variety is cultivated—solely for the sake of its seeds, which are used for food or for expression of the excellent oil they contain. As an oil-yielding plant it is extensively cultivated in many parts of Europe. It yields but a small quantity of opium, but that of good officinal quality, being rich in alkaloids; the *morphine* in excess of the *narcotine*.

(*b.*)—*P. Somniferum, album.*—The stem of this variety is less freely divided than that of the preceding, bearing only from 6 to 12 flowers; the leaves do not differ; the flowers are white with entire petals; the capsules, globose, glaucous, differing in opening not at all, or but slightly, by holes under the stigma. The seeds are white to greyish white. As regards its opium-yielding properties, it affords drug of a very similar quality to that of the preceding, and somewhat more copiously.

(*c.*)—*P. Somniferum, abnormale.*—This is a degenerate or wild form of the cultivated varieties. I am not aware at least of its ever having been found in a truly wild state, nor do I find it described in any botanical works to which I have access. The stem is usually much divided, bearing numerous solitary flowers; the leaves oblong to ovate, acutely lobed, and irregularly toothed; from 4½ to 8 inches long, by 2 to 4 in breadth, of a dull glaucous green; the flowers small, streaked with dull red and olive green; the petals always much crumpled and expanding imperfectly from 1 to 2 inches long by ½ to 1 inch broad; the capsule small, roundish—oblong, 1 to ½ inch long by ¾ to 1 inch in diameter, and opening by holes under the crown for the discharge of its seeds, which are of a purply grey colour. This variety I find reproduces itself very truly from the *seeds of untapped capsules*, but from the tapped, *i.e.* the drug extracted capsules—we have a considerable admixture. of white and red or purply coloured flowers, not distinguishable from varieties 1 and 2 above. The capsules open, however, by holes under the crown, and the seeds of the red flowers are of a purply black colour; those of the white, greyish-white or brown. The size of the capsule is also increased, and it is altogether a more copious drug producer. The third generation—selecting seeds only from the improved red and white flowered varieties—is a motley set; the flowers passing from white to red by various shades of rose, lilac, and purple, and self-coloured, blotched, variegated, or bordered with the latter colours on a white ground, quite equalling for variety and gaudiness the well known double-flowered Marseilles varieties, cultivated in our flower-gardens. They have also much more of the habit of the common cultivated sorts,—*i.e.* the opium-producing,—the capsules roundish or oblong, and of a green or glaucous colour, and affording from three to five drug-yielding incisions,—a considerable improvement relatively to their wilding parent. They present another noteworthy peculiarity—a considerable percentage of them, ere they have matured the seeds, acquire a purply-black stem, exactly similar to the cultivated variety, the *kalodanthi* of the assamees. In the season of 1873-74 I effected a few crosses between the above *abnormal* form and the locally cultivated sorts. Three of these only I will notice here:—

(*d.*)—*P. S. abnormale* crossed with the *kutila* variety. The mongrel character was scarcely observable in the first progeny of this cross—that of 1874-75,—the leaves differing from the female parent only in being of a somewhat thicker texture and of a paler glaucous green, and in this respect only tending to the male form: the flower in every case was similar to those of the former. This season, 1875-76, however, the mongrel character of the progeny is distinctly shown. The general habit of the plant is indeed more robust than that of either parent, and a considerable percentage have those thick-textured, pinnately-partite and glaucous leaves of the male—the *kutila var*,—parent. The remainder graduating from their much divided state to that of the nearly entire foliage of the female parent. The flowers are of various shades of colour—white, rose, lilac, and red; those with the *kutila* foliage being all of the two latter colours—large and showy. The difference in the appearance or unfolding of the flower of the mongrel progeny is interesting. Thus, the first flower opened on the 23rd of December (seeds having been sown on the 21st of October), and by the end of the month there were many flowers open. The first collection of opium was made on the 18th of January, that is, 89 days from the sowing of the seed. A considerable number, indeed I may safely say the majority of them, did not open their first flowers until from the 15th—20th of February, and the collection of opium on this plot was continued until the 19th March. I should also state the late flowering race were of much more vigorous habit than the early flowers. The majority of them also had the *kutila* or *kutiloid* foliage; they were also considerably the more copious drug producers.

(*e.*)—*P. S. abnormale* crossed with the red-flowered (*leela*) variety from Malwa; effected also in the opium season 1873-74. In the first progeny (1874-75) the mongrel origin was evident in the foliage and habit, which partook much of the Malwa plant; the flowers also, though smaller than those of the latter, were similarly coloured, and many of them had fringed petals; capsules ovate-oblong, opening, but slightly, by holes under the crown, and affording from three to four drug-yielding incisions. A very small number of them, I may add, presented the small, crumpled, and dirty-coloured flowers of the wilding parent. This season (1875-76) the habit of the plant is much the same, but there would appear to be a prepotent influence of the female parent, and we have accordingly a majority of the progeny with wilding flowers. They also, unlike the preceding mongrels, flower about the same time. From three to five drug-yielding incisions comprise their grades of produce, which is upon the whole somewhat more copious than that of last season's progeny.

(*c.*)—*P. Somniferum, var. Gungajulee* crossed with *P. S. abnormale.*—The female parent in this instance is a Malwa variety, locally known under the above. The first progeny, that of 1874-75, of this cross showed clearly their mongrel origin: nearly all had acquired a more robust habit than their female parent; the stem more branchy, with foliage of a thicker and firmer texture and darker colour—in these respects tending to the male parent; the flowers in size and shades of colour were those of the female parent; the capsules rather small, of a roundish oblong shape, and opening by holes under the stigma—a characteristic of the male parent. They afforded from three to five (but by no means copious) drug-yielding incisions. This season (1875-76) they exceed all the other crosses or varieties which I have here for their rank luxuriance, many of them having attained a height of from 5 to 5½ feet, with large, oblong, irregularly lobed and toothed leaves from 11 to 25 inches long by 5 to 7 in breadth; the texture firm, and the colour a dull glaucous green. Like the mongrel (*a.*)—*P. S. abnormale—kutila*—the progeny attain the flowering stage at very different periods; the earlier and dwarfer sorts in from 98 to 100 days, the more robust taking from 100 to 125 days. It is curious also to observe that though a considerable majority of the plants have the large, gaudy-coloured and fringed flowers of the female parent, many have assumed the small, crumpled, and dingy-coloured flowers of their male parent. A few of the latter, while presenting the small, crumpled, imperfectly expanding flowers, have them of the peculiar strawy-green and whitish-yellow, one or other of which by selection and crossing, perhaps with the white-flowered varieties, will in all probability give rise to a purely yellow-flowered race. The first collection of opium was made on the 18th of January from the early flowering varieties; whereas of the later a commencement had but been made on the 20th of February—a full month later!

3. "*Kalodanthi,*" *or Black-stalked poppy.*—This is a compact branchy plant of a somewhat dwarfer habit than any of our other local varieties. It is readily distinguished from these by the stem and flower stalks acquiring a purply-black colour shortly after the fall of the flower, and before the maturation of the capsule. The latter are rather small, globose or roundish-oblong, glaucous, and from 1¾ to 2 inches long by 1½ to 2 in diameter. It is an excellent variety, though not so

copious a drug-producer—on the lands here at least—as the *teyleah* variety. It would also appear to produce a drug less rich in alkaloids than some of the others, as in a sample analysed for me by Dr. Durrant the total alkaloids at 70° consistence was only 6·38, of which 2·98, however, was *morphine*.

(*a.*)—*Sabza-kalodanthi.*—This variety agrees with the preceding in habit, growth, and colouring of the stalks, but is readily distinguished by its dull-green capsules, wholly void of the glaucous coating of the other. I first observed a single plant of it in a plot of the preceding in the experimental gardens here in the season of 1873-74. I saved the seed, and raised from it the following season a considerable progeny, every one of which came true; and I have now (1875-76) from that single plant, fully a quarter of a beegha covered with its healthy progeny. It will, I believe, prove a more copious drug-producer than the *old kalodanthi.*

(*b.*)—*Sufaid-dherri.*—The white capsule poppy is the most common of all the varieties, and is chiefly distinguished by its roundish, oblong, and glaucous, or powdery—*i.e.* covered with a fine bloom or white powdery substance—capsules. Mixed with it, less or more, however, we find varieties with rather small sized, round or oblate, and powdery capsules, which as a rule are very scanty drug producers. So also another sort with roundish oblong capsules of a dull olive-green colour, and but slightly, if at all, powdery. The rind of this variety gets dry, hard, and almost woody before the capsule is full grown, and rarely affords more than one drug incision. In selecting seed, therefore, it is well to avoid either of those, and especially the latter. The true white-capsuled variety, as indicated above, is as a drug-producer, with the exception of the *teyleah var.*, one of our best. The capsules are from 2 to 2¼ inches long by 1¾ to 2 in diameter, and afford a fairly copious discharge of drug to from five to nine or more incisions with the ordinary 4-bladed nashtar or lancet. The drug is also of excellent quality, and in the sample analysed for me by Dr. Durrant contained, in nearly equal proportions, a total of 7·04 per cent. in *morphine* and *narcotine.*

(*c.*)—"*Monaria.*"—A local variety so-called, and sent to me in the season of 1873-74 by the Sub-Deputy Opium Agent of Patna. It is distinguished by its large, round or spherical, *i.e.* vertically depressed, capsules (from 2 to 2¼ inches by 2¼ to 2½ in diameter), covered with a fine white powdery matter. The better capsules afford a fairly copious discharge of drug to from five to nine incisions; but crops from the ordinary unselected seeds of the district cover a very large percentage of such as are wholly exhausted of their drug by the third or fourth incision. It would appear, according to the analysis of the sample sent by me to Dr. Durrant, to be less than any of our other varieties suitable for officinal use, as deficient in alkaloid matters, the total *narcotine* and *morphine* being only 6·19 per cent. Of this, however, 2·88 consist of the latter.

(*d.*)—"*Darhi, or Muedardanthi.*"—This is a well-marked new variety, with bristly flower-stalks, which I first observed in one of the poppy plots here in the season 1873-74. (A Spanish variety of the opium poppy which I had this season from the Board of Revenue, and directly imported from that country, presents the same peculiarities in the flower-stalks, but is very distinct in habit and foliage.) There was but a single plant of it. I collected the seed, and in the following season raised from it a similarly characterised progeny. The plant is of a robust, somewhat branchy habit, and readily distinguished by its strongly *setigerous flower-stalk*. The capsules are large, glaucous, and very similar in size and shape to the preceding variety. It has hitherto proved a less copious drug producer than that variety, but this will no doubt be remedied by the selection of seed from the best producing capsules. The drug, however, is of excellent quality, being richer in total alkaloids by 1·03 per cent. (thus in morphine 3·48, narcotine 5·03) than any of our other cultivated sorts: another important quality is its comparative immunity from the mould infection. During the season of 1874-75, when the mould was so mischievously prevalent on all the other common varieties in the gardens here, it was but very slightly affected. Indeed, for weeks after the sorts on the adjoining plots had been overrun and destroyed by the mould, this variety resisted it very effectively, retaining to the last its normal functions for the secretion of drug. This season (1875-76), which proved so very unfavourable to the germination and health of the early-sown plant, thinned considerably my plot of this variety, but fortunately a sufficiency of plants escaped to afford me a few seers of seed. The plant retains its robust habit, *setigerous* flower-stalks, with the large spherical capsules.

(*e.*)—*Gunagun-posta, or Sufaid-patta.*—This variety is distinguished by the variegation of its leaves, stalks, and capsules, all of which are more or less streaked and blotched with white. I first observed a few specimens of it in the poppy plots here in 1873 and 1874. Like the preceding, it is also but little liable to the poppy murrain. In my annual reports for 1873 and 1874, to the Board of Revenue, I suggested what appeared to me to be the cause for this comparative immunity of the variegated plant. Subsequent observations confirm that view, which will be explained in treating of the diseases and injuries of the poppy. In the meantime I may state that last season (1874-75), when all the generally cultivated varieties, with the exception of the kutila, were seriously affected with the poppy mould, this variety was scarcely at all injured by it, the extension of the mould-spawn in the leaf being wholly confined to the green streaks and blotches; in no instance did I observe it cause any injury to the white parts. Unfortunately there is at present one objection to the multiplication and extension of this variety, and that is, its scanty drug-producing quality. Thus the capsules, though of large size, about 2¼ inches in both diameters, as being round and vertically compressed, rarely afford more than three or four drug-yielding incisions. This will no doubt be obviated, however, by continued selection of seed from the most copious drug-producing capsules. The opium has also all the physical qualities of a good commercial article and yields 6·57 per cent of alkaloids.

(*f.*)—*Teyleah, or Sabza-dherri.*—This is perhaps the most copious drug-producing variety of the opium poppy. Unfortunately it is far less generally cultivated than some of the other varieties, especially the *sufaid-dherri:* No. 6 of this list. In habit it is very similar to the latter variety, but the capsules are ovate-oblong (from 2 to

2½ inches long by 1¼ to 2 inches broad) and of a dull-green colour, destitute of the fine white powdery matter of the above. It appears, however, to produce a drug less rich in alkaloids than that of some of the other varieties, as the sample analysed for me by Dr. Durant contained only 6·57 per cent., of which 3·16 was morphia. It has all the physical characters, however, of a first-class commercial article, and its comparative paucity in alkaloids does not at all lessen its value in the China market.

(*g.*)—"*Kutila*," *or* "*kat-patta*."—This is a very distinct variety, and readily distinguished by its foliage being deeply cut into less or more narrow segments. The plant is of robust habit, the main stem giving off upwards a few simple branches; the leaves thick-textured, of a glaucous or pale sea-green colour, oblong-ovate, from 5 to 9 inches long by 4 to 5 inches broad, and bipinnately cut into narrow and bluntish segments; the capsules 2 to 2½ inches long by 1½ to 2 inches broad, oblong or ovate-oblong, and covered with a fine white powdery matter. This variety is decidedly worthy of a more extended cultivation. As I will subsequently show, it is less liable to be seriously infected with the poppy-mould than any of the other varieties commonly cultivated. Again, the thick and comparatively firm texture of the leaves, divided as they are (nearly to the mid-rib and primary veins) into narrow segments, enables it to withstand hailstorms of force sufficient to wholly mince the broad and but slightly divided foliage of the other varieties. It is a fairly copious drug producer, and in the sample analysed for me by Dr. Durant the total alkaloids was 7·21 per cent. of which 3·56, or nearly half, was morphia.

(*h.*)—"*Sabza-kutila*."—This is a very rare variety as yet, but, like the other green-capsuled sorts, promises to be a copious drug producer. It is only distinguished from the preceding variety by its capsules, which are of a dull-green colour, entirely void of the fine powdery matter which covers the capsules of that variety. I first observed a single slender specimen of this variety in one of my plots of *kutila* in the season 1873-74. I sowed the seed, but unfortunately none germinated. Again, in the following season I found another plant which has this season afforded me a few more. I have also unexpectedly got an addition to these from a mongrel progeny raised first in the season 1874-75. The cross was with *kutila* as the female and the *sufaid-dherri*, or common glaucous capsuled poppy, as male. The effects of the cross were clear on the first season's progeny; as with many of the *kutila*-foliaged variety, there was also a considerable percentage with the leaves of the male parent—the remainder intermediate. This season's progeny presents a very small percentage of the male variety, nearly all having the *kutila* foliage, and considerably the major part of the remainder differing chiefly from it, in having more entire leaves. Curiously enough, this season I observed that not a few of the *kutila* foliaged plants had capsules of a dull-green colour, quite destitute of powdery matter. This is also the case, and more generally, with the more entire foliaged forms. I was surprised to observe this, as in the previous season, without an exception, every plant bore glaucous capsules.

(*i.*)—"*Dusra-katila*."—This is another very distinct variety, of more robust habit than the *kutila:* plants rather branchy; leaves oblong-ovate, from 6 to 12 inches long by 5 to 7 broad, rather deeply cut from about the middle upwards into from 4 to 6 broad, coarsely toothed, blunt, and wavy-margined lobes; texture thick and firm; the colour a pale sea-green; the capsules roundish, about two inches in both diameters, covered with a fine white powdery matter. It affords, as a rule, a fairly copious discharge of drug to from five to eight incisions. I have, however, as yet only a very few plants of this variety.

(*j.*)—*Chaura or* "*Tisra-kutila.*"—A robust but sparingly branched variety, with oblong, irregularly lobed leaves of a dull sea-green colour, from 12 to 20 inches long by 4 to 7 broad; the lobes acute or tapering; the margins coarsely toothed and wavy. The capsules are of an oblong shape, from 2 to 2½ inches long by 1⅓ to 2¼ in diameter, glaucous, and fairly copious drug producers. The opium, as judged by the sample analysed for me by Dr. Durant, is somewhat richer in alkaloids than the true *kutila*, yielding in *equal* proportions 7·42 per cent. of morphia and narcotine.

(*k.*)—"*Sabza Chaura-kutila.*"—This is a variety of the preceding, similar in habit, division of the leaves, texture, and colour, but readily distinguished from it by its capsules, which are of a dull-green colour and quite void of the white powdery matter which covers those of the other. It promises, judging from the few plants I have yet raised, to be even a more copious drug producer than that variety. The progeny I have at present are those of a single plant which I observed in one of my experimental plots last season, 1874-75.

(*l.*)—"*Teyleah-kutila, ka nash.*"—This, as indicated by the name, is a mongrel, between *teyleah* as female and *kutila* as male. I may here state that the cross between the above varieties was made with a view to raise a race of *green-capsuled kutila.* The first progeny, that of 1874-75, however, though varying much in the foliage, presenting every grade, from the nearly entire leaves of the *teyleah var.*, to the deep and narrowly segmented leaves of the *kutila*, with its denser texture and peculiar colour, had all, the *glaucous capsules* of the male parent. This season, 1875-76, the progeny nearly all present the kutila characters, *i.e.* the less or more narrowly divided foliage, thick and firm texture, and pale sea-green colour, with oblong and glaucous capsules, while a very few have partially reverted to the teyleah, though readily distinguished from it by their oblong capsules. The kutila or male element has thus maintained a prepotent influence. Curiously enough, as above remarked (*vide paragraph* 12) a cross between the kutila and sufaid-dherri has this season given rise to a few true kutila plants with dull green, non-glaucous capsules, though last season (1874-75) every plant bore glaucous capsules. It is interesting, as I have elsewhere remarked, to observe this strongly inheritive tendency in such a trifling character as the *bloom* of the capsule, while as regards the texture, colour, outline, and division of the leaves, every intermediate grade is presented by the progeny. As a drug producer, this mongrel promises to be no way (in quantity or quality) inferior to its female parent.

(*m.*)—*Monaria-teyleah, ka nash.*—This is a mongrel of *monaria* as female and *teyleah* as male parent. This mongrel variety has the robust habit of the female parent, as also the large spherical capsules;

but these are uniformly of a clear deep-green colour, and show no trace of the fine powdery coating of the male plants. It is a fairly copious drug producer, my small plot yielding at the rate of 8*s.* 9¾*c.* per beegha.

(*n.*)—*Monaria-kaladanthi, ka nash*: This mongrel inclines more to the somewhat spare habit of its male parent—*kaladanthi*—than its seed-bearer this season, 1875-76, much more markedly than last. The stalks also, as in the case of the former variety, acquire after flowering the peculiar bluish-black colour of that variety; the capsules somewhat larger, but similar in shape, and glaucous. The yield of opium was at the rate of 8*s.* 10½*c.* per beegha.

4. I will briefly notice here four of the Malwa varieties which were introduced to this district in the season 1871-72, but all were clearly unsuited to the climate and soil. They grew up spare and sickly, and Mr. Abercrombie remarks in his report to the Board that they "did not in any instance produce more than a seer of opium per beegha, and generally only a few chittacks, while local seed on adjacent lands produced in some cases from eight to ten seers." The cultivation of the Malwa varieties by the assamees was at once discontinued, and the seed they had collected purchased from them, to prevent them making use of it for the next season's sowings. A small portion was been tried by some of the sub-divisional officers in their gardens to ascertain whether the acclimatized seed will be increasingly productive. In the following season (1872-73) there was but a very slight increase in the opium produce, and I rather think the sub-divisional officers very generally discontinued their cultivation. I, that season having been specially deputed by Government to the opium districts (to ascertain the nature of the poppy blights, and suggest, if possible, mitigative or remedial measures for them, as also to have regard to the modes of improving the general husbandry of the plant), had likewise seeds of the different Malwa sorts for trial in the gardens which I had opened at Bankipore. The plants, however, grew up again poor and sickly, and gave a very small quantity of drug. In 1873-74 I repeated the experiment on the Deegah land. The plants generally acquired a somewhat more robust habit, but they again proved miserably poor drug-producers, the maximum produce being about 4½ seers per beegha. It is to be observed, however, that even this is a considerable increase on the first season's results. Again in 1874-75 I gave them a third season's trial. They all suffered, however, so seriously with the common poppy mould, that they gave considerably less opium than they had done the previous season. This blight injury, however, they suffered from in common with nearly all the local varieties. I will now describe the Malwa varieties from the specimens grown in the gardens last season: having now been grown in this district for *five* successive seasons, a period sufficient, as one might naturally anticipate, for the perfect acclimatization of an annual herb in a district, where others of its own kin are so extensively and successfully cultivated.

(*a.*)—*Lukria.*—This variety has increased much in vigor of habit, and is, so to speak, more hardy, *i.e.* better suited to the climate, &c., than it has hitherto proved. It has an erect, slightly branched stem from 4 to 5 feet high; the leaves oblong-ovate, from 12 to 16 inches long by 5 to 8 inches broad, the *margins* sinuous, irregularly lobed, coarsely and bluntly toothed; the texture thin, papery; the colour a pale sea-green; the flowers, large, white, usually with rose, lilac, or pink margins, and deeply fringed; the capsules oblong, from 2 to 2½ inches long by 1¾ to 2 broad, and of a dull glasseous green. It has now considerably improved in its drug-yielding qualities, having this season yielded 6s. 9c. per beegha of excellent drug.

The rains being unusually light last season, not a few of all the sorts sprung up in the plots from seed which had been left on the soil in the harvesting of that season's crop. This was the case with the *lukria.* The plot was sown up this season with a variety of black-seeded poppy from Turkey. Not a single seed, however, germinated of it on this plot, nor on two other plots on which it was sown. The few young plants that did spring up on the first plot ultimately proved to be of the *lukria* variety, cultivated thereon last season. The plants are remarkably vigorous in habit, more resembling the more robust of the local sorts than the hitherto spare forms of the Malwa kinds. They rise up with stout, branchy stems to a height of from 4 to 5 feet; the leaves large, oblong, with slightly lobed, irregularly toothed, and wavy margins, the lower leaves being from 16 to 21 inches long by 8 to 9 inches broad, of a thick, but soft texture, and of a dull sea-green colour. A very few have colored flowers; the others large, white, and deeply fringed. The capsules large, from 2½ to 3¼ inches long by 2 to 2½ in diameter. They have also proved a much more copious drug-producing race than any of the other Malwa kinds sown in the usual way. Thus from the 125 plants on the plot I collected 1¼c. of opium, so that allowing 14,520-12 inches apart, equal to the beegha (a low rather than a high estimate), we have a return of about 9s. 1c. of opium per beegha. We thus see that the process of acclimatization has been greatly accelerated by a purely natural selective agency, the more vigorous germs, or those best adapted to the conditions of climate, soil, &c., surviving; the weaker we may assume to have been destroyed. This, as I think, well illustrates the much disputed phenomena of acclimatization. In the Malwa and local poppies we have clearly varieties endowed with different constitutions best adapting them to their respective localities, while by a few years' cultivation we find this variety acquiring increased vigor of habit, yielding more drug, and ultimately equalling the local sort.

(*b.*)—*Leela*, a Malwa variety. The seed of this sort was much mixed with that of the preceding in the sample originally received by me from the Agent. It presented, however, a considerable percentage of two well-marked sorts which I have this season separated from the others. They are of vigorous but somewhat dwarf habit, 3½ to 4 feet high, rather branchy, the leaves ovately oblong, 9 to 12 inches long by 5 to 7 broad, the margins but slightly lobed and coarsely toothed; the texture rather thick and firm; the colour a dull sea-green; the flowers large, white, with entire margins; the capsules roundish-oblong (2½ to 3 inches long by 2¼ to 2½ broad) and glaucous in the one variety—*leela;* in the other—*sabza leela*—rather globose, about 2½ inches in both diameters, of a dull-green colour, and void of the white powdery matter coating the rind of the other. This season (1875-76) they have yielded an average of 5s. ½c. of opium per beegha.

(*c.*)—*Gungajulee*, a Malwa variety. This sort is very like *lukria* in habit and growth. The leaves oblong to ovate-oblong, from 10 to 16 inches long by 5 to 8 broad, of a pale-green colour, the margins less or more lobed and coarsely toothed; flowers large, white, with or without rosy or pink margins, and deeply fringed; the capsules large, oblong, 3 to 3½ inches long by 2½ to 3 broad, less or more furrowed longitudinally, and covered with a fine white powdery matter. The drug-produce this season averages 8*s.* 12¼*c.* seers per beegha.

(*d.*)—*Uggarya*, a Malwa variety. This is the least robust of all the Malwa kinds above described. The stems slender, and nearly simple, from 3 to 4 feet high; the leaves oblong, from 9 to 12 inches long by 5 to 7 broad, of a pale-green colour; the margins sinuous and toothed; the flowers smaller than those of the other varieties; the base of the cup stained with dull purple, the margins carmine-red or lilac, and generally deeply fringed; the capsules oblong or ovate-oblong, from 2 to 2½ inches long by 1¾ to 2¼ in diameter, glaucous, and containing seeds of a pale purply-grey colour, very similar to the maw-seed. The drug-produce of this variety averaged only 3*s.* 14½*c.* seers per beegha.

It has been a matter of surprise to many that the Malwa varieties should have proved so ill-suited to the climate or soil of the opium tracts in Behar and Benares. I have already remarked that four of the most productive of the Malwa poppies have now been cultivated for *five* successive seasons here, and it must be confessed they have not yet attained their normal standard of productiveness in Malwa, though now exceeding the average produce of the local varieties in the Behar Agency for the past ten seasons, the highest average being that of 1863-64, which was 6*s.* ½*c.* per beegha. The local poppy of Behar succeeded much better in Malwa, the minimum produce of the directly imported seed, according to the Superintendent of Rutlam, being 3*s.* 5*c.* per beegha, the maximum 5½*s.*, thus affording an average of 3*s.* 7*c.* *per beegha*. This, I may remark, exceeds the average produce of the local poppy in *four* of the *twelve* divisions of the Behar Agency in 1870-71, by 6*c.* per beegah, and indeed is only 5*c.* under the general average. A consideration of the climatic conditions of the two provinces affords, as I think, an explanation of the indifferent success of the Malwa plant in Behar. Malwa has a very uniformly mild and humid temperature, the cold season being extremely agreeable, and many of the products of the garden in temperate latitudes, which are destroyed by the heat of the Lower Provinces, succeed well on the table-land. The soil is extremely fertile, very generally consisting of a black vegetable loam, producing fine crops of cotton, indigo, opium, tobacco, wheat, &c. The cold season in Malwa, it is to be observed, differs much from that of Behar. It is never subject to the dry westerly winds so prevalent in the latter, nor is there those extremes between the day and night temperature. These with the atmospheric aridity are, as I think, the main cause of the indifferent success of the Malwa poppy in Behar. The foliage of the plant is of a much thinner and delicate texture than that of the local poppy, and it is thus exceedingly susceptible, in the early stages of its growth especially, to the cooling of the soil by the rapid and incessant evaporation of moisture. As illustrating this, I may observe that some of the most healthy of my Malwa plants have always been those sheltered less or more from the westerly winds. I have observed also that under a soft and moist easterly wind they quickly acquire a more healthy appearance. Again, if slightly overshadowed by a tree, they are also greatly more vigorous, than when fully exposed: this can be only due to decreased radiation and its consequent chilling effects, and some little perhaps to the plants being slightly screened from the direct rays of the sun. The chilling effects, however, of radiation is as I believe the main cause of the hitherto indifferent success of the Malwa plant here, and only when it has acquired a thicker and firmer textured foliage (as it now evidently has) will it afford a remunerative crop.

CHAPTER IX.

PERIOD AND MODES OF SOWING THE POPPY.

1 *Time of sowing.* 2—*Sowing.* 3—*The practice on naturallyi rriguous lands.* 4—*The drill system: its advantages.*

As regards the time of sowing the seed, much of course depends on the early or late cessation of the south-west or rainy monsoon. This, as a rule, occurs between the middle and end of September, though it is occasionally prolonged into October, thus greatly retarding the necessary tillage and pulverisation of the soil for the reception of the poppy seed. Other things being favourable, with a humid atmosphere and a night temperature, not exceeding, say 65° sowing may be commenced by the end of the first week of October; earlier than this, under any circumstances, is not to be recommended. Humidity and temperature may indeed occasionally favour earlier sowings, but there is always the risk of increased heat, accompanied with hot winds (ere the cold weather finally sets in), which will scorch and dry up the seedlings as they appear. As a general rule, therefore, the first sowings should be made from about the middle to the end of October. These will begin to yield drug by the middle of January, *i.e.* in from about 90 to 95 days. A succession sowing may extend from the end of October to the middle of November. This will begin yielding drug from the second to the last week in February, that is to say, in from 85 to 90 days. Later sown crops (than the middle of November) can in the most favourable season be expected to yield but a small quantity of drug, and, should the hot winds set in early, they may be so scorched as to yield no drug, and even little seed. Every endeavour should thus be made to have sowings finished by the middle of November, or at latest the last week. This season, from the scarcity of water, I was unable to complete the first watering of my *latest seed* *plots* until the 25th of November, and as the soil was naturally too dry to excite germination, the seed might as well not have been sown until then. The crop is consequently late, having begun to yield drug in the first week of March and continued until the last week of the month. Again, last season (1874-75) my late crops, those sown towards the end of November, were cut off with blight ere I had made more than one collection of drug. In the season 1873-74 I find from my notes that those sown in the first week of December gave a produce of only *one* and *two* seers of opium per beegha. One plot sown on the 12th of December yielded at the rate of about *half a seer per beegha.*

2. In sowing a plot of poppy, which, assuming, it has been frequently ploughed and well pulverised with the "hingah" (*i.e.* the native substitute for the roller or clod-crusher), the first step is to divide the land by a cross series of ridges into compartments varying from six to nine or even more feet in diameter, if the land is quite level. The alternate ridges are always made somewhat broader than the others, to form the water channels for the irrigation of the plant. Prior, however, to this bedding of the land, and after it has been finally ploughed, a very common and excellent practice is to give the land a thin sprinkling of seed, say two seers to the beegha. The soil is then levelled with the "hingah," and the bedding of the land, as above, commenced. A second sowing is then made at the rate of from *one* to *two* seers per beegha, or, if no seed has been applied prior to the bedding of the land, an application of from three to four seers is at once made. If the soil, as is generally the case, is not sufficiently moist to excite germination and sustain the germs, the land is irrigated immediately after the sowing of the seed, and the surface, as soon as it is sufficiently dry for working, is again lightly opened by the kodalee and well pulverised and levelled. If the atmosphere is humid, germination will be free by the sixth or seventh day; if dry, it may not occur until the tenth or twelvth day. I have indeed seen it not unfrequently occur only after the second watering, and when the seeds had been in the ground for upwards of three weeks. When the seeds, however, owing to excessive atmosphere aridity, do not germinate in due course, after the first watering it is a good plan to thinly re-sow the land prior to the second watering, after which again lightly break up the surface smoothing and levelling as formerly. The opening of the surface soil with the kodalee after the irrigation of the seed, as also its pulverisation and levelling are important operations, as facilitating a uniform germination. In dry weather, if this is not attended to, the soil soddens, a hard crust forming its surface, and the young germs unable to break through it, appear only along the lines of cracks or rents.

3. In the preparation for the sowing of the irriguous or naturally moist lands there is a considerable economy of labour, all that is necessary being the pulverisation of the soil with the plough and hingah. Immediately prior to seed time the soil is lightly run over with the plough, the seed is then sown at the rate of from *three* to *four* seers per beegha, and the soil is at once levelled and smoothed with the hingah. The early sown plant on those lands (as in the ordinary mode of bedding and flat surface cultivation on the irrigated lands), frequently suffers much from being fully exposed to the rays of the sun and

hot westerly winds. This might be greatly obviated (a regular and uniform germination excited, and the growth of the plant fostered in its early and delicate stages), by adopting a system of drill culture: this would incur but little additional labour. Thus the soil having in the first instance been thoroughly pulverised, sown, and levelled with the hingah, as above described, it is only necessary to sprinkle again over the smooth surface, say, *one* or *one and a half* seer of seed, when the surface may be lightly broken up by drills at distances of from *six* to *nine* inches. Now, the simplest and most efficient mode of doing this; is by the drill-rake. This is constructed of a hard piece, like that of a common rake, only double the size, and set with broad, flat wooden teeth, tapering towards the points and at such a distance apart as the drills are to be drawn. If the land is drilled or ridged over with this implement the advantage will soon be apparent (and this especially if the drills run in an east and west direction), by the cool and sheltered (the northern) sides of the ridges becoming covered with young plants, while the sunny and exposed side brings forth scarcely a single plant. I would strongly recommend the adoption of this system in the unirrigated districts.

4. The officers of this department are familiar with the fact that when the earlier sown plants utterly fail on the plain surface of the compartments in the ordinary bedding system, a regularly and healthy line of plants very generally spring up along the cool northern flank of the ridges, where they have humidity and shelter. It has been thus a matter of surprise to me that the assamees should persistently overlook this and continue the old practice of plane surface cultivation, instead of drilling or ridging their lands and giving the poppy the advantage of a cool ridge side, as they know well to do in the culture of the potato. I have successfully adopted the system in the experimental gardens here. The plants thus grown (I should say the plots thus prepared) bore incomparably the best and most uniform crop of any in the gardens under me, which, I may say, comprise upwards of fifty beeghas. In my reports to the Board I have frequently pointed out the advantages of this method, but as yet, with the exception of some small plots in the Ranchee division, I have nowhere seen it practised by the natives. This is to be regretted. The mode in which I would propose to have the lands drilled is either by the drill-rake as above described, but of course of larger size, and with the teeth set at a distance of *ten inches* from each other. In this case, however, as each furrow must form a lateral water channel, I have found it best to draw up the land in ridges with a well worn, small sized kodalee. This is easily done, and really incurs little extra labour on the old mode of compartment bedding. Thus, I in the first instance, have the land prepared in the usual way with plough and hingah. The seed is sown on a lightly ploughed surface, levelled and smoothed with the hingah. I again sprinkle the surface with seed at the rate of from *one* to *two* seers per beegha, after which I have a line set and parallel ridges drawn up with the kodalee at distances of from *nine* to *ten* inches, and running in an easterly direction. At right angles to these I run alternately the main water-channels and a blank dividing ridge at distances of from ten to twelve feet. The seed bed ridges are united

to the blank dividing ridge, but open on the water-channel side, so that by a small opening the water is given off for the irrigation of the ridges in the usual compartmental way. Indeed, uniform irrigation is greatly facilitated by forming compartments of the ridges; this is readily done by uniting a ridge with the water-channel at regular distances, say from eight to ten feet. I would strongly recommend the practice of this system for all the earlier sown plant, and that especially in hot and arid seasons, though even under the most favourable climatic conditions it best promotes a uniform germination and the health and vigour of the plant. Under this system the young plants are never flooded (as in the ordinary plane surface mode), the water running only along the furrows of the ridges, the flanks are kept sufficiently moist by filtration and absorptive powers of the soil, so that the surface is always open and freely permeable by the air, never soddened and crusted, as it always becomes by the other mode, after irrigation. The advantages are sufficiently apparent, and indeed forced upon us by nature. I have been often struck with the barren surface of the compartment plots in the native mode, the alternate barren and plant-bearing side of the dividing ridges, but I was more so on looking this season at my own uniformly ridged plots, to observe that while the *north side* of each long ridge was studded with healthy young plants, you could scarcely find a single plant on the *south* (the dry and sunny) *side* of the ridges, though the seed had been equally distributed over all. It was indeed very striking to see this repeated in every ridge from one side of the plot to the other.

CHAPTER X.

THE GERMINATION OF THE SEED AND MANAGEMENT OF THE YOUNG CROP.

1—*Time in germination.* 2—*Size of poppy seed: the relative value of small and large.* 3—*Thinning and weeding.* 4—*Aërating surface soil: its advantages.*

UNDER favourable conditions of heat and humidity the seed of the poppy will germinate, as we have seen, in from five to seven days. Under a deficiency of the latter it may remain long inactive: with an excess it will rot; and yet again, as we have seen, certain varieties baked, as it were, in the soil during the hot season, and bedded in plastic mud throughout the rains, will nevertheless resist both and germinate readily so soon as their wants are met by climatal and soil conditions. Moisture is indispensable. I have seen instances in the gardens here of poppy-seed, sown about the latter end of October, lying from 20 to 25 days in the soil before it germinated, and then do so freely. This was simply due to the soil, in the first instance, being insufficiently moist to perfect germination; and it was only after it had been again irrigated and lightly stirred up that the germs appeared. Darkness or shade also accelerates germination in this, as with all seeds, and we have an illustration of the conjoint influence of the latter and a slightly increased humidity of the soil in the drilled seed-bed, where germination is limited to the cool side of the ridges. "The agents in germination," remarks LeMaout and Decaisne, "are water, air, heat, and darkness...... Water softens the integuments, penetrates the tissues of the seed, and is decomposed; its hydrogen is absorbed; its oxygen, like that of the air, combines with the carbon of the seed to form carbonic acid, which is set free. Heat is indispensable to germination, and in the series of phenomena which accompany this process it acts alternately as cause and effect, for a seed is the theatre of chemical combinations. Light retards germination by causing the decomposition of carbonic acid, and hence preventing the formation of the gas. Under a combination of favourable circumstances the seed absorbs water, together with the oxygen of the air. The albumen, under the chemical action of these agents, loses a portion of its carbon, and at the same time combines with the elements of water; it soon changes into saccharine, milky, soluble matter, fit to be absorbed by the embryo. If the albumen has been absorbed previous to germination, the cotyledons enlarge and nourish the plumule. When the latter has emerged from the ground and become green the phenomena are reversed; the young plant, instead of absorbing oxygen to combine with its carbon, and disengaging carbonic acid, absorbs carbonic acid, separates the carbon, and assimilates it." ("*System of Botany.*" *English Translation by the late Mrs. J. D. Hooker.*)

2. The poppy is of the smaller sized seed class of our agricultural herbs. Thus, in sizing the seeds with fine sieves, I find that a very small percentage are retained on those with meshes 1-24th of an inch on the side of the square, those of the 1-30th of an inch retaining most; though a few even pass, but their germinal and vegetative qualities are low, and they give rise to a spare and sickly progeny.—The number of seeds produced by a healthy plant is very large. Thus I find on an average the ripe and air-dried seeds weigh 5 grains per 1,000. Now, as there is on an average from 75 to 80 grains of seeds in the 100 capsules, they will thus yield from 15,000 to 16,000 seeds each, so that the individual plants may be estimated to yield from 80,000 to 90,000 seeds. The local drug-yielding varieties in this country would thus appear to be very much more prolific than are the European sorts, as I observe that in Professor Balfour's "*Class-book of Botany*" the capsule is said to contain only 2,130 seeds. In either case, however, there is a large provision for the propagation of the species, as is generally the case in all minute seed-bearing plants, to compensate for the great loss sustained in the early stage of the progeny. It is thus, that unlike the seeds of our cereals, which contain an abundant store of nutriment for the independent development of the germ, the poppy, as it completes germination, must at once draw nourishment from the soil; hence the necessity for the extra tillage of the latter for the poppy.

3. The thinning of the young poppy crops is of prime importance; unlike the tobacco plant, they cannot bear transplanting, and their seeds being also very small, it is necessary to sow them thickly, to ensure

a full and uniform crop. Thinning is thus imperative, and should be commenced at an early stage of the plant's growth, so that all overcrowding may be obviated, and each free from its neighbour. This must of course be done gradually, and as the plant increases in size and vigour. The *first thinning*—for this must be a successional operation, and not done all at once—however should be made as soon as the young plants can be easily handled; they may then be separated to distances of from one to two inches. Should there have been partial failing in the germination, of course it must be attended to, and seed again sown on such parts immediately after the first watering, which is usually required by the time the young plants make their appearance. In the thinning operation the seed may be lightly wrought into the soil with the *nuranee* or weeder, and the surface smoothed and levelled. This supplemental sowing should have the earliest attention, as if the first sown plants are much advanced, the latter will be shaded and overgrown, grow up weak and sickly, flower prematurely, and produce little drug. Air and light are of prime importance to the young poppy. The period for the *second thinning* is indicated by the approach or commingling of foliage. At this stage the plants, having acquired considerable vigour, should be regularly thinned; the weaker plants being taken, and the stronger only left, at distances of four inches or so. The final thinning should be set about before there is any overcrowding of foliage. Now, as the local and Malwa varieties of poppy are all of upright growth, they should not be over-thinned, but only sufficiently to allow each plant to develop itself properly. In every instance, of course, the distance to which they must be finally separated will depend on the quality of soil; thus, in a poor sandy soil a *third thinning* will scarcely be required; their simple or branchless stems and spare foliage will have ample developing room if the plants are left at from *four* to *five inches* apart. In a rich loam or any well-conditioned soil, on the other hand, where the plants attain a height of from 3½ to 4½ feet, with less or more branchy stems and copious foliage, it will be necessary to thin them out to distances of from *seven* to *nine* and *ten inches* apart.

(*a.*)—Simultaneously with the successional thinning of the young crop, weeding must be also carefully attended to,—this particularly so if the rainfall has been light during the monsoon. The common agricultural weeds of the cold season then spring up with profusion with the young crops, and if not immediately attended to (in the case of the poppy) and early eradicated, they will quickly overgrow and destroy the delicate young poppy. They should thus be cut down with the *nuranee* while in their cotyledonary state, *i.e.* before the appearance of their first normal leaves. ...... I have remarked above on the weeds abounding—in our fields after a light rainy season. As illustrating this, I may record the results of observations on a few of the plots in the gardens here during the past cold season, which from beginning to end has been unusually dry, and preceded by a very light rainy monsoon. In the first instance the abounding weed was *Chenopodium album. var. viridis*—the *bhuttoa* of the natives, by whom it is generally used as a potherb. This plant, on a few plots of soil in proximity to the river, but on high and well-drained land, took exclusive possession of them, and though it was early cut down and weeded out, it re-appeared as quickly again from previously dormant seeds and caused much injury to the young poppy, with which it simultaneously germinated. Curiously enough, in three or four plots adjoining the above scarcely a plant could be seen, but in these its place was fully occupied by another variety of the same plant, *C, album var. purpureum*—the *cumarh bhuttoa* of the natives and not used as a potherb. Of the *bhuttoa* I counted in a square foot of soil 180 plants, and on an equal surface 200 plants of the *bhuttoa chumar*; and as there are 27,225 square feet in a beegha, we have them in the one case abounding to the extent of 5,445,000, and in the other 4,900,500 per beegha. In each case I may state that there was more than a beegha of land thus uniformly and densely studded with those plants Where the seed had come from I cannot say; as for the two previous years that I have cultivated those lands I observed comparatively few plants of either. Especially troublesome also this season has been the *Polygonum herniareoides*—the *doodhya* of the natives of Behar. It had exclusively invaded a strip of land of about 14 feet in breadth on the north, and of course shady side of the enclosing jail wall. Of this plant I counted 168 in a square foot of soil, which is equal to 4,573,800 per beegha. This plant, like the preceding, was by no means conspicuous for its abundance in previous seasons.

4. The regular and frequent aëration or stirring up of the surface soil is an operation of prime importance in the culture of the poppy on irrigated lands, nor must it be neglected in its husbandry on the naturally irriguous lands. That the surface soil of the irrigated lands should require more frequent loosening is of course due to the tendency of the soil to form a hard and compact crust, as it again gives off by evaporation the irrigative waters. Now, in leaving the surface in this dry and caked condition, it increases much its heat-conducting powers, and consequently the soils lose in moisture by evaporation. Paradoxical though it may appear to some of my readers, it is nevertheless true that soils with a loose and porous surface, lose moisture much less rapidly by evaporation than those that have a hard and compact crust. The healthy growth of the plant is also checked by the compression of the roots in the hardened and contracted soil; while its natural heat is prejudicially decreased by rapid evaporation from the leaf surfaces: it gradually acquires a dry woody character, presents a sickly worn-out appearance, runs up prematurely to flower, with impaired drug-yielding functions, and expends itself in the maturation of the seed. On the other hand, as Sir H. Davy observes, "by changing, loosening, or stirring of the surface, fresh soil is exposed to the action of the weather; thus by changing the position of all the parts new facilities for chemical changes are produced, and by loosening the whole mass of the soil air and rain are more readily admitted. Again, by loosening the soil, the air is admitted among its particles, and confined there; and hence it becomes a non-conductor of heat, and is much less affected by atmospheric changes of heat and cold than if it formed a firm compact mass." Soil under the latter conditions is relatively cooler than the atmosphere during the day and warmer at night. Vegetative

growth is promoted and a decided improvement is soon visible, the plant acquiring a grosser habit, the leaves larger and of a healthier or deeper green, and the flowering stage is thus attained with unimpaired vigour, and consequently the drug-secretive functions and the reproductive processes are thus promoted by a copious store of organised and nutrient fluids. I have dwelt particularly on this point, as I observe that the assamees in general do not trouble themselves with more than merely cutting down the weeds, rarely, if ever, working with a special view to the aëration of the soil: this indeed they, as a rule, regard as "labour lost." This is a great mistake. The soil after each irrigation is less or more laid or compressed, and quickly giving off its moisture by evaporation, its surface is converted into a hard and compact crust, prejudicial, as we have remarked, to healthy growth, and this especially in the case of the poppy, one of the most delicate and tiny of agricultural plants, in its earlier stages of development. I would thus strongly recommend the practice of stirring or breaking up and well pulverising the surface soil after each application of water, *i.e.* as soon as it is sufficiently dry for working. While at all sticky or adhesive it should not be touched, as it will but tend to consolidate the under-soil, while the broken surface will stick together again, and really more ill than good will result from the operation. These alternate operations—watering and aërating of soil—should be continued until the foliage of the plants have fairly covered the surface of the soil, and so checked any further rapid loss of moisture: the latter operation may then be discontinued.

CHAPTER XI.

IRRIGATION, AND THE RELATIVE FERTILISING PROPERTIES OF WATERS.

1—*Irrigation. Average temperature of the soil, the water, and the air during the poppy season* 1873 *and* 1874. 2—*Waters differ in fertilising virtue.* 3—*Hard water.* 4—*Soft water.* 5—*Canal and river water.* 6—*The relative temperature of a dry and a water-logged soil.* 7—*Tank and stagnant waters.*

We have in a previous chapter shown that a very small proportion of the land under poppy cultivation sustains naturally sufficient moisture for the growth or maturation of the plant; artificial irrigation being thus necessarily very generally practised, either from wells, tanks, rivers, or canals. The former as a rule afford the best irrigative waters, and this irrespective of their chemical properties—*i.e.* their superior richness in saline or mineral matters—that to which I allude being the relatively higher temperature of well as compared with tank or canal water during the poppy season. This is an important quality in an irrigative water. If applied at a lower temperature than that of the soil in which the plant grows, it so reduces the temperature and chills the roots, as to temporarily suspend less or more the growth of the plant. This, as might be expected, is severely felt by the poppy in its early stages of growth..... As showing the relative differences of the temperature in the well, river, and tank waters used in the irrigation of the experimental poppy crops here (Deegah), I append in a tabular form the *averages* for the months of October, November, December, January, and February. For the sake of comparison, I also add the average temperature of the soil and of the atmosphere, the maximum in the sun and in the shade, and the minimum temperature for the five months beginning October 1873 and ending February 1874.

		1873.			1874.		
		October.	November.	December.	January.	February.	
1	Maximum in the sun ...	99·30	115 32	99·29	88 39	93·60	
2	Ditto in the shade ...	87·50	79·89	79·49	73·87	74·80	
3	Minimum	63·45	56·88	45·88	42·13	44·85	
4	Temp. of soil at 1 foot ...	72·10	71·08	64·54	59·86	63 48	6 A.M.
5	Ditto ditto at 2 feet ...	74·50	76·20	68·12	63·49	65·35	6 A.M.
6	Ditto ditto at 1 foot ...	74·10	73·32	65 60	60 81	66·50	2 P.M.
7	Ditto ditto at 2 feet ...	75·10	77·09	67·97	63 69	67·78	2 P.M.
8	Well water	76·40	77·00	77·86	75·86	74·93	
9	Tank ditto	68 20	63·50	54·50	46 15	Dried up.	
10	River ditto	72·30	70·00	65·12	60·10	67·07	

2. "It seldom happens," remarks Professor Johnston, "that perfectly *pure* water is employed for the purposes of irrigation...... Even where the water employed is clear, and apparently undisturbed by mud, it almost always contains ammonia, nitric acid, and other organic and saline matters grateful to the plant in its search for food, and which plants always contrive to extract more or less copiously, as the water passes over their leaves or along their roots. The purest spring waters and mountain streams are never entirely free from impregnation of mineral, vegetable, and animal matters. Every fresh access of water therefore affords the plant in reality another liquid manuring." (*Agricultural Chemistry, p.* 325.) To those variations in the irrigative waters may no doubt be ascribed the relatively increased fertility of the poppy on regularly irrigated, as compared with that on non-irrigated lands; inasmuch as they are alike sparingly treated with other manurial substances. The different fertilising virtues of waters are well known to the native husbandman, as also their applicability to particular crops. The *kara* or "*hard*," water, as they call it after our own fashion, is rightly considered, well suited for the irrigation of the poppy, tobacco, potatoes, and onions. The *metha-pani* (*sweet* or *soft water* as we call it) is of no fertilising value in their estimation, but the better suited for household purposes. The native husbandmen thus, in their own way, familiarly distinguish as we do the "*hard*" from the "*soft*" water, with reference to their reactions with soap.

3. A "*hard*" as compared with a "*soft*" water requiring a larger expenditure of soap to produce a lather. This, it may be explained, is due to the action of the lime and magnesia salts; which decomposing the soap, form with its fatty constituent an insoluble sticky mass (the

stearates of lime and magnesia), which adheres to the hands or to clothes. "The comparative hardness of any number of waters," remarks Johnston, "may be ascertained by dissolving Castile soap in spirit of wine, and pouring a little of the solution into the several waters. That which forms the most curd when shaken, or is the most milky, contains the most lime." (*Lime in Agriculture, p.* 16.) Again, as is well known, by boiling or evaporating such waters the carbonic acid is driven off and insoluble carbonate of lime—*i.e.* common chalk—deposited as a hard crust or loose powder. A similar result, though of course less marked, takes place in the use of such waters for irrigation. In this case we find on the surface of the soil and the sides of the water channels a dry white powdery matter or incrustation left by the evaporation of the water. This will chiefly consist of lime and magnesia, with a certain admixture of soda salts; the potash, even though present in the water, will be completely withdrawn and taken up by the soil, so that unless the latter is saturated with that alkali it is not likely to appear in the superficial efflorescence. Those *hard* waters, whether in wells, rivers, or tanks, are unquestionably better than the *soft* for the irrigation of the poppy, though the well-water, as being of a higher temperature than the others, should, for reasons already assigned, have the preference when available.

4. The *softest waters* are those which contain neither solid nor gaseous matters in solution. Of this we have an example in *distilled water*, which is alike void of taste or smell, colourless and transparent, readily wets the fingers, and has quite a *soft feel. Rain-water*, as it falls at a distance from cities or large manufacturing towns, is as a rule the purest of all natural waters. Though then free, or nearly so, from all solid matters, however, it is always less or more impregnated with gaseous matters, as nitric acid, carbonic acid, and ammonia. It thus greatly promotes vegetation, not only as conveying alike to leaves and roots those important food-stuffs, but also in humidifying the atmosphere, and thus counteracting the chilling effects of evaporation consequent on the irrigation of our crops in dry and hot weather. It is more, as I think, in the *temporarily equalised humidity of the atmosphere, the soil, and the plant,* than any absolutely superior virtue in the rain, as compared with the water used in the artificial irrigation of our crops. "The fertilising effect of rain," remarks Liebig, "is on a superficial examination still more wonderful than that of manure. Its influence on the produce of a field is observable during weeks and months after it has fallen; and yet rain conveys to plants only very small quantities of carbonic acid and ammonia. The plant receives by the medium of water at the time of its first development the alkalies, the alkaline earths, and phosphates necessary to its organization. If these elements, which are necessary previous to its assimilation of atmospheric nourishment be absent, its growth is retarded........ If a soil be deficient in these mineral constituents required by our cultivated plants they will not flourish, even with an abundant supply of water. On the other hand, if the latter be wanting, a soil, though rich in nutritive matters, will be quite barren for most plants. It is by means of moisture that plants receive the necessary alkalies and salts from the soil. In dry seasons a phenomenon is

observed which, when the importance of the mineral elements to the life of a plant was unknown, could not be explained. Thus the leaves of plants first developed and perfected, and therefore nearer the surface of the soil, shrivel up and become yellow, lose their vitality, and fall off while the plant is in an active state of growth, without any visible cause. This phenomenon is not seen in moist years, and but rarely in plants which have deep-reaching roots, being more especially presented by the more shallow rooting class of annual herbs. As familiar examples of plants which thus suffer from deficient moisture we have the poppy, the tobacco, and many of our culinary vegetables. Now the cause of this decay is obvious. The perfectly developed leaves absorb continually carbonic acid and ammonia from the atmosphere, which are converted into the elements of new leaves, buds, and shoots; but this change cannot be effected without the aid of the alkalies and other mineral matters. If the soil is *moist* the latter are continually and adequately supplied, and the plant retains a healthy green colour, but if *this supply* ceases from a want of moisture to dissolve the mineral elements, a separation takes place in the plant itself. The mineral constituents of the juice are withdrawn from the leaves already formed and are used for the formation of the young shoots, and as soon as the seeds are developed the vitality of the leaves completely ceases. Those withered leaves contain only minute traces of soluble salts, while the buds and shoots are very rich in them."—(*Letters on Chemistry*.) The softest waters, then, as we have seen, are the least effective for irrigative purposes, and if the soil is wanting in the elements of fertility their application will be but poorly reciprocated by the crop. On the other hand, with a soil rich in the mineral or organic food-stuffs of plants, and requiring only a natural solvent to render them available, even a chemically pure water may under such conditions promote vegetation as eminently as a 'hard' water, rich in earthy and alkaline salts. It is thus easy to see, how much more largely particular crops may be benefited than others, by an equally distributed rainfall, from differences in the relative richness of the soil in the elements of fertility. Rain has a special and direct fertilising influence, as conveying carbonic acid and ammonia to the plant, but its most important mission is its reactions on the soil constituents. Johnston thus concisely enumerates the mission of rain to the soil and the plant:—"*1st.*—It causes the air to be removed. *2nd.*—It warms the undersoil. *3rd.*—It equalises the temperature of the soil during the season of growth. *4th.*—It carries down soluble substances to the roots of plants. *5th.*—It washes noxious matters from the undersoil" (this of course is a mission it can but imperfectly perform in the generality of our poppy-fields, from defective natural drainage and the non-adoption of any artificial system). "*6th.*—It brings down fertilising substances from the air."—(*Agricultural Chemistry and Geology*, p. 171 *et seq.*)

5. Canal waters with a regular flow, when they have once fairly washed their bed, are with *river waters*, as a rule, softer than those from wells or springs, and as a consequence more free from earthy or alkaline salts. Many indeed of the feeders of our rivers have waters rich in gaseous and mineral matters, but they are gradually robbed of these, partly by the absorption and deposition of muddy matters held in

suspension, as also by the agitation and very general increase of temperature, in their flow through long tracts of country, they give off gaseous matters, common air, carbonic acid, &c., and thus deposit much of the lime and other matters held in solution...... It has indeed been strongly insisted that the canal waters in the Upper Provinces are the main and direct source of that saline efflorescence known as *reh*, and which is now so prevalent in the vicinity of many of the canal lines. This I can hardly help thinking is a mistaken notion, as any of the canal waters of which we have analysis really contain such a small percentage of saline matters that it could only be expected after a very long series of years—and even then only on uncultivated, I should say desert, land—to accumulate in such quantities as to prejudicially affect vegetation. This is pointed out by Dr. Anderson of Glasgow in his remarks accompanying an analysis of a sample of reh from the Western Jumna Canal which had been sent to him by the Secretary, Public Works Department, to the Government of the Punjab. Dr. Anderson says that "if reh be derived from the water, it must be by evaporation, and 1,000 gallons would only deposit 1lb of it in the soil, even taking the whole solid contents to be *reh*, which is not the case, for it would appear that only about half of the seven grains consists of alkaline salts. I do not know what quantity of water is used for irrigation in India, but I apprehend it cannot be sufficient to account for the reh. If we suppose the soil to be covered with water a *foot deep*, and the whole of it to be evaporated, it would deposit on an acre of land about 128lb, or little more than 1 cwt. of alkaline salts, and reckoning the soil at ten inches deep, it would weigh per acre more than 1,000 tons. The alkaline salts thus added to the soil would amount to the 1·20,000th of its weight, a quantity which would not be perceptible." Professor Medlicott (to whom I am indebted for a copy of the correspondence "on the Deterioration of Land by the presence of Reh," published by the Government of India) is on the other hand strongly of opinion that the canal water is the *chief* source of reh. He regards these salts as the resultant of the gradual concentration of the river and canal waters (which contain them in minute quantities) with which the lands are irrigated, or less or more saturated for a considerable portion of the year, and almost solely dependent for relief on evaporation.. ... Now, no doubt, the canal waters, when impregnated with sulphates and chlorides, will contribute their quota of these as they evaporate from the soil, but it seems to me highly improbable that (containing as they do, as far as known, such minute quantities of those saline matters) they could from this source alone accumulate so rapidly and to such a prejudicial extent. Furthermore, if the water is really the main and only source of the reh, we might naturally expect it to extend in unbroken tracts along the canal ranges, *i.e.* in all the lower lands. It does not do this, but on the other hand is always less or more local, indicating, as it were, a merely solvent influence in the invading waters on the segregated saline matters of the soil. Moreover, Professor Medlicott himself shows from the analysis of the water from four wells in Roorkee (distant from the canal 500, 1,400, 3,500, and 4,000, feet) very marked differences in their relative richness in the reh constituents. The first of these (*a*) is richer in total salts than the water in the canal, with differences in the relative proportions of the chlorides and sulphates. The latter having been considerably increased, clearly enough pointing to a source of sulphuric acid in the soil which may have found a base in the decomposition of the chloride (of which there is a loss), by the action of lime. Again, the waters of (*b*) and (*c*) contain less by one half in total salts than that of (*a*), and nearly one half less than the canal water itself; while in both the chlorides are in considerable excess of the sulphates. Lastly, in well (*d*) the total salts, as compared with those in the canal water, is above *three* to *one*, the two salts being in this case very equally developed. Professor Medlicott in remarking on these differences says that the water levels in the wells are affected by the rise and fall in the canal, so that any saline deposit below should contaminate all equally, yet it is only in (*d*) that any such action is marked. "I cannot avoid concluding," he continues, "that the reh at (*d*) has been accumulated from canal water, *or at least from a solution of no greater strength.*" Now it is distinctly stated in the paper from which I quote that the water in each well is removed from any sensible influence of surface evaporation; consequently reflecting on the communication between the canal and well waters, I do think, in opposition to the above view, that there is every grounds for the assumption that the waters have local sources for the supply of saline matters. As for the objection that if there were a local source of supply for the well (*d*) it would equally contaminate all, with equal force may the converse proposition be urged, viz. if the canal is the sole source of the water and its salts, why should there be such great differences in the quantity of the latter present in the different wells?...... Now, the phenomenon of local deposits of saline matter is familiar to travellers in the salt tracts of Upper India, &c., where as lakes and pools dry up they leave in the hollows isolated patches of saline matter to be covered over to a greater or less depth by the ever moving sands. So in former periods may similar deposits have been made in those parts which now give rise to reh and kullur efflorescences, and lie far away from any canal influence. Indeed it appears to me highly probable that the tracts and patches of reh and kullur now appearing and disappearing on the same spots with the seasonal alternations of drought and humidity were originally deposited in the manner above indicated. We often observe the efflorescence appearing in oblong or circular patches, always richer or most fully developed towards the centre, thinning off and graduating into the ordinary soil in the circumference, just as if they sprung up from or rested on some concave and impervious pan of clay. Conversely with the quantity of rain we have a corresponding increase or decrease in the reh efflorescence. It is thus also that the continued land-soak of the canal waters accelerates the development of reh in their vicinity, in affording a continuous supply of water. It is highly probable, however (assuming the union of the canal waters with those normal to the undersoil), that there will be an underground circulation, the colder waters of the canal sinking and being replaced by the warmer waters of the subsoil, the latter being first evaporated. Thus, unless in cases of actual inundation or swamp, the canal waters are probably considerably altered in the course of this underground circulation, and before they are again raised up and evaporated....Commenting on the canal water as a *chief source* of the salt on newly affected lands, Professor Medlicott says—"The canal water is a known cause; it must act to its full extent; it affords an inexhaustible, an ever-renewed supply, and it may be adequate to the result.... Assuming that the soil, the sub-soil and the rock are perfectly free from these salts, the very result before us would eventuate under the conditions described, and from the canal water alone. A soil containing 30 parts of sulphuric acid in 1,000 produces barren reh-land. We may take 30 parts of sulphuric acid in 1,000,000 of water by weight as the greatest proportion contained in the canal water. Taking 2 as the specific gravity of sulphuric acid, it would require an evaporation of 5,000 inches deep of water to convert 10 inches cube of soil into reh soil...... Assuming 10 feet or 120 inches as the annual evaporation, we should get rid of our 5,000 inches in about 40 years."—I rather think the Reh-producing power of the canal water, *per se*, is here much over-estimated. First as to the rate of evaporation from the soil: this I think can scarcely exceed say 100 inches annually; that is, allowing 0·5 daily for the hot season and 0·2 for the remaining portion. This I think, will be considered when we consider that even for the Red Sea during the hot months the estimate is only half an inch per day. Mr. Medlicott's estimate would thus be reduced by one-sixth. The calculation is further more mistakingly based on the assumption of a sustained or continuously accumulating efflorescence. Now, obviously, during each rainy season those saline efflorescences will be again carried down into the soil, so that the degree of accumulation on the surface from year to year will conversely depend on the moistness or dryness of the seasons......It would thus appear that the canal water containing, as Mr. Medlicott shows, but minute quantities of the reh salts, are evidently inadequate to the production of those salts in sufficient quantity to cause any deterioration of soil. I think there can thus be no question that prior to the development of the canal systems, those salts formed natural constituents of the soil, and that in a sufficiently diffused state to promote fertility. There is no necessity for assuming that prior to the invasion of the canal waters the ultimate components only of these salts were diffused through the soil. Commenting on this view, Mr. Medlicott says—"*Ex nihilo nihil fit* is a proverb of old standing, and as the radicals of these salts are the most easily detected of all the substances in the categories of chemistry, we may fairly ask the advocates of this theory to bring some statement of facts in support of it." I will not attempt this. The question "*Where does the reh come from?* as it appears to me, is of easy explanation. Let us see.—As a rule it forms but a loose and thin superficial coating to the soil, and unless in local patches, rarely exceeds some two or three inches in depth. Now, a very prevalent notion, as we have seen, is that it arises from the use of canal waters in irrigation. On the other hand, I am of opinion, that as limited to the canal ranges, it is but the purgings, so to speak, of the soil by the infiltering of waters from the canal channels. Irrigation, however, increases the evil, in so far as temporarily raising the zone of saturation in the subsoil. But for this excess of waters in the latter, irrigation with the saline-tinctured waters of the canals could not have other than a fertilising influence, and there could then be no prejudicial development of reh matters on the surface. Again, the so-called *reh*, according to Mr. Medlicott, mainly consists of Glauber and common salts, there being as a rule an excess of the former. Now, from an air-dry sample I find on an average that six cubic inches weigh 8lb, and this covers one superficial foot to the depth of two inches. At this rate 26 tons of reh would cover an imperial acre to the depth of two inches, and I think it will be admitted that even in the most extensively reh-affected districts an unbroken surface of that extent with more than an average of *two inches* will rarely be found. We have here then, a reh-sterilised surface soil. Tacitly assuming that the presence of such large quantities of saline matters in the soil and subsoil is incompatible with any degree of healthy vegetation, Mr. Medlicott asks,—"*Where does the reh come from?*" Now, certainly in an accretion of two inches of soda salt on the surface the soil must needs be sterilised for all but the so-called *halophytic* or salt marsh forms of vegetable life. Nevertheless though thus an agricultural evil in the segregated state, it may, I say will, none the less exercise a fertilising influence if equally diffused through the soil to a depth of even six inches, as then constituting but 2 per cent. of the bulk. It could not possibly, however, be originally even thus highly concentrated in those soils. Prior to the introduction of the canals, when the water lay at its normal low level, they must have had an extremely dilute diffusion, as extending through zones of from ten to twenty and more feet. In those periods, indeed, of the soils history, the extreme dilution of saline matters then obtaining must have been unfavourable to any high degree of fertility. We can thus readily understand how such lands should have had their fertility increased in the first instance (as pointed out by Mr. Sherer and other officers after the introduction of the canals by the upward transmission and concentration of those saline matters in the root zones of the crop, with the gradual rise in the water level), attained their maximum, and suddenly sunk to a state of absolute sterilisation. Everywhere this has been brought about less or more rapidly by the abnormal rise in the water level. Mr. Sherer insists on this. Attributing the failing agricultural capabilities of the soil to the appearance of reh on the surface, he says, "it is naturally connected therefore with low and water-logged lands, increasing where it has once appeared, as the water is getting nearer and nearer to the surface. Water in those villages," he continues, "used to be 40 hâths (60 feet) below the surface, whereas it is now only two or three feet." This is the convulsion which has taken place, and altogether paralyzes the efforts of the cultivator.

(*a.*)—To resume, however, our remarks on Mr. Medlicott's views, it is desirable to observe that soils may contain from 3 to 4 per cent. of soluble saline matters, with no loss of fertility. The late Professor Johnston illustrates this in his works by examples of the analysis and agricultural history of certain Indian soils from the districts of Gya and Tirhoot. In these cases the soils by simple washing yielded from 1 to 7 per cent. of saline matters, and it is observed that those not exceeding 4 per cent. were perfectly fertile. On the other hand that containing the large amount of 7 per cent. (a Tirhoot sample), though *nearly* sterile from saline efflorescence in the *dry season*, produced *good crops* of Indian-corn in the rainy season. I particularly notice the degree of saline impregnation compatible with healthy vegetation, as Mr. Medlicott remarks that while "a first-rate soil in the climate of England may contain as much as 1 per cent. of sulphuric acid in the form of sulphate of soda, a soil in India may produce *reh* and be damaged by it, though it contain no more than 0·5 per cent." In such cases, I would observe, the reh could be but a secondary evil; its appearance on the surface and the decreased agricultural capabilities of the soil being doubtless due to the saturated condition of the subsoil. Mr. Medlicott indeed states, that "in the end of March 1862 the water lies at a depth of only *four* feet." Of course under such conditions *marsh plants* only could be expected to thrive. Again, as favouring the extraneous origin of reh, Mr. Medlicott insists on the rapid decrease in the proportion of salt with increase of depth in the soil. As it appears to me, this fact, on the other hand, altogether favors the opposite view......It is to be observed that the *soil analyses* referred to *were in every case made subsequently to the outgrowth of reh on the surface*, and consequently when the soil had been all but utterly purged of its more soluble saline constituents. The fact then, that there should be a gradual decrease in saline matters from above downwards is of course the natural result of concentration by the evaporation of the soil filtrates......Commenting on the minute quantities of saline matters present in the soils of reh lands, Mr. Medlicott says—"It is well known how retentive clays are of minute portions of those salts: it does not at all follow because a clay gives up all its soluble ingredients when well powdered and freely washed in a breaker glass, that it would do so under the natural conditions we are discussing." Now, as applied to the *soda salts*,—which, as Mr. Medlicott himself shows, are nearly always the sole constituents of reh,—this argument has really no force. It has been shown by Way in England and Liebig in Germany, as also by many others, that the absorptive power of the soil for the *soda salts* is comparatively weak; and this particularly so for its *sulphate* and *chloride*: the reh components. Thus, in discussing the special absorptive properties of the soil, Liebig observes that *potash* and *soda* are well known to stand to each other in the closest chemical relation, and that even their salts have many properties in common. An unpractised eye can scarcely distinguish them, but the *soil* can do this in the most perfect manner. "If we add," he continues, "any soil in powder to a dilute solution of chloride of potassium, in a short time there will not be found any potassium in solution. Now the same quantity of soil does not withdraw from a solution of chloride of sodium, containing an equal amount of chlorine, even the half of the sodium. Again, from the sulphate and nitrate of *soda* the soil withdraws only a part of the soda, but the whole of the potash from the corresponding salts." Reflecting then on those relations of the soil and its saline constituents, as also the saturated condition of the former when reh is produced along the canal ranges, it is easy to see why there should be an increasing paucity in the saline components of the soil from above downwards. Thus, as I believe, the *reh salt*, prior to the canal invasions formed natural components of those lands, and this in a *sufficiently diffused state to* *promote their fertility, their prejudicial concentration now being wholly attributable to the general rise of the water level.* A temporary relief from those mischievously abounding waters would, I am convinced, show this in the course of one, or at most two rainy seasons, by again harmlessly diffusing those salts in their original matrix. The answer to the question "*Whence came the reh salts?*" is thus, as I think, afforded without recourse to mystical combinings of latent elements, or "other vagaries" of the alchymists......Commenting on the views of those who insist on the soil origin of the reh salts, Mr. Medlicott somewhat impatiently says—"To such arguments I can only answer that, unless in cases where facts are brought to support the suppositions, it is irrational to accept them in opposition to what I have shown to be, necessarily at least, a partial source...... that the elements of these salts exist, to the full extent, latent in the *soil*, and are developed by irrigation, is quite inadmissible. The assertion must be proved." On the other hand from the point of view suggested above, the *onus*, as it appears to me, of affording the *argumentum clarum* that the canal waters are the original *menstrua* of the reh salts, is for those, who adopt that view, to show from the analytic history of reh-invaded lands that they did not originally contain in sufficient quantity the special kinds of saline matters necessary to the production of the phenomenon in question.

(*b.*)—I have but a few words more to add here on the deterioration of lands on the canal ranges. *Reh* is generally regarded as the main cause of this deterioration, and it is thought that if they could be but purged of it, their fertility would be renovated. I am of opinion that this is a mistake. The real evil is the undue rise of the normal water level. Water in quantities thus permanently in proximity to, or less or more invading the root range of the crops will to a certainty kill them. Reh is in such cases but a secondary evil, the real bane, or radical evil, being the water-logged condition of the soil. Our cereal crops generally can withstand a copious efflorescence of reh, as I have frequently observed, if the soil is favourably conditioned as to moisture. If too dry, crops of course suffer more on such lands than do those on less saline lands, but with a sufficiency of moisture, they will afford a fair return in grain; and I am thus strongly of opinion that those *pro tempore* reh lands, by a low level drainage, a liberal tilth, and exposure for a single rainy season, would have again their fertility restored......On a small scale, we often see the effects of water-logging in the case of the poppy by the percolation and infiltration of water from the main irrigating channels. The injury caused to the plant by this permeation and water-soak of the soil is very striking (and that with the surface soil by no means excessively moist, or even at all sticky or adhesive); growth is retarded, or altogether arrested according to the degree of moisture. In the former case the leaves assume a pale, sickly, yellow hue; the flower buds appear on the spare and dwarfish stalks; but so low is the vegetative force that they but imperfectly, if at all, expand, and the whole plant dies without perfecting its seeds or yielding any drug. In some instances where the plants were thus destroyed, the water, though in a channel only 12 inches in diameter, 13 inches deep, and but 8 inches above the level of the surface soil, had extended under the main road 11 feet broad, and destroyed, as above, the plants opposite to a distance of from 15 to 20 feet. This excellently illustrates in a small way the evil to be contended with in the canal ranges. Such questions as the origin, &c., of the *reh salts* have but a theoretic interest, the real bane of agriculture in those tracts, being, I repeat, their water-logged condition.

I have already noticed the prejudicial effects of water-logged soil on vegetation, and I will here only illustrate its chilling effects on the soil by the following table of the average temperature of wet and dry soil in the gardens here, with the maximum and minimum of the atmosphere, for the month of January last. The readings of the thermometer in the soil were taken at 5 P.M. :—

January 1876.

1.	Maximum temperature in the sun	80·49
2.	Maximum temperature in the shade	75·12
3.	Minimum temperature	43·14
4.	Temperature of soil in poppy plot (depth 1 foot) ...	75·00
5.	Temperature of water-logged soil (depth 1 foot) ...	62·50

7. The waters of tanks and jheels during the season of the poppy's growth abound less or more in decomposing organic matters. They are thus of high fertilising value, and but for their relatively cold temperature (as at that period, with a large evaporating surface, they have but little depth), they would form an excellent stimulant to the young poppy. On that account well water, as I have already remarked, though relatively poor in fertilising elements as compared with that of stagnant jheels and tanks, is nevertheless, as being of a higher temperature, the better irrigative water for the young poppy, unless indeed the soil itself is radically poor. If well water is available therefore, the better plan is to use it for irrigative purposes, and advantage should be taken of the drying up of the jheels in the hot weather, when their muddy deposits may be readily cleared out and applied with advantage to the land.

CHAPTER XII.

THE FLOWER: ITS PARTS AND FUNCTIONS.

1—*The period of flowering.* 2—*The flower: its parts.* 3—*Duration of the flower.* 4—*The flowers vigils.* 5—*The collection of flower leaves.* 6—*Their preparation as capsular laminæ.* 7—*The period of drug-yielding.* 8—*The precocious development of seed as affecting drug secretion.* 9—*The extraction of the drug.* 10—*The collection of the drug.* 11—*The colour of the drug.*

THE age at which the poppy produces its flowers varies considerably. Thus, in my own experimental plots during the past season, I find the several varieties and mongrels under similar treatment from the period of their germination, taking as a minimum; the *Malwa* varieties *seventy*, and the *local* varieties *seventy-five days*, and as a maximum the *local* varieties *eighty-six*, and the mongrels *one hundred and ten days*, until the unfolding of the first flower. We have thus differences in the arrival of the flowering stage, of from eleven to thirty-five days in the local varieties and their mongrel progeny. The relatively earlier flowering of the Malwa varieties is no doubt due to the dryer and hotter climate of Behar, which, lowering the vegetative powers of the plant, induces it to run up prematurely to the flowering stage. As contrasting with this and showing the influence of the higher average temperature—especially perhaps the chilling effects of the excessive evaporation during the night—and the shortened day of the tropical season, as compared with the summer day in the south of Europe and Turkey, it is noteworthy that the varieties of the opium poppy from directly imported seed, arrive at the flowering stage at a much later period than the local and acclimatised varieties. These exotic varieties are of course a summer's crop in their own countries. During the past season I had seeds direct from Turkey, Italy, France, and Spain. The age of the plant, *i.e.* from the date of germination to the unfolding of the *first flower* in each plot, was, for the Spanish 107 days, Turkey 113 days, for the Italian 119, and for the French 120. As compared with the local poppy, the flowering period was thus considerably retarded. This might be expected, however, as the plant in all those countries is, as I have remarked, a summer crop. Our short days and comparatively cold nights (especially those of December and January) being unfavourable to its rapid development. Indeed, this was so much the case that during the latter month they made little or no progress, and many of their lower leaves began to droop and wither. But, that water had been temporarily withheld from them (as increasing the chillness in its evaporation), few, I believe, would have survived. With an increase of night temperature in the beginning of February, they gradually resumed their vigor, and very soon, with a liberal supply of water, far exceeded in bulk and vigor any of the local sorts. As illustrating this I may state that while half a dozen plants of the Turkey poppy at the flowering stage weighed 8¼ seers, the same number of the local sorts (also in high vigor) weighed only 2 seers. I was indeed much surprised with the high luxuriance and really gross habit of all those newly imported poppies.

2. The flower, I need scarcely remark, is composed of parts essentials, and subservient to, the production of seed. The latter compries the leaves of the flower, and are merely protecting organs to the first class. In the poppy, as in every complete flower, they are disposed in two whorls or circles, one within the other. The outer set is called the *calyx*, and consists of two thick-textured, green-coloured leaves, technically distinguished as *sepals*. The inner set, of more delicate textured flower-leaves, forms the *corolla*, and is composed of four white, red, lilac, or pinky coloured leaves, each of which is called a *petal*. The two inner series of organs are those essential to the production of the seed; first, the *stamens* or male organs of the flower, consisting of two parts, viz. the *filament* or *stalk*, and the *anther*; the latter containing the fertilising powdery matter called *pollen*. The *stamens* in the poppy are normally numerous, from 140 to 160, though in starved and dwarfed specimens I have observed flowers with from two to three only, surrounding a miniature capsule, with a *three to five lobed stigma*, and containing perfect seeds. The *capsule* or central part of

the flower is the drug-producing and seed-bearing organ: technically the *pistil*, consisting of a *one-celled ovary*, and a sessile, overcapping *stigma* divided into from 3-16 rays. The functions of these are to receive the pollen grains from the anthers and excite the development of a delicate tube, which penetrates the loose tissues of the stigma, directs its way to the ovules, and effects the fertilisation of the seed. Such then are the parts and functions of the flower.

3. The flowers of the poppy are very ephemeral, the calyx falling off with the first expansion of the petals, while the latter with the stamens fall in the course of the third day; thus lasting in all from 54 to 60 hours only. The duration of the flower in many plants, as is well known, is prolonged by preventing the fertilisation of the ovary. It would appear to be inoperative in the poppy, as I find that the petals and stamens fall off simultaneously from the fertilised and unfertilised ovary. The sepals, petals, and stamens, the rind of the stalk and leaves, as well as the walls of the ovary, are all in their immature stages pregnant with opium juice. In the *petals* it is comparatively thin, but milky, colouring slowly by exposure to the atmosphere; in the *filaments* it is denser, and relatively to their size much more copious, and, like the juice of the ovary, undergoes a very rapid oxygenation when exposed to the atmosphere. With regard to the fertilisation of the ovary, it is to be observed that on the first expansion of the flower the stamens overcap the ovary, and the anthers, bursting almost immediately after the opening of the petals, discharge their pollen ere the stigma is sufficiently developed to be influenced by them. The ovary increases rapidly in size, and by the third day after the flower has opened, the stigmatic shield overtops the stamens by a half to three-quarters of an inch. The double crests of the stigmatic rays are now partially opened, but it is only on the fourth day, and thus after its own petals and stamens are cast off, that they are fully opened and expose their moist velvety crests to the pollen-bearing wafts of air. It is thus easy to see that the fertilisation of the individual flowers is more likely to be effected by pollen from other stamens than their own.

4. The vigils or the so-called sleep and awaking of flowers are exhibited by the poppy. Like the tulips and marigolds, of which Bishop Hall thus quaintly writes, "it is a true client of the sun; observant of his motion and influence! At eventide it closes, as mourning the departure of one without whom it can neither see nor flourish; in the morning it welcomes his rising with a cheerful openness, and at noon is equally displayed in a free acknowledgment of his bounty."—The first expansion of the poppy-blossoms takes place from shortly after sunrise to about noon; by far the majority are, however, open by 9 A.M., and few indeed expand in the afternoon. A day or so prior to this, the hitherto drooping flower-buds assume an erect position, and shortly after daybreak the crumpled petals begin to spread out and throw off their calyx covers. By sunset the corolla has again closed itself over the ovary and stamens, and opens again by sunrise the following morning. This, the evening of the second day's expansion it is less sensitive to decreasing light and heat, and is not fairly closed until it is nearly quite dark. Again, on the morning of the third day it is still less influenced by the sun's rays,

and it is only after it has attained a considerable elevation that the flowers are fully expanded. By noon the petals are all more or less drooping, and fall off by sunset; while the stamens are closely applied to the walls of the ovary with their filaments dry and shrivelled, and fall readily off with the slightest breath of air.

5. The petals or flower leaves are largely utilised in the formation of the shells or capsules of the opium, as prepared for the China trade. The collection of the petals is however made without the least injury to the plant, their natural fall being but barely anticipated.

(*a.*)—The assamees know well, from the appearance of the flowers (the deflection of the cup-forming petals, or the shrunk and discolored stamens applied to the ovary), when the petals are ready for collection, and rarely catch an immature flower. The process is simple: thus, they clasp the petals at the base with the forefinger and thumb, gently drawing them upwards, and tightening them over the apex of the capsules, when the matured petals at once disarticulate or detach themselves. There is thus no tearing or straining of the petals, and no loss of juice from the disarticulated surface, the collection being made usually by noon on the third day of the flower's expansion: while at all moist they are never collected, as they are then apt to become discoloured or even partially fermented. I may here add, as showing that the collection of the petals is in no way detrimental to the plant, that crops from which they have been taken produce from 15 to 40 seers of seed per beegha, more than those from which they have been left to fall naturally. It thus perfects fertilisation.

6. The mode of preparing the *capsular laminæ* from the *flower-leaves* is simple, but efficient. A tabular fireplace (12 to 18 inches high, by about 12 inches in diameter) of strong clay, with a thick shallow saucer to rest over it, and all well dried in the sun, comprise the necessary preparatory apparatus. When the saucer is heated to a degree slightly above that at which the hand can be kept on it, two or three handfuls of flower-leaves are spread regularly over it, covered with a moist piece of cloth, and all firmly pressed by a damp pad of cloth. What with the steam from the cloth, and the natural gum and resiny matters of the leaves, all soon become agglutinated, and are then turned over, any inequalities at the margin put right, all uniformly and somewhat firmly pressed again with a moist pad, and then carefully taken from the saucer and spread out in an airy place to dry. They are thus quickly, easily, and economically prepared. It is only necessary to have them thoroughly well dried before they are finally stored, as, if at all damp, and placed in a confined room, they soon undergo fermentation.—The annual consumption of those flower laminæ in the preparation of the capsules or shells for the China opium is very large. Including loss in storage from attacks of grub, &c., it is upwards of 16,000 maunds, to compose which the *entire* petals of no less than 4,710,400,000 flowers are required. I particularise *entire petals*, as in some localities the claws of the petals are taken off as they are collected, and of course there is a very considerable loss in weight; in fact fully one-third of the gross weight, *i.e.* of the freshly collected flower-leaves. The best laminæ are thus prepared, the texture being firmer and more elastic than those with the petal claws, but as it is a mere question of gain or loss to the assamees

they of course in general utilize the entire petal.—It may be as well to state here that the above estimate of the number of flowers annually required for the capsular laminæ is based on the following data:—I weighed a seer of fresh flower-leaves, and found that it comprised the corollas, *i.e.* the four petals, of 460 flowers, and that these were consumed in the preparation of 8 laminæ, which in the ordinary air-dried state, weighed only one chittack. This is of course equal to 128 cakes, and 7,360 flowers, *i.e.*, corollas, per seer, and so on for the higher numbers, which are indeed startling. In preparing the opium for the China market it is weighed out in portions of 1 seer $7\frac{1}{2}$ chittacks; each of which is enveloped in alternate layers of laminæ and liquid opium, lewa, pussewah, and the like, to give them the necessary adhesiveness, and form when dry a firm and compact shell. The weight of laminæ allowed for each shell is $5\frac{1}{4}$ chittacks, which is equal to 42 laminæ and 2,355 flowers. Then these flower-leaf laminæ, agglutinated with liquid opium, the drug as prepared for the China market, could not possibly have a better shell. The Court of Directors were indebted to Mr. Fleming of Barochan for the introduction of the flower-leaf shells, the drug having hitherto been chiefly enclosed in tobacco leaves. The opium consumers have thus a shell not greatly inferior to the unsophisticated drug, for mixing with finely chopped tobacco as a smoking material.

7. In the course of from seven to ten days from the fall of the flower-leaves the capsules are in a sufficiently mature condition for the extraction of the drug. As stray flowers, however, only in the first instance usually appear in our poppy khets or fields, it may, as in many of my own plots, be some ten or twenty days later ere there is a sufficient number in flower to make it worth the cultivator's while to commence the extraction of the drug. When once commenced, however, the capsules are regularly practised upon as they attain the above noted age. The drug-yielding stage is not, however, with the assamees a question of the capsules post-floral age; their criterions are the plumpness of form, firmness of texture, and the dry and discolored appearance of the stigmatic rays, which they in their own way describe as *munh, maila hua.* The duration of the drug-yielding quality in different plants varies much. In some cases we find a single scarification on each capsule wholly exhausting the drug, others affording from two to four incisions, and so on, from five to eight, ten, and even twelve copious discharges of drug. Now, as the ordinary practice is to allow an interval of two days between the successive scarifications, we have in the case of the more copious drug-producers the quality sustained for fifteen to thirty-six days. I have not myself observed capsules retaining the drug-yielding quality beyond the twenty-fourth day, and in those cases where capsules had afforded twelve distinct drug-yielding incisions, their plethoric habit had been taken advantage of, and the capsule at once *doubly scarified.* In dry seasons, and especially on light, sandy soils, the quality may be considerably prolonged by sustaining a healthy moisture in the soil from the first appearance of the flowers until the plants evince a failing supply of drug. The assamees generally are averse to this practice, and as a rule do not irrigate during the collection of the drug, a

less or more copious irrigation being made a day or two before the capsules are first scarified, and the last, as they say, to perfect the seeds, when the capsules have ceased to yield drug. This practice may answer well enough on moist and clayey soils, but there is plainly an advantage in occasional irrigations of the plant in its drug-yielding season on dry sandy soils, and as in the past excessively dry seasons 1875 and 1876 even on strong clayey soils. Variety, soil, manure and climate also, as we have shown in a previous chapter, have a direct influence on the duration of the drug-yielding period, as also on the quantity and quality of the produce.

8. Again we not unfrequently find plants of high precocity and prolificacy, concentrating from the stage of fertilisation their whole energy on the production of seed. In such cases the walls of the capsule quickly assume a dull olive-brown colour, become dry and woody, and yield little or no drug, while the inner walls—the *placenta*—are studded with the premature seeds. Another case of arrest of the drug-secreting quality is due to precocity and abnormal development of the seeds. In this instance (which is most frequently observed in *dry seasons* and on light *sandy soils*), probably in part from imperfect fertilisation and deficient humidity, a quasi-vegetative development is excited in the ovary, and the cord—technically the *funiculus*—by which the seed is attached to the placenta is abnormally elongated; the seed becomes abortive, or not unfrequently is converted into a bud-like body and gives off minute leaves, as occurs in many well-known viviparous or proliferous plants. (I may here remark, however, that I have never been able to sustain the vegetation of these buds, *i.e.* to rear them up to maturity.) In those cases, as in the preceding, we find the juice in the capsule walls also quickly drying up (rarely affording more than a single incision), and sooner or later bursting longitudinally from the strain by the increasing bulk of the seed processes.

9. The drug is obtained by the scarification of the immature capsule from below upwards in perpendicular, rarely oblique, lines. I here of course refer to the practice in the two agencies; as in Malwa the capsule is usually incised obliquely, in Asia Minor and Persia the incision forms a nearly complete spire from below upwards, while in Egypt the practice is to make short oblique incisions on the lower part of the capsule only, and the exudations are said to be generally collected a few hours after the incisions have been made. I must confine myself, however, to a notice of the modes practised in the Government agencies here. The scarifying instrument, though rude, serves the purpose well. It is indifferently called *nashtar* or *nurnee* by the natives. It consists of four concave-faced, sharp-pointed blades, tied together with cotton at about the $\frac{1}{30}$th of an inch apart, the parallel lines of incisions rarely exceeding $\frac{1}{8}$th of an inch. In some localities in the Upper Provinces a *three-bladed* nashtar is in use, while I have observed that in a few of the khotees in the Tehta, Gya, and Patna divisions a *two bladed* instrument is used, and on each occasion the incisions are twice or thrice repeated: there the incisions are very short, extending from near the base to little above the middle of the capsule. This is known as the *tikulea pach*, from some fancied

resemblance in the incisions to the marks on the forehead of Hindustani women. I have lately used with decided advantage on some of my selected varieties with large capsules, as also on the comparatively small capsuled kalodanthi, which has perhaps the least protracted drug-yielding period, from the early maturation of the seed—a bad habit in a variety—a five-bladed nashtar, with the blades at the same distance apart as in the four-bladed, and thus cut over a larger surface, and got a fine broad and plump cord of drug. The lancing of the capsules is usually done by women, and to perform it well and speedily it requires experience, much care, and considerable tact. A careless lancer may lose more than half the drug, in spite of the most careful superintendence: of course I refer to engaged labour, of which I have now had a few years' experience, and observed much wilful, I should rather say spiteful, negligence, both in the lancing of the capsule and the collection of the drug. This does not occur in the case of the assamees, few of whom have hired labour, all being done, from the tillage of the land to the final harvesting of the crop, by their own household.—To return, however, to the mode of lancing. The nashtar is grasped firmly between the second finger and thumb of the right hand, the first finger then resting on the top of the instrument, or it is caught between the thumb and forefinger, but in both modes very near the points. It is to be observed however that the position of the fingers does not in any way guide the operator in the depth of the incision (this being left entirely to his own skill and discretion). It but enables him to cut more steadily and uniformly. This is of prime importance, as in a superficial or unsteady incision, which merely passes through the rind, little or no drug will exude, while in a deep penetrating incision, any drug that escapes will of course lodge in the interior of the capsule and be lost to the cultivator. Capsules with their walls thus cut through are much injured, usually producing little or no drug afterwards, and this especially if the wound is between the placenta or seed-bearing walls; less so if opposite or over them. I should state here that the incisions are indifferently made either between or opposite to the latter processes. I have seen it somewhere remarked that every care is taken to make the incisions in a line with the rays of the stigma, and of course over the placental ridges. This is a mistake, at least as regards the mode in the Government agencies, though, as I have shown, unsteady, unskilful, or careless hands would then be less apt to permanently damage the capsules. The scarifying—*pachna-kara* or *pachin* of the natives—of the capsules is usually commenced by 2 P. M., and continued if necessary until sunset: the drug exuding as well and of as high consistency at the late as the early hour, and when collected presents no tangible difference, either as to quantity or quality. The lancers move backwards through the fields and expertly catch with their left hand the sufficiently mature capsule, draw their lancets perpendicularly over it, slip it, catch another, and so on. With *hired* labour I find it necessary to allow eight to ten lancers per beegha for an afternoon. Doubtless the assamee and his family go over their own khets at a much lower average of labour, but this they simply will not do when hired, and by pushing them on they but slip over the work badly and bring in less than a half of the normal quantity of drug. With such peculiarly nice work on hand, it is thus to the employer's interest to avoid anything of an irritative nature in the management of his lancers, and endeavour to have all working on good-naturedly.

10. By sunrise on the morning after the capsules have been scarified the collection of the drug is commenced. To this process the assamees apply the terms *puncho* or *uharo*, *i.e.* to scrape or take off. The implement used in this process is a small trowel-like scoop of thin iron, with smooth, even, sharpened edges, and called a *setwah* or *setoowah* by the natives. What by mere friction over the sides of such vast numbers of capsules and the chemical action of the natural and adventitious moisture in the fresh drug (which undergoes rapid oxygenation as its fresh surface is exposed to the air), it is curious to observe how they are worn down on the scraping side by the end of a single season.—It is no doubt through this that the often not inconsiderable percentage of iron shown in the analyses of the drug is introduced. It is not a natural constituent of the drug, any more, I believe, than other saline and earthy ingredients always less or more present, and due to the accidental mixing of fragments of the stamens and flower-leaves, as also the adhesion of dust to the fresh drug on the plants. Considering the prevalence of dust-laden westerly winds during the season of collection, it is indeed a surprise to me that the average percentage of such matters in the drug is not higher. In Asia Minor, the producing country of the finest medicinal opium, *shells* are said to be used both for scarifying and collecting the drug! So that it is likely to present a considerably higher percentage of lime than the Indian drug of iron.—In the process of scarifying we have seen that the operators move backwards, successively leaving the scarified capsules in front of them; on the other hand in collecting they have the crop in front, and collect the drug as they proceed, thus avoiding all rubbing or brushing of the drug-bearing capsules. The neck of the capsule is caught between the first and second finger of the left hand, the thumb being placed on the top or shield-like stigma and held firmly in a slightly inclined position while with the right hand the drug is drawn off with the *setwah* or scoop. From inequalities in the capsule a portion of the drug frequently escapes the *setwah*, and a careful collector will clean it off with the thumb or forefinger ere the capsule is slipped. From time to time as the scoop is filled with drug it is placed in a metal dish, and when the day's collection has been finished it is at once transferred to store saucers of unglazed earthenware.

11. The colour of the drug as it exudes and concretes on the capsule, and finally attains a mature consistence, varies considerably in the different varieties, and also in the individual plants composing those. The varieties in the Government agencies are in this respect well distinguished from those of Malwa both in the crude and mature drug. The juice as it exudes from the former is of a dull chalky-white colour, changing less or more rapidly to a dull reddish-brown or pinky-red. In the Malwa varieties, on the other hand, the juice exudes of a smoky-white, and—much less sensitive than the former to atmospheric action—*slowly* assumes a pale chocolate-brown colour. Especially marked is the change in the juice of the varieties *kalodanthi*—and

teyleah. In both the juice is almost a milk-white as it exudes, but almost instantly acquires a dull greyish tint, and still deepening in colour, and not exceeding a minute from the making of the incisions all are covered over with a cord of pinky-red drug. Again, plants of the *kalodanthi*, *teyleah*, &c., and particularly of the variety called *monaria*, have a somewhat curdy juice of a dull smoky-white as it exudes, slowly changing, as it covers the incision, to dull chestnut or red-brown. In the Malwa varieties the juice *very* slowly changes from its exuding colours of smoky-white and dull cream to tawny-yellow or chocolate-brown. The variations, I need scarcely say, are due on the one hand to differences in the susceptibility to atmospheric action, and on the other to the degree of ultimate oxygenation of the juices. Anyhow, they indicate marked differences in the chemical condition of the exuding juices; and that these differences are constitutional, and in no way related to climate or soil conditions, is shown by the fact of their presenting these distinctions while growing together under similar treatment on a single plot. Again, as in the crude drug, we have also some little variety of colour in the mature or prepared drug. Thus, we have light chocolate to dull chestnut-brown, and reddish brown passing to dirty brownish-black in the various local varieties, while in the Malwa sorts the colour varies from tawny to yellowish, or dark-brown and dull-red. As regards colour and texture, the Malwa drug more resembles that of Asia Minor than that of Behar or Benares. In a variety, however, of the local sorts which I picked up in the gardens here—well marked by its setigerous flower stalks—the drug presents all the physical characters of the Malwa sorts, while in alkaloids it is richer than either those, or any of the local varieties.

CHAPTER XIII.

THE LATEX: ITS CIRCULATION AND FUNCTIONS.

1—*The latex: its characters.* 2—*Its functions in the plant.* 3—*The "setting" of the milk-sap.* 4—*Its circulation.* 5—*Explanation of the phenomenon.* 6—*As correlated to the extraction of drug from the capsule.*

The function of the latex or milky juice in the poppy should not be altogether unnoticed in this little treatise (even though there is a confessed want of all positive information on the subject), inasmuch as authors on the physiology of vegetation very generally regard it of prime importance in the plant's nutrition. Thus, according to M. Schultz, "the *function* of the *latex* is to nourish the tissue among which it is found...... the latex is the only one of the fluids in the bark which can have a progressive motion, and it is therefore it which furnishes nutrition....... The loss of only small quantities of latex injures plants very much." In face of this latter statement we are all familiar with the fact that the opium poppy, though annually depleted of its last drop of milky juice for more than a century, does not evince the slightest symptoms of failing vigor, but now as hitherto, is alike healthy and prolific.......Again Sachs and Hanstein are of opinion that it (the latex) contains matter of a directly nutritive character and others of an excrementitious nature. Schleiden, in treating of the latex-vessels, their contents, the vegetable acids, alkaloids, &c., remarks that they "are never found in the ordinary plant-cells, while many amongst them under peculiar circumstances fail to be developed; for example, the poisonous secretion of hemlock, which is not found in the plant of the Asiatic steppes; whilst others are substituted the one for the other, without the vegetation of the plant suffering in the smallest degree. Therefore, in the contemplation of vegetable life, I think they may in a great measure be disregarded as unimportant substances." This view best accords with observed facts. Thus the poppy may, as we know, in successive generations be systematically depleted of its milky juice without affecting in any tangible way its vigor or fertility. Professor Schultz, however, asserts that "upon robbing *Asclepias syriaca* of a great quantity of its milk it *ceased* to *bear fruit*, but it sustained no inconvenience upon merely losing its sap."

2 I suspect there is some mistake in the statement: anyhow it requires confirmation. The plant is not a native of this country, nor is it in cultivation in any of our public gardens, but as common in India we have in the *mudar*—*Calotropis gigantea*—a near ally, which I know from direct experiment does bear fruit, perfect its full complement of seed, and is in no perceptible way injured by the extraction of its milky juice. I find this the case also with the poppy ally *Sheel-kanta*, —*Argemone mexicana*,—and the common lettuce. It would thus appear that the milky juce, as Schleiden suggests, is of little importance in the vital ecomomy of the plants in which it is found. I think this will hold very generally in all milky-juiced *annual* plants. In these the habit of producing this, having probably been acquired from a *perennial progenitor, to which* the storing of such surplus matters in the periods of high vegetative activity may subsequently have served an important purpose in its reactions with absorbed moisture, when the buds first began to unfold after the plant's season of rest. What, then, it may be now asked, is the source of the latex or milky juice? This, as regards the poppy, is plainly a most important question, as possibly indicating modes of enriching the plant in those very matters which give it a place amongst our agricultural—officinal plants, but unfortunately it is one on which there is a want of positive information. M. Schultz, indeed, who regards the latex as a highly elaborated and highly organized juice, does not hesitate in asserting that it originates in the sap which rises by the tissue of the wood, and introduces itself into the leaves; thence, *after being elaborated*, passing into the bark, where it is *deposited in the vessels in its mature form*. We have seen, however, that the latex can have but a very low physiological value in the vital economy of the plant; and observed facts clearly show that it does occur in its own peculiar vessels in other

than the *elaborated and mature form*, in which alone M. Schultz appears to have found it. In the case of the poppy, for example, we find in extracting drug from the capsule that after one, or in some cases two, incisions have been made, and afforded copious discharges of well matured drug, a third, if immediately following, will give rise to a very crude drug of almost watery consistence and colour. Again, it is to be observed that if the capsules of the poppy are lanced during or immediately after strong gusty wind the drug invariably oozes out of a poor watery consistence and colour, much of it dropping from the capsule ere it can form a coagulum. From the foregoing illustrations then, it would appear that the milk possesses both absorptive and assimilative properties. I may also state here that besides the *latex*, the milk-vessels do occasionally contain air-bubbles. I have seen them escape in scarifying the capsule. This is noteworthy, as there can be no question as to the function of these tissues, and respecting the functions of the spiral, annular, and other vascular tissues it has been held, that as containing air, they cannot possibly be distributors of sap. ..... Than the above views of M. Schultz, Schleiden's appears to me the much more feasible. Thus in discussing the peculiar vital properties of the liber-cells and milk-vessels in certain plants, the latter authority remarks that the contents of the latex-vessels differ specifically in almost every plant, and frequently in different individuals of the same species, at least in the proportion of the separate constituents. This, I may remark, is well illustrated in the several varieties of the opium poppy. "Again," he continues, "with regard to the value of the latex, in respect to the life of the plant, if we disregard Schultz's wholly unfounded fancies, we are also entirely in ignorance......" Probably all these organs, like the *latex receptacles*, by which they are frequently replaced, are for the purpose of receiving matters and preventing their reaction upon the living cells, which would otherwise be detrimental to the life of the plant. This is at all events indicated by the circumstance that almost all vegetable poisons, and which even act as such on the very plants by which they are yielded, are found in the *latex*; but as yet nothing but the most vague suppositions can be broached. With regard to the phenomena in the poppy, however, I do think we have grounds for assuming that the functions of the milk-vessels are of an excretary nature, and that these are probably largely promoted by, if not dependent on, the action of those irregular club-shaped expansions of fibrous cells which I have elsewhere shown, so abound in the prosenchyma—technically the mesocarp or middle part of the wall of the seed-vessel. (I have also observed them in the corresponding parts of the leaf—the *mesophyllum*—and the bark—the *mesophleoum*) and always intimately associated with the system of milk-vessels. As it appears to me, these peculiar vessels are specially related to the milk-system, and, as I will subsequently attempt to show, may be the main agent in inducing that peculiar circulation of the *latex*—*cyclosis*—which has been regarded as *analogous* to the motion of the blood in the lower forms of animal life. In a subsequent section I shall, however, recur to the phenomenon of cyclosis; in the meantime we have to do with the functions of the milk-system, and the probable origin of its contents in the poppy. In illustrating these phenomena I adopt Schleiden's suggestion, and regard the milk-system as a special reservoir for certain saline matters which may accumulate in undue proportion in the normal working sap, as also certain peculiar organic products resulting, it may be, from the waste, or I should rather say surplus, organic elements liberated in the development of the tissues. As supporting this view, we find the latex most abundant in the young or developing parts of the plants, and decreasing after they have attained their full development. Let us see, then, how far these views are supported by the observed phenomena.—In the first place, however, it is to be observed that the milk-system of the poppy is more largely developed, and consequently its power of secretion is perhaps greater relative to its bulk than that of any other milky-juiced plant. I of course refer to the local cultivated varieties of the Government Agencies, which I believe produce larger quantities of drug than those in the Indian native states, or in any extra-Indian poppy-growing districts. As compared with what we may presume to be the normal or wild form of the opium poppy, the best of our local sorts yield from *eight* to *twelvefold* more drug. This, I may add, is wholly due to the inherited effects of increased action continued through a long series of years, as the selection of seed from the most copious drug-producing plant is but initiated for two seasons past in the experimental gardens under my charge. To proceed, however, with our illustrations. – First, as showing that the juices do occur in a crude state in the milk system, we have only to take a vigorous poppy plant in the prefloral stage and subject it to a process of depletion. Thus, by cutting off the apex of a growing plant we have the wound almost instantly and copiously coated with a dense, readily coagulable milky-juice. The wound being thus closed by a coagulum of the extravated latex, the stem is again cut across, a fresh surface exposed and re-coated with juice, and so on. Now, by thus repeating the process from four to six or more times, according as the plant is less or more advanced, we find the milky-juice becoming thinner, paler, and less sensitive to atmospheric action, until it attains quite a watery consistence and colour not tangibly affected by the air, while still possessing highly acid qualities. Thus depleted, we now allow the plant to rest for two or three days, again cut it across, and we have a repetition of the above phenomena ; the dense and quick changing colour of the normal latex giving place to a very slightly colourable fluid of watery consistence. Hitherto we have been presumably treating a growing plant, but now subject a fully mature plant to a similar depletive process. I mean a plant after it has ceased flowering, but prior to the maturation of the seeds.—Observe the different results : a dense, readily coagulable milky-juice, quickly changing colour under the action of the air, is first produced, and so also in repeatedly exposing a fresh surface for some six or eight times, but at last a thin, but milky coloured juice slowly exudes, and is scarcely at all coagulable, forming only a thin film over the surface as it dries up. The process of depletion is now completed, and in cutting the stem across again on the following day we have no exudation ; the secretion of the milk-juice has altogether ceased. We have thus clear evidence that the milk or drug-secreting function of the poppy is contingent on, and limited by, the function of nutrition or vegetation, as opposed to that of reproduction.

(*a*.)—It may now be asked, does the milky juice in any way contribute to the nourishment of the seeds? Let us consider this question: we will best do so by a comparative examination of mature plants *with* and *without* the drug, *i.e.* plants which have had no drug artificially withdrawn, and those from which it has been wholly taken by capsular scarifications. Now, in the first instance, it is to be observed that throughout the vegetative period the drug-forming juice abounds in a less or more concentrated state in all the parts of the plants, and is evidently an unutilised educt of those processes. This is shown by the fact that the gross weight of seed in drug extracted and drug-retaining capsules is much the same. Furthermore the seeds present no tangible difference in size or density in their oil-yielding property, their germinative quality or vigor of progeny. In all these respects the seeds from drug-exhausted capsules are in no way inferior to those from plants whose progenitors have been allowed to retain the drug-juices for generations past. This at least is the result of my own comparative observations on "tapped" and "untapped" poppy for this and three previous seasons. Again, as regards drug produce, the seed-progeny of untapped capsules certainly are not a whit more productive than those that have had a continued series of drug-exhausted progenitors. This also appears to have been the conclusion of the Opium Agent for Behar, Mr. Abercrombie. Thus, commenting on the experiments in that Agency with seeds from tapped and untapped capsules, he says, "the produce from the plant obtained from the seed of the untapped capsule is not so much greater than that obtained from the seed of the tapped capsule, as to render it *worth while* to introduce it generally, and that the *continual use of seed* from the *tapped capsule does not, as a rule, tend to cause a deterioration in the plant*":—Indeed, after numerous and careful observations on this head, I can add that I have in no case seen the slightest symptom of such a falling off either as regards vegetative vigor or reproductive prolificacy. Plants systematically deprived of their milky-juice, by puncturing of the nodes, or leaf-joints and flower-buds, have more or less perfectly performed their reproductive function, *i.e.* matured a full complement of seed." Positive evidence of the inutility of the drug as a contributor to, or promoter of, the vegetal and reproductive functions is afforded by a physiological study of the plant in its maturation of those functions, when allowed to retain the whole of its milky juice. Observe the phenomena.—These will be more clearly set forth by comparative experimental observations on the maturing fruit, *i.e.* the seed-capsule, *with* and *without* the milky juices. Thus, under the latter conditions, the seeds, as being surrounded by walls more pervious to heat rays than those with the milk-laden vessels, are fully matured in from 15 to 30 days after the fall of the flower. This is indicated externally by the capsule acquiring a dry and woody texture, and a dirty brown colour, the leaves having simultaneously withered from below upwards, while the stem and root are also dry and hard; in short, all parts of the plant quite dead. On the other hand, in the case of plants from which the milky-juice has not been extracted, we find that even after the capsule is full grown, and the seeds in an advanced stage of maturation, the milk system is full of drug of high consistence. Obviously the reproductive processes are completed without tangible loss by assimilation, or indeed any chemical change whatever in the milky-juices. As compared with those in the immature capsules, they differ only in degree of density, which is no doubt due to evaporation of their watery contents, and the thickening of the whole vascular membranes. As the leaves wither and the stems dry up, we find irregular deposits of various matters—mucus granules, globules of gum, resin and fat, with occasional crystals—on the inner surface of the milk vessels, and this is especially the case when they end in a blind extremity—*cul-de-sac*. In the latter, indeed, we have not unfrequently a coagulated mass of mucus and other matters which have doubtless been deposited by the evaporation of their watery solvent. As regards the roots, it is to be observed that while those of drug-extracted plants dry up and die simultaneously with, or rather prior to the stem, those of plants matured and retaining their milk-sap, continue quite fresh for some little time after all the upper parts, stem, leaves, &c., are dry and dead. This temporarily prolonged vitality of the root is of course due to the unutilised store of milk-sap, and indicates the mode by which those matters may have been utilised by an early perennial progenitor of the poppy, as they are, for example, in the case of the dandelion and other herbaceous, milk-sap producers. As a practical inference from the above, it is obvious that in promoting and prolonging the vegetative vigor of the plant, and retarding the maturations of the seed, we afford conditions most favorable to a copious development of drug. Obviously then, and as a consequence of that all pervading law of antagonism between the nutritive and reproductive functions, by delaying the period of reproduction, lowering, so to speak, the reproductive activity, the secretion of drug will be correspondingly promoted and prolonged. This can best be done by enriching the soil with ammoniacal or nitrogenous matters and sustaining a sufficient humidity in the earlier stages of the plant's growth, and thus check any tendency to the premature production of flowers; and lastly, when the plant has attained the flowering stage, to irrigate freely, only discontinuing it wholly if the soil is of a strong clayey nature, whereas if light and sandy, continuing it occasionally during the earlier collections of the drug. It is important to observe this, inasmuch as a deficiency of root-moisture during the flowering stage will tend greatly to accelerate the maturation of the seed, and consequently the death of the plant.

(*b*) - The latex or milk-sap consists of a watery fluid, probably containing albumen in solution, and with suspended globules of fatty and gum-resinous matters. To observe the general characters or peculiarities of the latex, it is necessary to examine it fresh from the plant with a microscope of from 250 to 400 *linear* magnifying power.—This linear or *diametrical* magnifying power will of course be distinguished by my readers from that called the *superficial*, which is equal to the square of the linear, so that the above instruments have a superficial magnifying power of 52,500 and 160,000 respectively: measurements, I need scarcely say, of senational microscopists only—that class who impose on an over-credulous public with their oxy-hydrogen microscopes, in which the so-called *drop* of water is represented as containing monstrous animalculæ, which are but the larva of dragon-flies, beetles, &c., requiring no microscope for their examination, being fully an inch long.—Let us now resume the examination of the *milk-sap*. Commenting on the latex, M. Schultz says—"If we consider the organization of the latex, the globules it contains, its property of coagulating and separating into serum, and a sort of febrine, we are tempted to believe that there is a considerable analogy between it and the blood of animals." As opposed to Schultz's views on the organization of the latex, Professor Mohl shows "that the globules (which according to Schultz *constitute its living part*) are destitute of any trace of organization, and can no more be compared with blood-corpuscles than can any other drops of resin, oil, &c., met with in vegetable fluids. The caoutchouc of the latex cannot be compared with the fibrine of the blood, since it is not met with, as that is, in solution in the serum, and does not transform this latter into a plasma; it is met with, on the contrary, in a complete state of development under the form of globules"* Observe them in the poppy.—In it, as we have remarked, the essential morphological or structural elements, consist of minute globules and granules of fatty and gum-resinous matters. These are suspended in a less or more concentrated milky fluid, which (probably from the presence of free meconic acid) has always a distinct acid reaction: apparently more so in the morning than the evening. In the natural state (*i.e.* when the vegetative processes are in full activity) it is, so to speak, the mother liquid of that singular series (no less than tenfold!) of alkaline and neutral matters which give it a first place in the Materia Medica. In the milk-vessels of the mature plant, when the watery fluid has been wholly resolved or evaporated, traces of these matters in their normal crystalline forms may generally be detected. They may readily be separated, however, from the fresh juice by placing a portion of the latter on a glass slide and treating it with alcohol. As the alcohol evaporates, the crystal may be readily detected by an ordinary lense. Placed under a microscope with a magnifying power of about 250, the mass of them will be found to consist of minute tufts of silky needles (narcotia and narcein probably), and isolated, right and oblique prisms, variously truncate (chiefly morphine, with codia and probably thebaia), while on the slide they may be readily stained with magenta or a dilute solution of carmine and ammonia; the morphia acquiring a pale carmine tint, those of narcotia a faint violet tinge. As regards the proportion of solid constituents in the newly extracted milk-sap, I find, in the various samples which I have examined, from 17 to 22 per cent.; the state of concentration of the sap being affected by the physical and chemical properties of the soil, by heat and cold, humidity, and (very markedly by) strong or gusty winds. Thus, in the light sandy soils, even with a considerable degree of humidity, the juice as it exudes, at once forms a firmly adhesive cord, while, under like conditions of humidity, plants on a strong clayey soil will give off a thin liquid drug which drops less or more from the capsule.

(*c.*)—As a rule, the drug is also thinner in the morning than in the afternoon or evening—a result no doubt of evaporation being in excess of absorption during the day, and in the night *vice versâ*. Gusty winds also in a marked way do somehow reduce the consistence of the drug, as all must have observed in scarifying the capsules, either when or immediately after they had been thus shaken, strained, and jostled: the strain on the tissues apparently causing a direct and reciprocal transudation of the milk and ordinary sap from their respective vessels. It has anyhow nothing to do with evaporation from the leaves, as the phenomenon is the same with a *moist*, as a *dry*, gusty wind. The colour of the juice also, as I have already remarked, varies in the individuals of all the varieties from dull milky and greyish-white to pinky-red, but I only lately observed *both colours on different capsules*, of a *single plant*. In this instance the juice from the terminal and two adjoining lateral capsules was of the former colour, while the capsules on the lower branches (with the exception of one which had, strangely enough, also dull grey juice) had juice of a deep pinky-red. Even at the points of origin from the main stalk, each branch when punctured gave off juice similar in colour to that of its capsule. It was an interesting variation.

3. Let us now then, pass on to the "*setting*" of the milk-sap, which M. Schultz, agreeable to his notions of the functions of the latex, considers analogous to the coagulation of the blood of animals. This is a great mistake, as the blood and milk-sap are alike distinct in function and constitution. The *setting* of the milk-sap is simply a process of inspissation or drying, altogether distinct from the *coagulation* of the blood, which is caused by the deposition of numerous delicate filaments, called *fibrine*, and the ultimate segregation of its elements—the one a clear yellowish liquid called the *serum*, the other a red semi-solid mass, the *clot* or *crassamentum* containing the fibrine and corpuscles. Though, thus, a purely physico-chemical phenomenon, it is none the less distinct from the setting of the milk-sap. In it—the milk-sap—we find no separation or segregation of constituents: a superficial film forms by desiccation in the first instance, and ultimately the bulk thus sets and forms a granular or homogeneous mass. As in the case of blood, however, this *setting* or drying of the drug, may be considerably retarded by sprinkling over the exuding juice a few granules of common salt or other saline matters. While treated, either in the fresh or mature state, with a solution of alcohol and sulphuric acid, a black or purply-black (according to the degree of acid tincture) liquid results; very much akin, as we will subsequently see, to that drug-deteriorating product called *pussewah*. I need not dwell longer, however, on these phenomena, and in passing on to those relating to the circulation of the milk-sap, I will but remark that the microscopic characters the general nature, and properties of the latex, are quite opposed (as Mohl asserts), to the views of M. Schultz.

We will now briefly notice the phenomenon of *cyclosis* as that peculiar circulation of the milk-sap in its capillary network of vessels is called. In the poppy they are less or more numerously developed in the roots, the stem, the leaves, and the various parts of the flower; thus forming from base to apex a minute, surrounding, and continuous network of capillary tubes, in which the drug-forming juice of the plant is segregated and circulates in a peculiar way. By their branching and freely anastomosing they are readily distinguished from all other forms of vegetable tissue. Their origin is still obscure: some authors regard them as cellular canals covered with a special membrane, others that they are intercellular passages originally devoid of a special membrane or envelope, but subsequently acquiring one from the secretions they contain. From a careful examination of them in the germinal plant, and the nascent state of the petals and stamens, one is tempted to refer them to that division of vascular tissue hitherto regarded as peculiar to the higher flowerless plants—the ferns, club-mosses, &c.,—and which Schleiden calls "*simultaneous vascular bundles.*" This form of tissue is variously disposed in the different orders of flowerless plants, but throughout there is a uniform and characteristic mode of development, namely in growing only at the apex, *i.e.*, the end next the *punctum vegetationes*, and that *simultaneously* with the elongation of the parts (stem, leaves, &c.) in which they are found. However, be this as it may, they are the reservoirs of the milk-sap, the peculiar circulation of which, as facilitating exudation and drug-produce, it is very desirable to illustrate in this little treatise on opium husbandry. We will begin with the germinating plantlet.—First we find the tiny radicle protruding through the foramen, or opening of the seed-coats, and thus with a fixed process in the soil the seed is raised, and cast off by the developing cotyledons or first leaves of the embryo. At this stage the plantlet is from two to three lines long, and less than half a line in diameter. Under the microscope we find it is chiefly composed of oblong and cubical cellular tissue with a delicate central cord of spiral ducts, associated with elongated cellular tissue—technically, *the cylindrical parenchyma.* The central cord of spiral ducts extends from near the apex of the root through the compact layer of hexagonal or six-angled cells—which form the "*collar*" of the plantlet—upwards in the stem to the point of origin of the cotyledons where it parts, one branch passing into each, and forming a nascent midrib. From the apex of the cotyledon to near the apex of the root, there is thus through those spiral ducts, direct and continuous channels for the circulation of the sap. The oblong and cylindrical cells both contain amylaceous granules. These are generally disposed over the sides of the walls. The vessels contain a limpid watery juice, which gives a feeble acid reaction..... The root now extends and ramifies downwards, while the first true leaf unfolds itself from the points of origin of the two seed-leaves, and so on, a successional spirally disposed series being given off by the developing stem. As the poppy plant unfolds its primordial leaves, the hitherto colourless latex is sufficiently concentrated to present a milky character, with well-marked acid qualities. A section of the stem now exhibits a central zone of cellular tissue (the pith or medulla), imbedding towards its circumference a series of isolated spiral cords (the foundation of the woody fibres) associated with the delicate milk-vessels, and a zone of slender oblong cells (readily distinguishable from the less or more regular hexagonal cells of the pith), constituting the nascent woody-layers; while surrounding all, we have a somewhat dense zone of rounded cellular tissue forming the rind or bark. In vigorous plants the pith or central zone composes the bulk of the stem. In the rapid development of the latter it is ultimately much broken up, presenting distinct, less or more elongated chambers, or drying up altogether below, it leaves the centre of the stem quite hollow.—— I casually notice this, as specimens of plants exhibiting a curiously chambered or fistular pith, and affected with specific diseases, have been sent to me with the observation that they had been injured by the operations of insects or their larvæ in the interior of the stem. Of course this was quite a misapprehension: the hollowing or chambering of the stem being a result of high vegetative activity, and by no means symptomatic of disease in the plant.—— There is a great similarity in the structure of the stem and the root; the latter also having a less or more distinct central zone of cellular tissue corresponding to that in the stem, but distinguished by its firmer or more consolidated texture, and the absence of that colouring matter (the chlorophyll) which gives a green hue to the stem-pith. Thus, in the poppy the points of origin of the root and the stem are well marked, as also their polarity of growth; the one growing downwards in the soil and avoiding light, while the other courting the latter, grows upwards and unfolds itself in the free air. The woody zone of the root and stem have no clear line of demarcation, the loosely structured pith-shell of woody bundles passing gradually from near the neck of the plant into the more consolidated shell of the root zone. Applied to, and extending over the woody zone, we find a delicate tissue of young and forming cells, and chiefly in the outer zone of this occurs a mazy system of minute canals, which branch and inosculate in every direction, and perhaps more than any other vegetable tissues, resemble the capillaries of animals. This constitutes the milk-sap system, and is of course that which attaches to the poppy its high value as a medicinal, and indeed economic plant, to by no means an inconsiderable quota of the world's population..... This layer, as I have remarked, consists of the nascent formative tissues, its inner surface forming the successive layers of wood, while the outer is transformed into the liber and bark coverings. It is thus the seat of highest vital activity. Unless in those cases, therefore, where the milk-ducts are embedded in the pith, it is evident that in the gradual evolution and transformation of the cambium layer—as this glutinous slimy tissue is called—into wood on the one side and bark on the other, there must be a simultaneous development of the milk-ducts, and this probably mainly in an inward direction, while the outer parts thus rendered effete are successively embedded or absorbed in the increasing layers of the liber or bark. I am led to believe that the milk-canals are *mainly inside growers* (*i.e.*, increase by the new matter pushing out that already formed), partly because they are as a rule largely confined to the outer or liber-forming zone of the cambium, and also from the fact that, in the scarification of the poppy capsule, while their normal function is but temporarily impeded by a superficial cut, it is less or more completely arrested when the depth is sufficient to sever the shell of the capsule. This I attribute to the incision of the growing points of the milk-ducts (which it is to be observed are by no means confined to a single plane, but on the contrary form a relatively broad band in their containing tissues), and the consequent free admission of air to the channels. Be this as it may, we find the milk-sap vessels associated with the cambium layer from the apex of the root to the apex of the stem, passing along its branches and freely ramifying in the leaves and the various parts of the flowers, thus presenting a mazy labrynth of minute but continuous channels all through the plant.

It has already been observed that the fluid contents of those milk-ducts present a peculiar less or more regular motion, which has received the name of *cyclosis.* Mr. Schultz, who was amongst the first to notice these movements, regarded them as vital He remarked that "when the vessels are parallel and near each other, the currents rise in some and fall in others, but in connecting or lateral vessels the currents are directed from right to left, or the reverse, according to no apparent rule. The *essential cause* of the motion is the perpetual oscillation of the globules. They have an incessant tendency to unite and to separate without the one tendency ever overcoming the other; and as the organic elements of vessels are of the same nature as the globules of latex, it follows that the walls of the vessels and the globules they contain have the same tendency to approach and retreat as the globules themselves have with respect to each other. As this motion of coming and going takes place in a determinate direction, it necessitates and regulates the progressive motion of the latex.".... This mutual attraction and repulsion of the globules and the walls of the vessels are regarded by M. Mohl as pure creations of the fancy.—— Commenting on the phenomenon of *cyclosis*, Schleiden says,—"It is to be remarked that in the very young condition only a clear watery fluid is contained in the milk vessels, and consequently that it is impossible to observe any motions in it; and that in vessels of a certain age and with thick walls, the latex coagulates in many ways, and is transformed into a solid mass, as for instance in the Euphorbiaceæ. The question respecting a motion is thus confined to vessels of an intermediate age. Under these circumstances, when a section is placed under the microscope, a rapid motion is noticed in the granular sap, frequently in opposite directions. Upon looking at the extremeties of the cut vessels a protruded and coagulated mass will be found at each end of the same vessel, and at the same time an outward current will be established on the other side, so that it is impossible, without a preconceived notion, to regard this motion as it appears in these observations as one having a determinate direction..... Of a regular motion in a determinate direction I have never been able to observe any indications. Let any one that will have recourse to the convenient scapegoat of an universal *vital power*, amuse himself with it, but he must not imagine in doing so that he is proposing anything really scientific."—— Trecul is of opinion that the milk canals are in direct communication with the pitted ducts, and other vascular tissues, participate in the general circulation, and functionally form as it were various reservoirs.—— Commenting on the views of Schultz, Mohl, and others, Professor Balfour observes "that it—the so called *cyclosis*—is not caused by a *vis a tergo,* because it is by no means constant in its direction, and there is no organ to supply a propelling force; and it cannot be attributed to a *vis a fronte* like that which operates in causing the sap to ascend from the roots to the leaves. Moreover, it goes on for some time in parts detached from the root, where neither of these powers can be exerted. There is no evidence of contraction in the vessels themselves to account for the phenomenon. It seems to be a peculiar vital movement connected with formative actions, and attributable to affinities existing between the tissues and the fluids concerned in nutrition. The cause of the motion is thus still *sub judice*.

Now, as has been shown by Mohl and others, there is no regular or sustained circulation of the milk-sap. By placing undetached and uninjured petals with fringed margins of the opium poppy (dwarfed specimens are well suited for the observation, the texture being then quite pellucid; showing clearly its whole structure,) under the microscope, an irregular, fitful current can generally be perceived, and this lasting only in any particular direction for a few seconds. It is occasionally intercepted as it were by an active flow, suddenly setting up in a lateral and differently directed canal. Again by severing the apex of the petal fringe, a rapid flow is at once set up in the direction of the wound, and continued for a few seconds, or until the wound is closed by the congealed sap. Whatever part of the petal may be wounded the flow is set up in that direction. In observing the milk-sap movements in the petals, I find it best to fix the petal in the first instance on the slide with a very thin coating of glycerine. This should of course be applied to the slide, and the petal equally spread out on it. Cover over a portion of the petal with a slip of thin glass or a flake of mica, and place it under the microscope. Having carefully adjusted the instrument to the focus of the milk-ducts, the less or more fugitive and erratic movements will generally be readily detected, and this the more markedly if the petals of a recently expanded or expanding flower are taken. The younger indeed the part is the better, the circulation being rarely perceptible in the mature petals. It may also be observed that the flow of the sap may to a certain extent be excited and directed by slightly moistening parts of the petals beyond the field of the microscope with ether. The rapid evaporation of this liquid generally excites a flow very similar to that induced by cutting or pricking the petals. In this result, as it appears to me, *we* have a new light on the nature and cause of these peculiar movements of the milk-sap. To illustrate these points we must needs introduce the reader to a set of peculiar vessels less or more generally associated with the milk-ducts throughout their whole course. These are the absorbent vessels of Mr. Herbert Spencer. They are found in the root, the stem, and the leaves of the poppy, and generally abound in the capsule. They were first observed by Unger in several of the Australian Acacias more than thirty years ago. He regarded them, however, merely as excretory (saccharine) glands, and had no idea of the function now accredited to them by Mr. Spencer. This author, in his *Principles of Biology*, describes them as "masses of irregular and imperfectly united fibrous cells, such as those out of which vessels are developed; and they are sometimes slender, sometimes bulky, usually however being more or less club-shaped." Commenting on their occurrence in the Australian Acacias, he says "these have them abundantly developed, and it is interesting to observe that here, where the two vertically placed surfaces of the flattened out petiole are equally adapted to the assimilative function, there exist two layers of these expanded vascular terminations, one applied to the inner surface of each layer of parenchyma. . . . . Considering the structures and positions of these organs, as well as the nature of the plants possessing them, may we not form a shrewd suspicion respecting their function? Is it not probable that they facilitate absorption of the juices carried back from the leaf for the nutrition of the stem and roots? They are admirably adapted for performing this office." Let us briefly note their structural relations and probable functions in the poppy.

2. The absorbent organs are very variable in size and outline; some consisting of isolated, ovoid, fuciform or club-shaped, and less or more elongated fibrous cells; others occur in clusters or masses, are club-shaped, fuciform, cylindrical or knob-like in outline, and very generally pass into the ordinary vascular system of the part in which they lie. They may generally be observed in the cotyledons or seed-leaves, forming the apex to the central cord of vessels, either as slightly elongated twin-cells or small clusters, and continuous with the cord of ordinary vessels. In the roots of the nascent plantlet they are also present and there associated with the cord of ducts. Clusters of them are found in the leaves, in the sepals, and petals, generally near the branchings and inosculations of the veins, with which they coalesce and diverge in free extremities. Especially do they abound in the parenchyma of the capsule. They vary much in outline and bulk, though generally less or more regularly club-shaped or fusiform, and more bulky than those in the other organs of the plant. They also inosculate freely, forming meshes or loops of variable size, and shooting out in solitary cells or clusters with free tapering extremities. They vary in pattern of fibrous markings, from less or more distinctly spiral to the reticulated and pitted structure, the most common pattern being the *netted* or *reticulate*. All are soft and flexible, less or more swollen or vesicular, and contain a colourless fluid with finely granular matter very different from that of the general parenchyma.

(*a.*) There can, I think, be no question that the function of these organs has been other than rightly interpreted by Mr. Herbert Spencer. This, as has been stated, is that they are absorbent organs, and, as Mr. Spencer further points out, comparable with the spongioles (*i.e.*, the cellular absorbing extremity) of the root. These *spongioles* of the leaves, like the *spongioles* of the roots, being appliances by which liquid is taken up to be carried into the mass of the plant, we are obliged to regard the vessels that end in these spongioles of the leaves as being the channels of the down current whenever it is produced. They thus promote the general circulation of the sap and in a special way, as I am inclined to think, do they excite those erratic movements of the milk-sap. Reflecting on the intimate relative position of these soft, flexible—and probably highly hygroscopic—absorbent organs of the leaves with the milk-sap vessels, it is easy to see how largely these tiny tubes must be influenced by the ever changing degree of pressure of those comparatively bulky absorbents. Exposed as they are less or more directly to the atmosphere by the *stomata*, or breathing pores, and thus increasing in volume here, decreasing there, we have obviously a force quite competent to the production of the phenomenon of cyclosis. Take a portion of the pericarp of a capsule or a sepal for example, observe in the first instance its numerous stomata (in the one organ from 360 to 1,080 in a square inch, in the other from 2,160 to 4,140), their structure, and consider their function.—Now as these breathing pores of plants are minute openings (oblong or roundish in the poppy) in the epidermis, which establish a direct communication between the external air and that in the intercellular passages of the plant. They are in fact the ærating organs of the plant, forming as the case may be, inlets and outlets for air and moisture. They usually, as in the poppy, consist of two thin-walled semi-lunar cells called *pore* or *guard-cells* united by their outer convex faces to the epidermis, free on their flat inner faces, and thus exerted or depressed—so to speak, *extrorse*, or turned outwards, or *introrse*, or turned inwards. They thus—to a certain degree reciprocally with the hygroscopic condition of the atmosphere—present in the one case a slit-like orifice conducive to the processes of respiration and evaporation, while in the other the orifice is closed and all direct communication between the interior of the plant and the external air cut off. As above indicated, this opening and closing of the guard cells, though largely, is not wholly, dependent on the hygrometric condition of the air; inasmuch as we not unfrequently find them in a single field of vision in different degrees of openness and even quite closed. This has an important bearing on the subject of illustration—I of course refer to the movements of the milk-sap. With this explanation then of the structure and general functions of the stomata, we will now resume the illustration of the phenomenon of *cyclosis* as dependent on the reactions of the absorbent organs and stomata.

3. The leaves and the petals, consist, as we know, of a few or several less or more loosely aggregated layers of cellular tissue, intercepted by air channels or intercellular spaces, and variously traversed by the vascular tissues in the ribs or veins, all being encased in plates of cellular tissue; one or both surfaces of which have numerous minute orifices overlying comparativley large air spaces—the *stomata*, which are in direct communication with those of the inner layers. The processes of nutrition, it is to be observed, are most actively performed by the cellular form of tissue. It consists of, and contains, those gaseous and liquid matters essential to vegetative growth, therewith mysteriously compounding such primary matters as *cellulose*, *fæcula*, *chlorophyll*, and *aleurone* or *protein*. Though presenting no visible openings or pores, it is nevertheless freely permeable by liquid matters, and when in functional activity always contains a mother liquid, through which are diffused granules of chlorophyll, starch, &c. The vascular tissue may be simply characterized as an elongated form of cellular tissue, consisting of closed tubes, very generally tapering to each extremity, and not truncate, as in the cellular forms of tissue, from which it is further distinguished by its more specialised functions. This vascular tissue when present as it is in all but the lower forms of vegetals, is the main circulating channel of those gaseous and liquid matters which the cellular tissue, *per se* is incompetent to supply in

sufficient quantity for any high degree of active development in the higher forms of vegetal life. The absorbents, as indicated by Mr. Spencer, appear to have a functional correlation to the parts in which they occur, corresponding to that of the spongioles in the soil. They are, so to speak, foci of absorption and diffusion of the aerated juices of the plant. Their osmotic properties (*i.e.*, fluid transmitive powers, that from within outward being called *exosmose*—from *ex*, out of, *mo*, I seek,—the converse *endosmose*—from *endon*, within), are also doubtless promoted by the reticulate or pitted distribution of those matters deposited or developed on the inner wall of the cell—*i.e.*, as compared with those in which continuous layers are produced and the wall then uniformly thickened. The milk-ducts or canals, which are very generally regarded as the recipients of the elaborated juices, can—as I have shown—be scarcely regarded as other than mere recipients of effete matters. At least in annual plants there are, I think, no grounds for the belief in the utilisation of their contents: that they may aid in recruiting, so to speak, the recurrent vegetation of perennial herbs is not improbable. The stomata or breathing pores are not, as we have indicated, wholly dependent on the hygrometric conditions of the atmosphere, as has been tacitly assumed by many writers on vegetable physiology. This is shown by the fact of approximate stoma being simultaneously fully open or less or more completely closed, so that if due to the hygroscopic condition of the atmosphere alone, we would thus have the same cause producing opposite effects. This is obviated by the following explanation:—It is a well-known fact that by placing a unicellular plant in a dense fluid, the exosmotic action thereby induced will cause it to collapse or shrivel up, whereas by placing it in a thin fluid an excessive endosmotic action results; it then increases in bulk and becomes quite plump. Approximate cells also vary as they become old, in the thickness and rigidity of their walls, and consequently vary in their osmotic properties; increased density of course decreasing their permeability by fluids. It is thus easy to see how the above noted diversity in degree of destension of the stomatic guard cells may be thereby caused. Less or more modified, then, those are the conditions and causes whereby we would largely explain the above noted diversity guard-cells of approximate stoma. Now, it is to be observed that the leaves and petals of the poppy are centrifugally developed (*i.e.*, increase from the centre or base outwards and upwards), and that consequently on the fully developed leaf the most functionally active stoma will naturally be those of the circumference, as being the youngest. Those towards the outer zones of the leaf will thus, so to speak, be more sensitive to atmospheric action than those on the more mature parts within, and this not only as being younger, but as drawing on a less tenuous or watery sap; and have thus, as in the case of the unicellular plant, its reciprocal osmotic relations with the atmosphere relatively increased. As it appears to me, however, the main cause of the opening and closing of the stomata is neither due to osmotic nor vital forces, but is of a purely physical nature. A hasty and ungrounded assumption hitherto unquestioned teaches that the guard-cells of the stoma collapse, *i.e.*, open, in a moist atmosphere to facilitate exhalation and promptly distend (*close*) in a dry and hot atmosphere, thereby checking any undue dessication of the inner tissues. Such results could only be produced by the so-called vital force, as they are plainly opposed to any of a purely physical nature. In this instance, however, there is no need for recourse to vital or other obscure agencies. The phenomenon has a simple physical explanation. In a word, when in full vegetative activity they respond to the atmosphere with barometric accuracy: in moist weather, or when the atmosphere is charged with clouds or fogs, the air, as is well known, is light, and thus the stomatic pore-cells have their free margins up-raised by the escape of the denser air within the intercellular passages, thus facilitating the general processes of exhalation or respiration; whereas with a clear and dry atmosphere the increased gravity of the air causes a depression of the guard-cells, and the orifice is again closed. In some cases, as it appears to me, those phenomena are due to the lengthening and shortening of the guard-cells—*i.e.*, in presenting an open orifice they extend longitudinally, whereas in the converse they expand in their transverse or shorter axis. Be this as it may, there can be no doubt that the opening and closing of the stomata are mainly due to the barometric action of the air.

4. Let us now address ourselves more particularly to the oscillations of the milk-sap: their origin and nature. Now, as has been shown by Mohl and others, the milk-sap exhibits no sustained or regular circulation. When undisturbed by external causes it is in *statu quo*: oscillations, however, as we have seen, can be produced in any desired direction by pressing or wounding the tissues, as also quickened or retarded by heating or chilling and electric action. Transitory oscillations of the sap in all directions do however naturally occur, and are generally readily distinguished from those artificially produced: in the one case the flow is rather slow and rhythmical, in the other quick, bounding, or jerky. Now, it is to be observed that under artificial stimulus, the motion, is directed to or from the points of application. Thus, by wounding the tissues, or by chilling with ether, &c., a centripetal flow is excited, whereas by pressure, heat, or the application of dilute sulphuric acid (so as to cause expansion of the cell-membranes), the flow is centrifugal. In either case this is of course only relatively to the point of application, the flow being variously directed in the many diverging channels. We have thus in the one case an apparent *vis a fronte*—a sucking or drawing force—in the other a *vis a tergo*,—a propulsive or pushing force. First, then, of this *apparent vis a fronte*: the change from *static* or *potential force* to that of a *dynamic* or *motive nature*. It has a simple physical explanation, as I will now show by an illustration in point, and this from the physics of the so called inert and impassive soil. Observant agriculturists have been struck by the fact that drains previously dry have commenced to discharge without any rain falling on the surface of the drained land. The phenomenon is illustrated by Mr. Bailey Denton, from whose lecture on "Agricultural Drainage" I quote:—"In one instance, after a very dry season, the barometer having fallen rapidly for four consecutive days, the *drains ran*; they did more than drop, and ditches which were previously dry became quite wet, with a perceptible stream of water; this gradually ceased with the change in the density of the atmosphere, as

shown by the barometer. That the phenomenon is clearly attributable to the diminished atmospheric pressure which exists before rain, will be readily admitted when we reflect that in moderately well pulverised soil the interstitial canals (filled with air) amount to no less than *one-fourth* of its whole bulk. For example, 100 cubic inches of *moist* soil (*i.e.*, of soil in which the pores are filled with water, and the canals with air) contain no less than 25 cubic inches of air.—*Practice with Science, vol.* I, *p.p.* 33-36. Now in the plant, we have as analogues of the interstitial canals of the soil, the intercellular passages, whereas the pores are represented by its various forms of cellular and vascular tissue, though specially, as I would observe, by the capillary system of milk-ducts. It is easy to see that those capillary ducts more than any other form of tissue will respond to the ever-varying pressure of the air in the intercellular passages. Irrespective then of all other influences, we have in these many air columns a *vis à tergo* competent *per se* to raise, sustain, and cause the discharge of the milk-sap from the cut extremities of the vessels. This air force, and the capillarity of the canals are, I believe, the main cause of the upward current, whereas opposed to these we have in the hygroscopic characters of the absorbent organs, or leaf spongioles, an opposed force maintaining all *in equilibrio:* motion in one or other or many directions being due the disturbance of this equilibrium. The erratic movements of the milk-sap are thus of easy explanation when we regard them as the combined results of the barometric action of the air and capillarity from below upwards; and the hygroscopic, osmotic, and thermic action of the absorbents from above downwards, and laterally. These erratic movements, so peculiarly characteristic, are doubtless largely due to the thermic respondings of the absorbent organs, which we find so abundantly diffused through the plant, and thus ever varyingly exposed to solar influence. From this point of view the harmonious relations of the stomata and absorbents are noteworthy. Thus, with a moist or cloudy atmosphere and open stomata, the osmotic and hygroscopic action of the absorbents is largely promoted, and from the relatively decreased air-force, it is probable that the milk-sap, will then present a less or more continuous rhythmical motion; whereas in hot and dry weather, when the air is heaviest, we have closed stoma promptly checking any undue dessication of the absorbents or other organs, while the increased thermic stimuli enables them to counterpoise or balance the *vis a tergo* of the heavier air-columns, and thus maintain a comparative equilibrium. With such competent ever-acting forces as these then, the phenomenon of cyclosis may not longer be regarded as a "peculiar vital movement connected with formative actions and attributable to affinities existing between the tissues and the fluids concerned in nutrition."—*Class Book of Botany,* by J. H. Balfour, M.A., &c., *p.* 424.

5. From the above point of view we are also enabled to explain all the phenomena observed in the extraction of drug from the poppy. The effects of meteorological phenomena are well marked. Thus, an easterly wind, which throughout the poppy districts is always less or more moist, retards the exudation of drug, whereas a light westerly wind with

a clear atmosphere promotes it. Now, as we have shown in a moist atmosphere the absorbent organs are in full activity, while the opposed force is at a minimum (owing to decreased atmospheric pressure) ; this result of the relative abeyance of the upward force is, that the outer extremities of the plant undergo a partial depletion of their milk-sap. This will especially hold of the capsule, as abounding more than any other part in absorbent vessels, so that the milk-canals thus naturally deprived less or more of their sap must necessarily afford but sparing exudations. Again, in the other case, with a light westerly wind and a clear atmosphere, the absorbent organs are in abeyance; and the increased pressure of air, concentrates the milk-sap largely in the capsule, and this on incision affords a full and copious exudation. I think there can be no doubt, that I have above, briefly indicated the true cause of the phenomena in question. Prior to my having wrought out the explanations above given, I had been greatly struck with the really scanty and comparatively tenuous exudings, from the scarified capsule, when a moist easterly wind prevailed. Strong, gusty winds also, as I have observed, markedly reduce the flow of drug and lower its consistence, so that it is apt to drip from the capsule ere it sufficiently congeals. Now, so far as I have had an opportunity of observing these are, so to speak, wind-respondings of the barometer: thus with easterly weather we have the most marked falls of the mercury; while with westerly weather the fall is inconsiderable, and especially so when south-westerly. Hence as might be expected, with gusty, easterly winds the drug exudings are spare, of low density, and of a dark colour, while with a westerly, though more copious, they are still of a thin and rather watery character. There are, however, peculiar variations observable in the physical character of the drug under strong westerly winds, which could no doubt be explained by careful observations with a really good *barometer* or *æthrioscope* (neither of which I have here) and *thermometer*. As regards the general influence of stormy and gusty winds on the quantity and quality of the drug, I will here only remark that, irrespective of their barometric relations, they doubtless tend to increase the fluidity of the drug by transfusion of the juices from the strain on the various tissues......In discussing and illustrating the general circulation of the sap, Mr. Herbert Spencer explains its transfusion through compressed vessels. According to his views, however, this lateral oscillation or strain of the parts by the wind is mainly effective in the longitudinal transmission (the up and down circulation) of the sap, he overlooking, as I think, from this point of view, a very much more important agent in the oscillations of the atmosphere, or, as ordinarily termed, *barometric pressure.*

As favouring the views above indicated on the peculiar movements of the milk-sap, it is noteworthy that while a poppy plant can be readily depleted of that sap by scarification of the capsule, this can be but slowly and imperfectly effected by wounding the lower part of the stem. This is explained by the *vis a tergo* from below (barometric pressure) being greater than that generated by the absorbents in the upper parts and directed downwards. We have a further proof of this in the fact that sap exudes more freely from wounds in the stem when the mercury is low than when under high pressure.

CHAPTER XIV.

THE INFLUENCE OF WEATHER AND SEASON, &c., ON THE QUANTITY AND QUALITY OF THE DRUG.

Dry years are emphatically those in which the Assamee reaps his largest and best crops of opium—a result probably largely due to the soil being in those seasons better tilled (*i. e.*, ærated and pulverised) than in wet years. A dry, and even hot atmosphere would also appear to have a direct and important effect on an opium crop, inasmuch as we find, that though the rains may have been light throughout the monsoon, favouring in every way general tilth, should the cold weather, or crop-bearing period of the poppy prove wet the returns will be lowered both in quantity and quality. .....The *opium season* comprises the whole of the cold and the early part of the hot season, say from the middle of October to the end of March. Weather and season as essential factors of climate, affect as we have seen in a marked way the physical properties and quantity of drug-produce of the poppy. Including, as they do, however, so many atmospheric phenomena—for example, the range and variation of temperature, degree of humidity, direction and force of wind, the kind and quantity of cloud, rain, mist and dew, the electrical condition of the air, and the not unfrequently devastating hailstorms—their general results, as might be expected, are most perplexing......The most important of these however, as regards poppy culture, are heat and moisture, to which we will confine ourselves in the present section. First, then, as to heat.—I may, I think, without fear of contradiction, say that a dry (and comparatively hot) season best promotes the drug-secreting quality of the poppy, and that not only in quantity, but also, and in a marked way, improving its physical properties—aroma, colour, and texture. Drought, though excessive and indeed prejudicial to the common cereal and pulse crops of the district, is especially in the post-floral or fructifying stage of the plant favourable to opium produce. Prior to that, or in the germination and vegetative stages, the plant is of course benefited by moist or occasionally rainy weather. In the maturing or drug-producing period of the plant, I have in the preceding chapter indicated the nature and action of atmospheric phenomena generally on the milk-sap and correlated tissues, and it will suffice here to briefly notice the effects of temperature on the physical properties of the drug. First, then, it is to be observed that a drug of high quality can be produced under a considerable range of temperature.....Less indeed than any other cognate vegetal product does opium appear to be affected by such changes. It has been shown for example that the virulently poisonous monkshoods (*Aconitum napellus*), &c., are nearly or quite innocuous when cultivated in the plains of India: the mismee teeta (*Coptis teeta*), which grows naturally at considerable elevations in the Mishmi mountains (Upper Assam), loses its excellent tonic properties when cultivated in the Calcutta gardens: the common henbane

(*Hyoscyamus niger*) and the khorasanee—ajowan of the native herbalists—are less highly officinal when cultivated in Lower Bengal than in Upper India, and so in the case of many other medicinal plants. Opium, on the other hand, under any conditions in which the plant will grow, retains less or more perfectly its normal officinal properties. The China opium is the only exception, and in this it is not a failing in narcotic qualities only, but in aroma and texture and some superinduced principle which gives rise to certain forms of skin disease. As a question of mere temperature, and I will also add light (regard being of course had to the dew point in degree of atmospheric humidity), opium of as fine quality, physically or chemically, may be produced in a comparatively cold, as in a warm, climate. To the production of such it is only necessary to acclimatise the plant to its new conditions.

2. Variations in the degree of atmospheric humidity affect in a very marked way the physical properties of the drug when being extracted from the poppy. This is a fact familiar to the officers of the department.—Thus Mr. Gennoe, commenting on the conditions, &c., favourable to the production of opium, observes (*vide* appendix F, of "Rules for the guidance of officers in the Opium Department,"—new edition) "that there is a wide difference between the *produce* of the earlier compared with the later sowings; the former is of low spissitude, but more bulky, whereas the latter are quite the reverse, small in quantity, but of higher and superior consistence."—The difference of course is no doubt due to the relatively decreased atmospheric humidity when the later sown crops are maturing, and by no means to the increase of temperature.—"Gentle westerly winds," continues Mr. Gennoe, "are most favourable for our opium collections, as also for inspissating the juice when collected. Opium gathered during the prevalence of easterly winds is scanty, because the juice does not exude freely from the incisions, and the opium collected is somewhat dark in colour, from the atmospheric humidity with which it gets impregnated."—The more copious yield of drug in westerly than easterly weather is, as I have shown in the preceding chapter, due to variations in the atmospheric pressure on the one hand, and the reactions of the absorbent organs on the other. The exudations in strong easterly weather are not only spare, but likewise more tenuous or watery; and thus even when there is apparently a full cord on the capsule in the evening, this, after a night's exposure to such winds, presents but a thin dry film to the collector in the morning. This is markedly the case when the plant-temperature is below that of the air, the watery matter being then wholly extracted from the drug. It is thus that the Assamees will have it that an easterly wind "*eats the opium.*" Thus paradoxical though it may at first appear, with a light, dry, westerly breeze the capsule affords a full, plump, cord of drug. The explanation is simple: the drug exudes at a high consistence, and a firm protective film quickly forms over it, and thus checks evaporation or loss of watery matter.

3. In the course of my experimental observations on the poppy, I have been struck with the fact that the capsules yield a drug of considerably lower density when scarified in the morning than in the afternoon, and this alike in easterly and westerly weather. This is no doubt due to the decreased longitudinal circulation (*i.e.*, from below upwards

and *vice versâ*) favouring or facilitating transfusion of the juices from the wind-strained tissues, under a low night temperature. This will be appreciated when we take into consideration the great *diurnal range* of temperature prevailing less or more throughout the poppy season. From carefully recorded observations here I find the daily thermometric range is very commonly 30 to 50 degrees, and for days together in 1874 and 1875 I have observed it amount to 45 degrees! The air immediately surrounding the plant I have occasionally found at the freezing point 328, while the maximum temperature ranged from 85 to 95 degrees. On a few occasions I have observed films of ice on the surface of the soil. The poppy was in no way injured by this, though the ordinary pulse crops of the district were all less or more injured. The opium poppy is thus evidently a plant cultivable under a considerable range of temperature.—In the movements of its milk-sap, as we have shown, it is really a sensitive weather indicator; responding with the barometer, the milk-sap (even as the mercury) rises and falls with the degree of atmospheric pressure. Any exceptions to this, I believe, will be found on careful examination rather apparent than real. For example, when the *air is perfectly clear*, we may yet find with a light easterly air that the drug exudes but sparingly from the scarified capsules. Now, as Tyndall observes, a *clear* air is not necessarily a dry air, "great clearness to light is perfectly compatible with great opacity to heat: the atmosphere may be charged with aqueous vapour, while a deep-blue sky is overhead; and on such occasions the terrestrial radiation would, notwithstanding the *clearness*, be intercepted." It is thus that I in a preceding chapter suggested the use of the *æthrioscope* (in studying the phenomenon of cyclosis), an instrument delicately sensitive to changes of atmospheric pressure. "This instrument," quoting from the above admirable exposition of physical science, "exposed to the air in clear weather, will at all times, both during the day and the night, indicate an impression of cold shot downwards from the higher regions. The sensibility of the instrument is very striking, for the liquor incessantly falls and rises in the stem with every passing cloud. But the cause of its variations does not always appear so obvious. Under a fine blue sky, the *æthrioscope* will sometimes indicate a cold of 50 millesimal degrees; yet on other days, *when the air seems equally bright*, the effect is hardly 30°." "This anomaly," remarks Tyndall, "is simply due to the difference in the quantity of aqueous vapour present in the atmosphere." Indeed, Leslie, the inventor of the above instrument, himself connects the effect with aqueous vapour in these words:—"The pressure of hygrometric moisture in the air probably affects the instrument It is not, however, the *pressure* that is effective; the presence of invisible vapour intercepted the radiation from the æthrioscope, while its absence opened a door for the escape of this radiation into space......Could we make the constituents of the atmosphere, its vapours included, objects of vision, we should see sufficient to account for this result.—" *Heat as a mode of motion," page* 398.

4. It is well known to the officers of the Opium Department that high and recently broken-up land produces a dull chestnut or reddish-brown drug, whereas that from low and old lands presents it in various shades of brownish-black. This variation of colour holds with the

marc also according to Dr. Eatwell, who states in his rules for the examination of opium, that the drug from "new and high lands affords a *marc* of a bright gamboge yellow, while the drug from old and low lands, when containing much pussewah is a dark brownish-yellow inclining to brown. The colour varies, however, from the above through all the shades of brown to black, denoting deterioration or adulteration in some form or other." Generally speaking, light or sandy soils, I believe produce a reddish or chestnut-brown coloured drug, of less or more granular texture; the stronger loams and clays, that of a dark brown or blackish colour and homogeneous texture. With regard to recently broken-up lands, as also those which have been previously under the ordinary crops of the district—*i.e.*, cereals, pulses, oil-yielding seeds, &c.,—the outturn of opium is comparatively low. This is even the case when the plant relatively to that on well-tilled opium lands adjoining is of more robust habit, and markedly so when the soil is of a clayey or tenacious character. This, I believe, is wholly attributable to the insufficiently pulverised condition of the soil.—The Assamee is fully alive to the advantages of a thoroughly pulverised soil in opium cropping. The *rationale* of it is of course beyond his care or scope, and like most of his other modes and ideas, is *de facto* a purely hereditive intuition.—The beneficial effects, as we all know, is due to the high permeability of a thoroughly disintegrated soil, by air, gases, and water. The long continued fertility of some of our poppy lands is no doubt largely due to this effective surface æration and the continued use of less or more saline-tinctured water in the irrigation of the plant. I insert an abstract of a table drawn up by Mr. Abercrombie illustrating the relative fertility of recently broken-up and old opium-producing lands. The old districts are Gya and Tehta, the *former* of which for the eleven years ending the season 1861-62 gave an average of 6*s.* 3½*c.* per beegah, the latter 6*s.* 6¼*c.* It is to be observed, however, that while the average of the three years ending 1853-54 was 7*s.* 10½*c.*, it had declined to 5*s.* 6¾*c.* in the three years ending 1861-62. The table indeed rather goes to confirm the converse of what it was intended to illustrate, *i.e.*, the undiminished fertility of old opium lands. An important element has also been quite overlooked by Mr. Abercrombie in his comparative statement; this is the annual and very considerable extension of cultivation on new lands in the old districts.

Average Opium produce per beegha.

Seasons.	Gya district.		Tehta district.		Burhee kotee.		Doomree kotee.		Hazaribagh kotee.	
	S.	C.	S.	C.	S.	C.	S.	C.	S.	C.
1862-63	5	11¾	6	11¾	4	2¼	......		......	
1863-64	6	13¾	6	11½	5	13¾	......		......	
1864-65	5	7¾	5	8¼	5	3½	......		......	
1865-66	5	5½	5	12¼	5	6	......		......	
1866-67	5	15	5	9¼	5	5	......		......	
1867-68	5	3½	5	0¾	5	6½	......		......	
1868-69	6	1¼	6	4½	4	10¾	......		......	
1869-70	6	3¾	6	5	5	5¼	3	14½	2	13¼
1870-71	4	11¾	4	7¾	4	9½	4	0¼	2	9
1871-72	5	3¾	5	2½	5	10½	4	8¾	2	14½
1872-73	6	9¼	7	0¾	5	8½	4	10	2	14¾

The old districts are Gya and Tehta, of which Burhee, Doomree, and Hazareebagh, are new kotees, opened respectively in the seasons 1862-63 and 1869-70 As illustrating the variation in the area under cultivation, it may be observed that while the Gya district comprised an area of 35,821 beeghas in 1851-52, it was only 32,673 in 1860-61, since which there has been an annual increase to 65,663 in 1872-73.

5. The nature and condition of the soil affects, as we have seen, the physical properties of the drug, and as having similarly modifying effects, we will now briefly advert to the manures. Certain manures, in promoting the growth of the poppy, give marked characters to the drug. They also promote the drug-secretive function, but there is yet a want of any positive evidence to show that they either increase the total quantity or alter the proportions of the alkaloids. As regards meconic acid, however, I think we have indications of its increase and decrease, under certain conditions of soil, atmosphere, and manure from the difference in the colour of the drug of the same variety under such changed conditions. For example, in a light sandy loam any particular variety will produce in dry weather drug of a dull reddish-brown colour, whereas in a strong clay, and especially with moist weather, it will quickly acquire various shades of brownish-black. So in the case of ammoniacal manures; these, in so far as I have observed, have a strong tendency to give a dark-coloured drug. Now, this darkening of the drug I am strongly disposed to attribute to a relative excess of *free* meconic acid in the juice as it exudes, and the subsequent formation of meconates on exposure to the atmosphere. It remains to be seen whether or not this view will be supported, or another explanation afforded by a well conducted series of analyses.

(*a*.) As above stated, I believe the ammoniacal manures generally have a tendency to darken the colour of the drug. This is very markedly the case, when applications of night-soil and urine are made in a fresh or unfermented state. Thus, on two adjoining plots in the gardens here, one had a liberal application of night-soil and urine from the Patna jail during the rainy season, while the other had a green crop of Soni (*Crotolaria juncea*), overlaid with about ten inches of surface soil as a manurial dressing in the beginning of September. Both plots were frequently reploughed during the latter month, and finally sown with poppy-seed of the same variety about the middle of October. The drug from the plot treated with fresh night-soil was of a brown or almost pitch black-colour, of a nearly homogeneous texture, flabby, and of low consistency, parting very slowly with its natural moisture, and giving off a musty and disagreeable odour. On analyses it was found no way deficient in alkaloids or extractive matter, but as above noted, very much so in its physical characters: indeed, as regards odour the Assistant Examiner could all but believe that it gave off a fœtidity akin to that of the manurial application. On the other hand, the sample of opium from the plot treated with *green soni* was of a pale reddish-brown colour, minutely granular texture, and a fresh, bland and agreeable odour. Again, plots treated, immediately before the seed was sown, with ammoniacal liquor from the Calcutta gas-works, gave also opium of a dull brownish-black colour, but the odour in this case was fresh, strong, and not unpleasant. In repeating experiments with green manurial applications, I found that *soni* in particular tends to lighten the colour of the drug, and as a rule gives it a more agreeable odour than fresh cowdung or stable-yard manure. The mineral manures generally also appear to lighten the colour of the drug, improve its odour, and give it a less or more granular texture. This holds at least with all the mineral matters which I have yet tried, with the exception of the iron sulphates. The plants top-dressed with them when the flower-buds were setting gave drug of a pitchy-brown colour and of a more homogenous texture than that from plots treated with other mineral manure—lime, potash, &c.—or wholly untreated.

(*b.*) The physical and chemical properties of the soils of cultivation, and the extraneous manurial applications, are thus shown to affect the physical characters of the drug; but as I have already remarked, we have really no positive evidence as to the *specific action* of particular soils or manures in altering the relative proportion of the alkaline constituents of the drug. That peculiarities in the constituents of the soil do affect the total quantity and relative proportions of the opium alkaloids has, however, been shown by Dr. O'Shaughnessy in his analysis of opium samples from the different divisions of the Behar Agency. Thus, in the opium from eight divisions of the agency, he found the quantity of *morphia* to range from 1¾ *grains* to 3½ *grains per cent.*, and the amount of *narcotine* to vary from ¾ to 3½ *grains per cent.*, the consistence of the various specimens being between 75 and 79 per cent. Again in the opium from the Hazareebagh district, at a consistence of 77°, he found 4½ *per cent.* of *morphia* and 4 *per cent. narcotine;* whilst from a specimen of "*Patna garden*" opium he extracted no less than 10¾ *per cent.* of *morphia* and 6 *per cent.* of *narcotine*, the consistence of the drug being 87°. "It is much to be regretted," continues Simmonds, from whom I quote, "that these interesting results were not coupled with an analysis of the soils on which the samples were produced, for to chemical variations in these must be attributed the widely different results above recorded."—*The Commercial Products of the Vegetable Kingdom, page* 584 At the period of Dr. O'Shaughnessy's analysis, the Behar opium is thus shown to have contained *morphine* in excess of *narcotine,* whereas at the present time and for years back, the latter has been considerably in excess. This is a remarkable fact, which would apparently indicate and be attributable to, some general change in the chemical constituents of the soil under the native modes of opium husbandry. I think this is very much more likely, than to attribute it to any mere discrepancy in the process of analysis adopted by Dr. O'Shaughnessy. The sample of *Patna garden* opium is specially noteworthy as presenting relative to the *narcotine* an excess of no less than 4¾ *per cent. of morphia.* No such opium, I may say, is produced by any variety of the white poppy in either of the agencies now. Thus, the average of the Behar kotee standards from the seasons 1874 and 1875—as given in an analytic statement of various samples of opium sent by me to the Principal Assistant Opium Agent from the gardens here,—is *morphine* 2·69, *narcotine* 4·47 *per cent.*, the drug consistence 70°. As compared with this the samples of *the distinct varieties* produced in the gardens here are shown in the above tabular statement to afford an average of *morphia* 3·35 and of *narcotine* 6·57 *per cent.*, *i.e.* relative to the kotee standard a maximum in *morphia* of 0·66 *per cent.* and in *narcotine* a minimum of 0·90. It is noteworthy also that while the kotee standard opium is richer in *narcotine* than *morphine* by 1·78 *per cent.*, my experimental garden drug presented a difference of less than ½ *per cent.* Presuming in the exactitude of the several analyses, we have thus evidence—indefinite though it be—of the conditions of growth, increasing or otherwise the absolute quantity, and altering the relative proportion of the alkaline constituents.

6. This is perhaps as fit a place as any to notice another remarkable result elicited in the comparative analyses of opium samples from the several varieties of poppy cultivated in the garden under my charge, and the Behar provision and kotee standards. This is the very great difference in the proportionate development of what is called the "*extractive matter*." This substance is of a pale brown or reddish-brown colour, has an acid reaction on litmus, and is thought to be of a hyterogeneous nature. It is present in various quantities and apparently considerably more copious in Indian than in the Smyrna or Constantinople opium, but in all forming with mucilage and caoutchouc the matrix and bulk of the drug. Thus, the mean of five analyses of Smyrna opium by Mulder gave only ¼ *per cent. of extractive*, whereas various analyses of the Indian drug shows it in quantities of from 32 to 50 *per cent.* "It has been supposed," observes Pereira, "to be one of the active principles of opium. The reasons for this opinion are the following:—In the *first* place, it has been asserted that after the morphia has been separated from an infusion of opium by magnesia, the filtered liquor gives by evaporation an extract which produces the same kind of narcotic effect that opium does; *secondly*, the effects of the known active principles of opium are not sufficiently powerful to authorize us to refer the whole of the active properties of opium to them." We have in this doubtless an explanation of the well known fact that the Indian drug, though containing much less *morphia* than Levant or Constantinople opium, is no way inferior to either in its therapeutic or physiological effects. It is to be observed, however, that there is no definite relation in the proportionate development of *morphine*, *narcotine*, *&c.*, and the *extractive matter*, so that its true action is not by any means thus explicable. In the words of Professor Johnston, "the full and peculiar effect of the natural drug is due to the combined and simultaneous action of all the numerous substances it contains. Each of these modifies the effect which would be produced by any one of the others taken singly......It is from the result of all these conjoined actions that the singular pleasure of the opium-consumer is derived."

(*a*.) I have been much struck with the comparative poorness in extractive matter of a large series of samples of opium from the gardens under my charge, as shown by the analyses of the present Principal Assistant to the Opium Agent of Behar—Dr. Durant, and his *locum tenens* in the seasons 1873 and 1874, Dr. Duncan. It first attracted my notice in the results of the latter officer's analyses of my samples for 1873 and 1874, and I was then disposed to attribute the relative deficiency in extractive matter (repeated less or more largely in every sample), as compared with the Behar standard for the preceding year, to my plants being very extensively affected and indeed seriously injured by the poppy-mould. I suggested this subsequently to Dr. Durant, and forwarded him for analysis samples of opinion produced by seriously mould-blighted plants. The results however show no deficiency in *extractive matter*: I was much struck however to find an increase in morphia (as compared with the Behar standard) of 1·04 *per cent.* Commenting on the above suggestion Dr. Durant observes that "it is a well ascertained fact that the presence of *pussewah* adds materially to the amount of *extractive matter* obtainable, and as your samples were perfectly free from that adventitious substance, the decrease in the *extractive* obtained from them may to a great extent be accounted for by this circumstance." This explanation, however, is far from satisfactory. In the first place it appears that *pussewah* relatively to pure opium, is scarcely if at all richer in extractive matter; and *secondly*, even admitting Dr. Durant's assumption, the presence of pussewah in quantity sufficient to impart from 15 to 20 *per cent.* of extractive matter to the drug, would, I am sure, render it altogether unfit for the China market. On this point Dr. Sheppard of the Benares Agency observes, "that if *pussewah exists in opium only in a very small quantity*, and the drug, possessing full aroma and unexceptionable purity, it is passed as pure, and is fit for the China market."

(*b.*) As another source of increase in extractive matter, Dr. Durant observes "that the presence of an excess of *gum* beyond what the drug should naturally contain, or any other similarly soluble vegetable matter" (of a like nature I may add) "will also add *materially* to the weight of the *extract*, though it may not at the same time be a proof of the superior excellence of the drug, but on the contrary of its inferiority, owing to the *excess* shown being caused by adulterative matters." I strongly suspect that this is a main source of that comparative poorness in extractive matter of the opium produce of the gardens under my charge—the specific purity of which I will guarantee; allowing some small percentage for dust, &c., accruing from the exposure of the drug in the capsule in windy weather; and some little iron from the implements used in the collection of the drug—and the standard produce of the agency. We shall, however, recur to this topic under the head of impurities and adulterations.

CHAPTER XV.

INFLUENCE OF VARIETY ON THE ALKALINE CHARACTER OF THE DRUG.

The influence of variety on the quantity and proportions of the alkaline constituents of the drug is apparently well marked, but there is a great want of analyses specially illustrative of these relations. With this point in view, I last season requested the Principal Assistant to the Opium Agent of Behar to analyse samples of the drug produce of the several varieties of the opium poppy cultivated in the gardens under my charge. I afforded him pure samples of each variety. The results of the analysis are interesting, even though confined to *morphine*, *narcotine*, and *extractive matter*. They are shown in the following tabular statement.

TABLE A.

		Extractive.	Morphine.	Narcotine.
1	Kotee standards—Behar	47·92	2·69	4·47
2	Chaura-kutila	38·80	3·71	3·71
3	Kutila	35·64	3·56	3·65
4	Sufaid-danthi	35·20	3·36	3·68
5	Do.—drug for the preceding season not extracted	38·80	2·66	3·88
6	Teyleah	37·13	3·16	3·41
7	Kalo-danthi	33 34	2 98	3·40
8	Monaria	37·33	2·88	3·31
9	Darhi-danthi	43·31	3·48	5·03
10	Sufaid-patta	42 54	3·09	3·48

2. These results show (1), that relatively to the Kotee standard the produce of the several varieties in the gardens here is poorer in extractive matter by from 4·61 to 14·58 per cent.; (2), that with a single exception it also yields less *narcotine;* but (3), on the other hand that it is in every case *richer* in *morphine*. A slight decrease, indeed, is shown by the variety on the fifth line of table, and this it is interesting to observe, is the produce of seeds which for three preceding generations had no opium extracted from their capsules. Relatively to that of the regularly drug—extracted plants of the same variety, as given on the fourth line of table, we find the former giving about ¾ per cent. less *morphine*, while in *narcotine* we have an increase by about ¼ per cent. The varieties known as Kutila (*vide*, lines 2 and 3 of table) afford the highest percentage of morphia—the first the two alkaloids in *equal proportions*, which distinguishes it from all the other varieties. The Darhi-danthi, a bristly stalked variety (line 9 of table) is specially rich in narcotine, but poorer than some of the others in morphia. In total alkaloids it indeed exceeds by 1·35 per cent. the Behar standard (*vide* 1st line of table), but as compared with some of the other old varieties it presents an excess of the less valued alkaline base (*narcotine*), which appears to possess but little activity. Some years ago, indeed, Dr. O'Shaughnessy introduced it as an excellent Indian substitute for quinine, but its general therapeutic action is very inferior, and it is but sparingly exhibited when the quinia salts are available.

3. It will be observed that the several varieties vary not a little in their *morphine*-secretive quality, and curiously enough, though the samples of my opium are, relatively to the Kotee standard, deficient in

extractive and *narcotine*, the converse is the case as regards the important principle *morphine*. Thus, taking the results of the five varieties generally grown in the agency (*vide* lines 2, 3, 4, 6, and 7 of table), the relative average products are of *extractive* and *narcotine* 11·90 and 0·90 per cent. respectively, in favour of the Kotee standard drug, whereas in *morphine* my own samples are the richer by 0·52 per cent. I note this difference particularly, as my samples have been disparagingly treated, as relatively deficient in total *alkaloids*, as if *narcotine* was equally as valuable a principle as *morphine*. As it is obviously however, of high importance that the more copious morphine-producing varieties of the agencies should be satisfactorily distinguished; from three to five separate analyses should at least be made of each sample, as really little stress can be laid on a single analysis. It is also of the first importance, that the process of analysis in each case be identical, otherwise the results will be most conflictive .....Soil conditions, manures, and waters used in irrigation, have also as we have seen, an important influence on the drug product, so that to afford anything like complete evidence, a series of samples carefully selected, would in each case need to be repeated. As illustrative of this variation under slightly changed conditions, I append the results of a series of analyses of samples of the *sufaid-danthi var* (4 of the above table) by Mr. A. Pedler, Professor of Chemistry, Presidency College, Calcutta. The samples I should state were also the produce of the gardens under my charge, and I may add that the soils and waters of cultivation did not greatly differ either physically or chemically. For the sake of comparison it is worth while giving the results of the principal ash-constituents of the plants in each case conjointly with their produce of morphine and narcotine, thus—

	PARTS OF THE PLANT.									DRUG.	
	Lime.	Magnesia.	Potassium oxide.	Silica.	Chlorine.	Sulphuric acid.	Carbonic acid.	Phosphoric acid.	Carbon.	Morphia.	Narcotine.
B ...	23·80	5·82	27·47	11·14	5·60	10·08	9·04	6·17	0·88	4·65	8·56
C ...	27·48	5 21	30·21	9·77	5·46	7·64	7·11	5·50	0·82	6·47	13 06
D ...	25·00	5·62	30·44	10·36	6·64	5·93	7·60	6·73	1 68	8 66	10·59

4. It will be observed that the ash-constituents though varying somewhat indefinitely in the different samples, show some sort of relation between their basic components, *lime* and *potash*, and the quantity of alkaloids in the drug. For example, B with a minimum of those salts in its ash 6·42 per cent., is poorer in alkaloids than D by 6·32 per cent.

The alkaline qualities of the drug is thus shown to be very superior to that of last season (*vide* table A above) according to Dr. Durant's analyses. It should be stated, however, that Professor Pedler's results are from samples at a consistence of 100°, so that at a consistence of 70° as in table A, we reduce them respectively to—

B.—Morphine	... 3·25	Narcotine	... 5·99
C.— „	... 4·52	„	... 9·14
D.— „	... 6·06	„	... 7·41

CHAPTER XVI.

INFLUENCE OF VARIETY, &c., ON THE QUANTITY OF AN OPIUM CROP.

We have thus far treated only of the relative richness of the drug in the alkaline bases,—*morphine* and *narcotine.* Let us now briefly advert to the influence of variety, &c., on the total opium produce. Though the alkaline richness of the drug is a character of prime import in the selection of samples for specific medical purposes, we have seen that relatively to the merely physical properties, it has quite a secondary import in the estimation of that for the China market. Thus, irrespective of the alkaline qualities of the drug, the real commercial criteria of particular varieties are the quantity and physical excellence of the produce.... First, then as to the general and special average returns from the agencies. In the Behar Agency the highest general average per beegha for the last twelve years was in the season 1863-64, and amounted to 6 seers ½ kutcha. Correlatively, the outturn was also high that season in the Benares Agency: the general average being only 4¾ chittacks under that of Behar, and only since exceeded by one chittack on the average of the season 1865-66. During the same period the highest divisional average for Behar is that of Shahabad, in 1863-64, which was 7 seers 13½ chittacks. This was exceeded, however, in the Benares agency: the Benares division giving the high average return of 8 seers 6½ chittacks.

The minimum general average for the above ten years occurred in the evil-famed season of 1870-71, and was obviously due to *the* mould-blight: the produce for the Behar Agency being only 3 seers 12½ chittacks per beegha, while that of Benares was less by 3¼ chittacks per beegha. No lower general returns than the above, have I believe, been recorded in the Behar Agency, though in the following season the Benares Agency gave a still lower return, viz. 3 seers 3¼ chittacks per beegha: this I believe is the lowest seasonal average on record. It is to be observed, however, that it was in no way attributable to blight, but wholly to unfavourable conditions of weather. The divisional returns during the above period also reached a very low ebb: thus we find in Behar that the Tirhoot division for 1870-71 gave only 2 seers 6 chittacks per beegha, this being exceeded in the adjoining divisions of Motiharee and Bettiah by a few chittacks only. Low though the returns thus are from the Behar Agency, we have still lower ebbs in the Benares records. Thus, exclusive of the miserably poor returns from Rohilkhund and Saharunpore, we find the old division of Bustee yielding, an average of 1 seer 13½ chittacks only per beegha in the season 1871-72, and in the preceding season 2 seers 12½ chittacks. In the blight season, however, the former Agency, that of Behar, had been most seriously affected, as shown by the relatively higher average returns of the preceding and succeeding seasons.

For the sake of comparison, as also for subsequent reference, in illustration of the periodical recurrence of the mould-blight I insert in a tabular form the average returns per beegha for ten successive seasons viz. from 1862-63 to 1871-72.

Seasons.	Behar Agency. S. C.	Benares Agency. S. C.
1862-63	5 $2\frac{1}{4}$	5 11
1863-64	6 $0\frac{1}{2}$	5 $11\frac{3}{4}$
1864-65	4 8	4 $8\frac{1}{4}$
1865-66	4 $14\frac{1}{4}$	5 $12\frac{3}{4}$
1866-67	5 $3\frac{3}{4}$	5 8
1867-68	4 $6\frac{3}{4}$	4 15
1868-69	4 $11\frac{3}{4}$	4 6
1869-70	5 $5\frac{1}{4}$	4 $11\frac{3}{4}$
1870-71	3 $12\frac{1}{4}$	3 9
1871-72	4 $2\frac{3}{4}$	3 $3\frac{3}{4}$
General average =	4 $13\frac{1}{2}$	4 $14\frac{3}{4}$

2. The general average of the agency returns comprises the results of at least some half-dozen less or more generally cultivated varieties, but so far as I can learn there are no records whatever of their relative fertilities. In the experimental gardens under my charge, where all are grown separately, this can be pretty fairly illustrated. A tabular statement of these is given in the appendix, and I will thus confine myself here to a brief review of the results. Mould-blight affected very seriously the poppy crops in the season 1874-75, and nearly all the varieties gave but a very small quantity of drug. The most marked exception to this was afforded by the variety called Kutila. Thus, while I had as much as $11\frac{1}{4}$ seers of drug at a consistence of 75° and on an average $10\frac{1}{4}$ seers per beegha from that variety, the highest average of the other varieties was only $6\frac{1}{8}$ seer per beegha. This, as I have shown in the annual report for that season, was clearly due to the comparative immunity of the former variety from the mould infection. I on this account recommended strongly its more extensive cultivation in both agencies.

3. The last season (1875-76) as one in which the poppy was but slightly affected, and in no instance I believe, appreciably injured by mould, was one specially favourable for a comparative examination of the relative fertilities of the several varieties.

Name of Variety.	Metapore.		Deegah A.		Deegah B.	
	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.
	S. C.	S. C.	S. C.	S. C.	S. C.	S. C.
Teyleah	15 $0\frac{1}{2}$	9 12	12 1	9 $0\frac{1}{2}$	......	......
Sufeid-danthi	......	......	6 $4\frac{1}{2}$	5 $4\frac{3}{4}$	8 4	5 $4\frac{3}{4}$
Kala-danthi	11 $2\frac{1}{2}$	8 12	9 $14\frac{1}{4}$	9 10	13 $6\frac{3}{4}$	12 6
Subza-kala-danthi	......	......	14 9	14 9	......	......
Kutila	15 2	10 11	12 $2\frac{1}{4}$	7 $3\frac{3}{4}$	......	......
Chaura kutila	......	......	11 1	9 $3\frac{1}{4}$	......	......
Monaria	11 15	7 11	9 12	9 12	12 2	9 $3\frac{1}{2}$
Darhi-danthi	......	......	5 $10\frac{1}{2}$	5 $10\frac{1}{2}$	......	......
Malwah	3 $0\frac{1}{4}$	3 $0\frac{1}{2}$	6 9	4 14	8 $12\frac{1}{4}$	4 12
Italian	......	......	......	......	6 $3\frac{1}{2}$	5 12
Turkey	......	......	......	......	3 $4\frac{1}{2}$	3 $4\frac{1}{2}$
Spanish	......	......	......	......	2 $2\frac{1}{4}$	2 $2\frac{1}{4}$
French	......	......	......	......	0 $13\frac{1}{2}$	0 $12\frac{1}{4}$

On the Metapore lands the Kutila and Teyleah varieties afford nearly an equal maximum of 15 seers per beegha, though as regards the general average there is a falling off in the latter of about *one seer* per beegha. The Kalo-danthi and Monarea varieties are also fairly productive, the Malwah very poorly so. This I attribute to the seeds having been the produce of the Deegah lands, where the soil differs considerably from that of Meetapore. By reference to the tabular statement, we find that the same seeds on the Deegah lands (where it had been sown and raised for three successive seasons) gave a maximum of from 8 seers 12¼ chittacks, to 6 seers 9 chittacks, whereas at Meetapore the produce was only 3 seers 0¼ chittacks. This result will illustrate the prejudicial effects of any marked changes in the soil in opium cropping, as weather could be no factor in the result, the two gardens being separated by a few miles only. As regards the general results of the Deegah, relatively to the Meetapore lands, we find them somewhat in favour of the latter, which I believe is mainly attributable to the work-people being so much better practised in the processes of scarifying and collecting the drug in the latter zillah. It may also in part be due to the soil being in a more highly pulverised state, the Meetapore garden comprising old poppy lands, whereas that at Deegah has been only lately broken up..... It is from results such as these that I would urge a careful regard to the physical and chemical character of the soil in the interchange of poppy seed.

The results under column A., Deegah, comprise those of that portion of the garden enclosed by the jail walls, whereas that marked B. comprises the results of the lands to the east and north of the wall forming the old jail garden. For some years subsequent to the abandonment of the jail as a penal settlement the garden lands had been annually let to native gardeners and cropped unremittingly until they were all but utterly exhausted. On breaking them up again, some three years ago, they were quite overrun with the troublesome "Mootha weed" of the natives (*Cyperus hexastachyus*). The enclosed lands were also in a bad state, bedded mainly with dhoob-grass (*Cynoden dactylon*), broken with patches and dense tufts of "*ooloo*" and "*kasu*," the *Imperata cylindrica* and *Saccharum spontaneum*. Neither of these were thus at all promising for experimental opium husbandry. They have greatly improved, however, as shown by the results of this season. The general average return of opium was about *half a seer* per beegha in favour of the outer lands, the maximum produce of the old varieties being attained by that called *kalo-danthi*, which gave 13 seer 6¾ chittacks per beegha, and a general average of 12 seers 6 chittacks. This was only exceeded by a small plot of a new variety, *Subza Kalodanthi* in the enclosed lands, which yielded 14 seers 9 chittacks per beegha. As regards the other varieties, the *kutila* and *teyleah* on the enclosed lands, and *Monarea* on the outer lands, were the most productive, each affording a slight excess on 12 seers per beegha.

4. With the exception of a few of the recently imported exotic varieties, the Malwa sorts were the least productive, affording a maximum of 8 seers 12 chittacks and a general average of about 4 seers 11 chittacks per beegha. The effects of acclimatization on the Malwa sorts, it should be observed, has however been very strongly brought out

this season. Thus, in a previous chapter, on the authority of the late Opium Agent for Behar, we learn that the Malwa poppy in the season of its introduction to Behar, 1871, yielded "in no case more than *one seer, per beegha*, and generally only a few *chittacks*." I have continued its cultivation in the gardens here, with the above results; and as the capsules from my selected seed-plants are considerably larger than those produced by any of the Behar varieties, I do not doubt that it may ultimately prove well worthy of the cultivator's attention in the surrounding districts........Of the exotic varieties of the opium poppy the most productive were those from the seed grown in Italy, the Turkey seed crop yielding little more than half the quantity of drug, that from Spanish seed still less, and the least productive of all being that of French origin, which on a par with the Malwa varieties on their first introduction to Behar, yielded only some $\frac{3}{4}$ of a seer per beegha. From the so-to-speak gross habit and high luxuriance of the Italian, Turkey, and Spanish varieties of the poppy on the lands here, and also the fairly copious drug-produce for the first season, I am strongly of opinion that they may yet be, with advantage, largely substituted for the local varieties.

CHAPTER XVII.

STRUCTURE OF CAPSULE AS RELATED TO THE PRODUCE OF DRUG.

The structure of the capsule—that is, in so far as relates to the development of the milk and absorbent vessels—has important relations to the production of drug, and requires special illustration. I first drew attention to this in my annual report for 1874, and accompanied it with illustrations of the relative development of both systems in copious and spare drug-producing capsules. These illustrations are already in the hands of the officers of the department, and need not be reproduced here.—The capsule varies much in form and size, from ovate to roundish or oblate, and from half an inch or so in the miniature form to 2½ and 3½ inches longitudinally by 2 to 2½, and even 3 inches transversely, as in the finer local and Malwa sorts; thus presenting a very large drug-yielding surface.

2. In the wild varieties of the opium poppy the seed-vessels open by chinks or pores under the stigma for the discharge of the seeds. This holds also in those cultivated for seed only, or ornament in the gardens, whereas in those varieties from which the drug is regularly extracted the capsule is non-dehiscent, or completely closed to the last, the seeds being only discharged by the natural decay of the outer coverings of the capsule. This non-dehiscence of those from which the drug is regularly extracted is obviously a result of the process, as thereby increasing and prolonging the general circulation of the sap and enlarging the vascular system, so that the placental or seed-bearing walls and the pericarpal or enclosing walls dry up simultaneously, and there is thus no shrinkage in the interplacental parts to effect the normal dehiscence. This will be readily understood by a comparative examination of the woody framework of a dehiscent and non-dehiscent capsule........

3. The pericarp or enclosing wall of the seed-vessel consists of three distinct parts: *first*, the outer or epidermal, forming the skin technically the epicarp; *second*, the middle or mesocarpal zone; and *third*, the inner or endocarpal, and; from our point of view, the most important zone as containing the drug-yielding and absorbent vessels. It consists of several layers of loose cellular tissues interspersed with absorptive organs, and permeated by a fine network of drug-yielding vessels. In all the more copious drug-producing capsules, the milk system is very much more fully developed than in those which produce it scantily. It is a quality dependent on structure and constitution, and may be largely increased by habit or functional exercise. Let us illustrate this.—The variability in the drug-yielding quality of individual plants is a phenomena familiar to all the officers of the department, to which this little treatise is addressed. One individual plant for example bears capsules which but sparingly yield drug to from *one* to *three incisions*, others—though it may be of sparer habit—give origin to capsules which yield drug copiously to from *six* to *eight* and even *twelve* incisions. Now, this is not, as is generally supposed, a merely casual phenomenon. It is, so to speak, a result of pedigree: increased functional exercise on the one hand giving rise to an enlarged structure, or *vice versâ*. Seeds from the more copious drug-producing capsules give rise to a progeny after their own kind, even as any other improved variety of a plant or highbred animal gives rise to a progeny after its kind. In fact the scanty, relatively to the more copious drug-yielding poppies, are so from a less specialized or improved function, and this again is dependent on the enlarged development of the drug-secreting system. These relations have been hitherto singularly overlooked, and I regret to say that even yet, though now some three seasons since I first directed attention to them, they appear to be all but practically ignored by the officers of the department. This is to be regretted, as there can be no doubt as to the great good that would result from their practical observance. It is not for me to dwell on this point however; my duties are those of an examinator only, and I fulfil them in explaining the observed phenomena.

4. To resume.—In the more copious drug-producing capsules then, as I have already remarked, the milk-system is relatively much more fully developed than in those which yield it scantily. I have given various sectional illustrations of these in the supplement to my annual report for 1873-74. I have there shown that in the more copious drug-producing capsules the milk-ducts are very generally from the 500th to the 800th of an inch in diameter, whereas in the more scanty producers they rarely exceed the latter diameter, and consist mainly of a delicate cobweb-like network of ducts varying from 1,000th to the 1,500th of an inch in diameter. Moreover, the woody system is more largely developed in poor than in copious drug-yielding capsules; and this as tending to promote the earlier development and maturation of the seed further decreases the drug-yielding quality. Obviously, then, the relative drug-yielding value of individual plants is dependant on congenital structure, or progenital habit; so that, as I have elsewhere remarked, "it is not a whit more absurd to think of raising a *new race of copious drug-yielding poppy* from the present mixed and

unselected crops, than to think of so rearing *per saltum* copious milk-yielding cows,—comparable for example with the Devon or Ayrshire breeds which yield from 20 to 30 quarts daily—from the unimproved races of this country.

5. In my report of 1873-74 I have shown that the poppy crops generally as at present deteriorated by the predominance of scanty drug-producing plants. I made collections of drug from 50 capsules of the latter varieties, and from the same number of the more copious drug-producers. I may state that in each case the drug was taken from the *second* incision on the capsule, and in the scant—producers from a single capsule only on each plant; whereas in the other case I took it from two to three capsules on one plant. Had I limited the collection to the central capsule only, or to one on each plant, the contrast, would have been even more striking. To resume,—The *crude drug* from 50 capsules of the scant—producers weighed only 23 grains, whereas that from the superior class was 140 grains, that is, fully as six to one! From a reference to the tabular statements in my report showing the relative proportion of copious and scanty drug-producing plants in the present unselected state of the crops, we are thus enabled to make a comparative estimate of the produce of one beegha of poppy as it is, and as it should be—*i.e.* by selection or elimination of the scant-producing class. Now, allowing 27,225 plants *per beegha* (that is, *one* plant per square foot, they should really not have more as a rule in the generality of the lands than *six* or *nine inches*), the proportion of copious to scant drug-producers (as shown by my tabular statements), would be as 4,537 to 12,688, or very nearly *one* to *three!*

		Number of plants per beegha.	Crude drug in lbs Troy.	Prepared drug in lbs Troy.
1	Copious drug-producers ...	4,537		
2.	Scanty drug-producers	12,688		
3.	Selected seed progeny	27,225		
4.	Produce of Nos. 1.—5 collections	......	15·5	
5.	Ditto of „ 2.—3 ditto	......	12·0	
6.	Ditto of „ 3.—5 ditto	......	263·80	
7.	Ditto of „ 1.	......	......	5·10
8.	Ditto of „ 2	......	......	4·0
9.	Ditto of „ 3.	......	......	87·93

Now, with reference to the above tabular statement, it is to be observed, with regard to the scanty drug-producing plants, the average of *three drug collections* is high, whereas from the other class *five* is low: a fairer average would have been *two* and *seven*, which would of course have afforded much more striking results in our comparative examination of their fertility. As shown in the tabular statement, the selected as compared with the ordinary unselected crops should stand in the proportion of nine to one. I see no reason to doubt that by the careful selection of seeds from the most copious drug-producing plants the above rate of produce per beegha will be attained. I hold this simply on the eliminatability of the scanty from the copious drug-producers, a result which should be effected in very few seasons. On the other hand, the selective improvement of the latter, as in all analogous cases, will of course be the slow work of years; but as I have elsewhere remarked, I do not dbout that the most copious of our drug-producers now, will be as inferior to those of the future as these are to their wild progenitors

6. Before passing from the phenomena of drug-secretion, I think it desirable to repeat what I have elsewhere stated, "that while increase of function in the drug-secretive system of the poppy is largely attributable to the inherited effect of increased ancestral action; nevertheless, and in a limited extent, the functional excellence of each individual is dependent on early and active exercise. For example, I am of opinion that a capsule from which drug has been extracted in an early stage (that is, as soon as its tissues are plump and firm) and frequently repeated, say at intervals of two days for the first week or so, and subsequently three days, will yield relatively more drug than capsules similar in so far as regards congenital structure, but which had attained a more mature stage when drug was first extracted, and the process subsequently practised at longer intervals. Increased function is recuperative, as entailing extra growth or development of organs thus exercised. Hence, to promote fully the secretion of drug in the individual plant of the poppy, it is absolutely necessary that the function be early and frequently exercised.

In opposition to the above views, it has been insisted that the best seed is the produce of those capsules which have yielded the smallest quantity of drug. Theory, analogy, and practice, are alike opposed to this view............Thus it is to be oservbed that there is much analogy in the processes of secretion of drug in the opium poppy, and those of milk and lymph; increased action in all cases entailing an increase in the bulk and power of the secretory system. The domesticated cow and the goat well illustrate this phenomenon......... "If we compare," remarks Mr. Darwin, "the size of the udders and their powers of secretion in cows which have been long domesticated, and in certain goats, in which the udders nearly touch the ground, with the size and power of secretion of these organs in wild or half-domesticated animals, the difference is great.......... We may attribute the excellence of our cows and goats partly to the continued selection of the best milking animals, and partly to the inherited effects of the increased action, through man's art, on the secreting glands." Now, nobody will say that our highly improved cows, &c., have their constitution weakened by the extraction of milk, so greatly in excess of that normally requisite for the nourishment of their offspring. Nevertheless, we know that by the most careful selective breeding from the best milkers, only the present high economical value of those animals has been attained. No one would ever think of raising their counterparts by breeds of scanty milk-producing animals, on the ground that as these have not been weakened by the abnormal extraction of milk, they will give rise to a more healthy and vigorous progeny of copious milk-producers. Such however, are the principles with which our views have been confronted in the case of the poppy, though alike disproved by theory and analogy. Moreover my own practice has clearly shown that the drug-yielding quality of the poppy is increased and confirmed, by selection of seeds from the most copiously productive capsules.

CHAPTER XVIII.

MODES OF INCREASING AND PROLONGING THE DRUG-YIELDING QUALITY.

The modes of increasing or developing the drug-yielding quality of the poppy have been already cursorily treated, but as they are of great importance in opium husbandry they deserve to be separately treated. This we will now do.—The nature of the soil, as we have seen, affects the quantity of the drug and, in a marked way, its physical characters. With those above objects in view I instituted last season many experiments with various saline and organic manures, both in the way of applications to the soil, and to the plant directly, as a top-dressing. A careful analyses of these will show in how far I may have succeeded if at all, in altering the proportion or increasing the alkaline character of the drug; but in the meantime, as will be seen from the subjoined tabular statement, we have distinct evidence of increase in quantity. (*The tabular statement is given in the appendix,—vide Table E.*) First for the manurial application to the soil.—It will be observed on reference to the tabular statement that the manured plots, though not greatly exceeding, and in one case, indeed, falling below the untreated plot in the weight of capsules and seed, nevertheless exceeded the latter considerably in the produce of opium. The most productive as regards opium was that treated with an excess of bone superphosphate and pure potash-nitrate. Each of the manured plots, however, produced considerably more drug than the unmanured. It is also to be observed that the plot yielding the largest quantity of opium (15 seers 2 chittacks) exceeds the others in the total of seeds and capsules, though the largest quantity of *seeds*, is the produce of the plot treated with mineral matters only. The average of the three manured plots in opium is 13 seers 6¾ chittacks—that is 4 seers 13¾ chittacks in excess of the unmanured.

Again, in section 2 of table, the returns from manured and unmanured crops of the variety called *Monarea*, are shown. The difference is striking. The land selected for this experiment was uniformly poor, having the preceding season yielded only 4 seers 4 chittacks per beegha, the variety cultivated being the *Sufaid-danthi*—one apparently much better suited to a poor soil than the *Monarea, var.* The whole land was cropped during the rains with *soni* (*Crotolarea juncea*), *all* of which was cut and buried in a *green state* in that portion of the land to be treated with other manures. These were applied in kind and quantity as given in the table, prior to the sowing of the seed in October. Nothing in the first instance was applied to the other plot, but subsequently the young crop continued so poor and sickly that on two occasions I gave it a top-dressing with *nonimattee* alone, and on a third with a mixture of that and lime. These applications much recruited the plant. Though on both plots the plants were very uniformly distributed, it will be seen by a comparison of the total returns of seed and capsules that those on the unmanured plot must have been very poor. The variety grown is naturally of a vigorous and robust habit, and more than any other would known to me requires a rich or well manured soil. In a poor soil it degenerates rapidly, and with its low, simple, almost branchless stalks and small ovate or elliptic capsules, be recognized as the same variety with that grown on a well manured soil, where it attains a height of from four to five feet; the stalks stout and branchy; foliage large and of a deep glaucous green; the capsules large, and of a roundish-oblate form. An idea of the size of the capsule in the healthy plant may be found by comparing the weights of capsules and seeds in my tabular statements, the former being considerably in excess of the latter, whereas in the poor soil the case is reversed; the seeds then exceeding the weight of capsules in the proportion of about three to four. Again, as regards opium, we find the manured plot yields 8½ seers per beegha more, than the unmanured plot, or about 3½ to 1! The difference in the results of cropping in rich and poor lands is thus very much greater with this variety than the preceding.

2. We will now pass on to the effects of manurial top-dressings on an opium crop as illustrated in the appendix,—*vide Tables C and D.* We have first the untreated plants, in which with an equal weight of seeds and capsules there is a falling off in opium, as compared with the manured crop, of 4 seers 5 chittacks, per beegha. The most productive of the manured set is that treated with *shorah* and *nonimattee*, which affords in opium the high return of about 21¼ seers, the weight of seeds to capsules being as 500 to 453. This corresponds also with the highest grade of fertility in seeds, viz. 6 maunds 25 seers per beegha. The plot 2 of table, is the next most highly productive in seeds and capsules, and the result of a top-dressing with *bicarbonate of lime* and *shorah*. The return in seeds was 6 maunds 11 seers, and opium 16 seers 10 chittacks per beegha. The effects of *bicarbonate of lime* alone are shown in the fourth of the tabulated experiments. They are well marked, the return in opium being close on 20 seers per beegha and in seeds 5½ maunds. It should be observed that the appearance of the plants treated with *bicarbonate of lime* were early and to the last distinguished from those treated with *shorah*, the other *lime* and *iron salts*, by their pale green foliage, and somewhat sparer habit. Especially striking was the contrast as compared with those treated with *shorah* and *nonimattee*: the latter being distinguished by their gross habit and full foliage of a deep glaucous green. As regards opium, the least productive is that set treated with *iron sulphate* and the *salts of lime* and *potash*, the results of which are given under series 7 of table. I need not particularise the others. . . . . . It is clearly shown by the tabulated results of the manurial top-dressed series, as compared with those untreated, that the opium and seed-produce generally had been thereby greatly increased. This is especially the case with the *opium*, and in one single instance only (that in which ammoniac sulphate of iron with lime, soda, and potash salts were used) was the *seed produce* lower then that of the untreated set. Under this head I will only further

add that the above-noted manurial dressings were applied as the flower *buds* generally began to make their appearance, and about *three weeks* prior to the first extraction of drug from the most advanced plants.

3. The prolongation of the drug-yielding period of the poppy is another interesting and important branch of opium husbandry. Unfortunately, I can illustrate this subject but very crudely and cursorily, as being limited to a few experiments and personal observations.

4. We will first notice the general effects of irrigation at and subsequent to, the expansion of the flower. This should be particularly attended to as the assamees by no means appreciate its beneficial effects. They will irrigate as the plant comes into flower, only if the soil is absolutely dry, but their system generally is to defer it then if possible, until a day or so before they begin to extract drug, and then very generally withhold it until the capsules have ceased to yield drug, when they strangely enough, liberally irrigate the plants to perfect, as they say, the maturation of the seed. This labour might well be spared, as the plants, after ceasing to yield drug, have always more than a sufficiency of sap for all subsequent requirements. On the other hand, a liberal application of water as the flowers begin to unfold, and indeed to that period when the capsules are sufficiently developed for the extraction of drug, is of the first importance, as tending to suppress the reproductive functions and increase and prolong those of a purely *vegetative* character. In short, plants in a dry soil during their floral period will much more rapidly mature their seeds than will those in the opposite condition. Now, as drug-secretion is a purely vegetative function, it is obviously of the first importance to retard the ultimate reproductive function if we would increase or prolong the former. On these grounds, then, I would strongly recommend, that throughout at least the flowering period of our poppy crops, irrigation should be specially attended to, and the soil always kept in a more than usually moist state. The assamee practice, of withholding water while the plant is in flower, and applying it when the capsule is plump and firm, does not at all meet the requirements; drought in the preceding or floral period tending greatly to the early maturation of the whole plant.

5. I will now draw attention to two other modes of prolonging the drug-yielding period. I must premise, however, that they have rather a theoretical than practical interest, and indeed it is only from the former point of view that I notice them here. I have inadvertently said two modes, I should have said degrees of the same process: they are the effects of a more or less complete and an abortive fertilization. Well, as I have already observed, the collection of the petals (which are required for the formation of shells to cover the China opium), promotes and perfects the fertilization of the capsule, and consequently in increasing the quantity of seeds, tends to the early maturation of the plant. In other words, it would appear that under similar conditions of humidity, &c., the less perfectly fertilised poppy will longer maintain its vegetative functions than that in which the function has been perfected. I should thus anticipate

that a plot of poppy, which has not had the petals collected in the usual away will yield opium longer and probably in larger quantity than another from which they have been collected. I have but a single illustration of this, and that of a confirmative nature. Here it is.—One beegha of land under similar treatment and of the same variety of poppy was set apart, half of which had the petals duly collected in the usual way, the other was left untouched, the petals falling off as they naturally matured. The results were that the plot from which the petals had been collected yielded of opium 7 seers 4 chittacks per beegha, while the other half, from which the petals had been allowed to drop off naturally, yielded 8 seers 9 chittacks per beegha—that is, 1 seer 5 chittacks in excess of the former Again, as regards the *relative proportion of seeds and capsules* from the two plots, we have the following results:—

Plants with petals collected,	of seeds in weight, as 500;	to capsules	214
Ditto ditto uncollected,	„ „ „ 500;	„	355

(*b.*) Absolutely I should state that there was an excess in the total weight of capsules and seeds produced by the collected petal plants, but it will be seen that as regards the relative proportions (which is of paramount import from our point of view) of seeds and capsules, there was an excess of capsules (those parts which are really the drug reservoirs), produced by those from which the petals had not been collected, and this doubtless from their less perfect fertilization. It is also to be observed that in the present instance the latter plants (*i.e.* those from which the petals had not been collected) yielded drug for fully one week later than the other. The differences might have been greater but for the prevalence of light westerly winds and breezes during the flowering period, which of course promoted fertilization generally.

6. (*c.*) We have now to treat of abortive fertilization. This, as related to the yield of drug, is a curious and interesting topic. It is worthy of remark that an analagous result to that which I am about to notice has been observed in the function of lactation in the cow. "Connected with the interesting object of obtaining a continued supply of milk from the cow," observes Seller and Stephens, "there is a very singular belief that has not yet obtained an attention commensurate with its importance. If the functions of the organs concerned in lactation have *once* been called into full activity by the act of breeding in the cow, it would appear that the function of the ovaries may be put an end to, and yet that those of lactation may continue on uninterrupted vigour for years. This is the theoretical foundation of a proposal to remove the ovaries from (that is to say) a young cow after its first calf, subsequently to which proceeding *it is said to afford milk uninterruptedly for many years.*"—(*Physiology at the Farm*, page 559.) This might, I think, with advantage be largely practised in India with cows, buffaloes, and goats, from which milk rather than progeny are required.....To obtain an analogous effect, that is, the abortion of the seed in the poppy, I in my first experiments cut off the stigmatic rays as soon as the flowers began to expand. This practice, however, entailed a considerable loss of milky-juice, and I

discontinued it, though capsules even thus maltreated yielded quite as many copious drug-incisions as those treated in the ordinary way. To effect the abortion of the ovules without any mechanical injury to the stigmas, I coated them with glycerine, prior to and as the flower began to expand. In this, however, I altogether failed in effecting the above purpose, as the capsules thus treated ultimately proved as highly fertile (*i.e.* produced quite as much seed), as those naturally fertilized. The pollen-grains would thus appear to perform their function quite as effectively on the glycerine-coated stigma as when wholly untreated. The failure of this experiment disappointed me much, especially as I discovered it late in the season, when I had but little time for further experimentation. I subsequently tried bland oils of various sorts; these I found injured and discolored the stigmatic rays. Latterly, I effected my purpose with a mixture of fine salad oil and glycerine. The capsules thus treated as the flowers began to unfold producing no *perfect seed*, though the capsules in every case attained their normal size. It was unfortunately very late in the season ere I made this experiment, and I will not tabulate the results, as they were on much too limited a scale to afford really crucial evidence. In the meantime, however, and so far as they go, the results I may add were satisfactory. They show that though the seed may be thoroughly aborted, the capsules will nevertheless attain their normal size, while the plants do longer retain their vegetative vigour, and yield as judged by this necessarily limited experiment, more drug than the normally fertilised plants. I cannot further illustrate this curious subject now, but I shall do so next season, should I again have the facilities afforded me in that past.

CHAPTER XIX.

THE DRUG: ITS PREPARATION, IMPURITIES, AND ADULTERATIONS.

Dry seasons, as I have already remarked, are those in which we have the largest and best returns of opium, though, as we have seen, there is a want of positive evidence as to the composition of the drug being thereby materially affected. It should be observed, however, that in dry seasons the drug, as a rule, is eminently free from pussewah, and from a remark by Dr. Durant, who writes me, " I have just completed an analysis of samples from all the different districts and kotees belonging to this agency, to obtain the standards, and find the results *throughout better* than they were *five* years ago, when the last standards were taken. The increase has been markedly in *morphia*, the average of this salt being now for *all* the districts in this agency 3·17 *per cent.*, whereas it was only 2·69 *per cent.* before." In these results an absolute and permanent increase in the alkaloids is tacitly assumed to have occurred during the past five years. I am afraid the results are casual, or as I should rather say, contingent wholly on weather and season. Thus the past season has been throughout eminently dry and hot, and the opium is of high quality and rich in alkaloids. Five years ago the opium season (that of the evil-famed blight) was wet; the drug was scant, of low quality, and, as it appeared, relatively poor in alkaloids. These, then, being the general characteristics of the two seasons in which the standards were taken there is plainly but a very slim basis for the assumption that the poppy is permanently improved as an alkaloid yielder. On the other hand, I am disposed to attribute the difference in the results wholly to seasonal peculiarities—a *dry* season being more favourable to the production of the alkaloids than a wet season—and that we may thus have indications of the direct influence of weather in altering the quantity and proportion of alkaloids in the drug. We will now briefly notice the general composition of the drug.

Pure opium is entirely destructible by heat, leaving no residue, though even the purest of the commercial and officinal drug always gives a certain percentage of ash. Indeed, in the processes of extracting and collecting the drug, the introduction of certain extraneous matters is almost unavoidable. Atmospheric dust, for example, adheres to and gets mixed up with the exuding drug, while in scraping it from the capsule, parts of the rind and its powdery coatings, are introduced along with traces of iron by the abrasion of the drug-collecting scoop. Opium, as secreted by the poppy, consists exclusively of two series of organic constituents, of which the principal are the *Nitrogenous* or *Azotised* compounds, as *morphine, narcotine, codeine, thebaine, paparerine, narceine;* the others or *Unazotised*, are chiefly *Carbo-hydrates*, as *meconine, meconic acid, fatty, resinous, gummy,* and *mucilaginous* matters. I regret that I have no exhaustive analysis of the Indian drug to afford a comparison with that of Smyrna, of which the following is the mean of *five* analyses by Mulder, and quoted by the late Professor Johnston:—

Morphine	6·3	Resin	2·7
Narcotine	7·7	Gummy extractive ...	25·3
Codeine	0·7	Gum	1·7
Narceine	9·0	Mucilage	18·7
Meconine	0·6	Water and loss	14·5
Meconic acid	6·1		
Fat	2·2	Total ...	100·0
Caoutchouc	4·5		

Besides the above substances, five others, viz. *thebaine, opeanine, pseudo-morphine, porphyroxine,* and *papaverine* are found in opium in small proportions. All these have been discovered since the period of Mulder's analyses.—*Chemistry of Common Life.* The above analyses, I believe, are of opium at a consistence of 100°, reduced to 70°; and assuming that in the ordinary analyses of the Indian drug the *Morphine* is mixed with *codeine, meconine,* and *meconic acid* the *Narcotine* with *narceine,* the results as compared with the Indian drug of the same consistence are shown in the following tabular statement:—

	Smyrna opium.	Indian opium.
Morphine	9·59	2·83
Narcotine	11·69	4·65

The relative proportion of the alkaloid in the Smyrna and Indian drug is thus in *morphine* as 1 to 3·38, and in *narcotine* as 1 to 2·51. It will be observed, however, that the narcotine in both samples is in excess of the *morphine*. The converse of this is very generally believed to obtain in the Smyrna drug—*i.e.* morphine in excess of narcotine. The relative paucity of gummy extractive in the Smyrna drug is very striking, being nearly as 1 to 2.

The composition of the milky-juice of the poppy, according to Biltz, Mulder, and Schindler is as follows:—

Morphine	from	2·84	to	20·00	per cent.
Narcotine	,,	1·30	,,	33·00	,,
Caoutchouc	,,	2·00	,,	6·01	,,

2. The treatment of the drug after its collection from the capsule differs less or more in the different countries in which it is produced. In Asia Minor it is kept in an earthen pot, and then after undergoing a certain degree of inspissation it is taken out and worked up with *saliva*. This process is said to be frequently repeated. In Malwa the practice is, after a few days' inspissation of the drug in shallow earthen pots, to work it up with the hands, form it into a ball, and immerse it in poppy or linseed oil in closed vessels. In this state it is sold by the assamees to the bunneahs, who, prior to taking it to market, suspend it in strong cotton bags so as to strain off all the free oil. It is then taken and thoroughly worked up with the hands for hours, so as to bring all to a uniform colour and consistence. By action of the above processes the drug is thus considerably sophisticated. This cannot be said of the practice in the Government agencies when carried out in its integrity. Thus, immediately after collection the drug is spread over the sides of unglazed earthen pans so as to drain off all free moisture and pussewah. As soon as it acquires a consistence of 70° or even lower, it is worked up with the hands, formed into a ball, and placed in another clean earthenware vessel, and put aside in a cool, moist, and dark part of the house. In this state it is made over by the assamees to the departmental officers. The process of preparation under the Government agency is thus simple, clean, and unsophisticative; affording a drug of great purity.—I would here remark, however, that I am now strongly of opinion that the primary preparation of the drug in unglazed and highly porous earthen pots tends to deteriorate it as a purely officinal product; inasmuch as entailing, as I now believe, a less or more considerable loss in extractive matters and alkaloids. Indeed, I would thus largely explain certain hitherto perplexing results in the comparative analyses of opium from the gardens under my charge and the ordinary produce of the Behar Agency. Thus, every sample of my opium has shown relatively to that of the agency a less or more marked deficiency in extractive matters and total alkaloids. As regards extractive matter, the deficiency in some samples being no less than 17 and 18 per cent., and in the majority from 6 to 10 per cent.

3.—I was much struck with these results, considering, as I then did, that my mode of preparation of the drug did not in any respect differ from that practised by the assamees. In this, however, I have only very lately and casually ascertained, my mistake: the processes differ importantly; *i.e.*, *in the degree of inspissation over a large surface of porous earthenware.* The native plan, as indicated above, is to store it in bulk, and only allow all actually free moisture to drain off before working it up in any way, but to avoid exposing at any time a large surface of the drug either to the surface of the earthen pot or to the atmosphere. I, on the contrary, spread my drug out over the interior of the earthen saucers, and thus allowed it to remain until it had attained a general consistence of from 75° to 80°. In this I am now convinced I greatly erred: the process entailing an excessive loss of extractive matter, and affording as I think the true explanation of the great relative deficiency of my drug in extractive matters. Those porous earthenware pans, with high absorptive powers must necessarily have carried off much extractive matter, and to a smaller, but none the less appreciable extent, alkaloids, along with the natural moisture of the drug. Now, it is plain that in the process of evaporation from the outer surface of the earthen dishes those solid matters would be either chemically or mechanically retained in their clayey filter. The assamee practice, on the other hand, greatly reduces evaporation from the drug generally, and in exposing but a small surface to the earthen pot, promotes atmospheric evaporation, in which the loss is simply in moisture, the extractive matters and alkaloids being wholly retained. It is thus, as I believe, largely if not solely due to the above-noted differences in the preparation of the drug that, the samples prepared under my direction as compared with those of the assamees, prove relatively so very poor in extractive matters. The use, however, of porous earthen pots by the assamees must necessarily entail a certain degree of loss in extractive matters and alkaloids, which could be easily obviated by the use of glazed earthenware. It would only incur some little more care in the manipulation of the drug to drain it, of superfluous moisture and pussewah. I certainly do purpose next season preparing the whole of the drug in the gardens under my charge in well glazed earthen pans, fully confident that I shall thus produce drug no way deficient in the above matters.

4.—"After collection," remarks Pereira,—"the masses of tears are either worked up into a homogeneous mass in a mortar or otherwise, as in Egypt and India, or the separate portions are merely put together, as in Asia Minor or Persia. In the latter case, opium when examined by means of a magnifying-glass is seen to be composed of agglutinated tears, and may be termed *granular opium;* in the former the opium appears perfectly homogeneous, and is called *homogeneous opium.*" The differences, as above pointed out by Pereira, are largely dependant in the first instance on the minuteness of the network of milk-vessels in the capsules, and secondly, the degree of atmospheric humidity. Thus, when the network of milk-vessels is very minute, and the atmosphere at all humid, the oozings from each vessel at once unite, and a thin film unites all, thus affording a cord of homogeneous opium. On the other hand, in a dry atmosphere, and especially when the vessels are sufficiently disconnected (as they frequently are), to exhibit in the first instance distinct drops, the ultimate amalgamation of these is much less perfect and we have then a drug of a less or more distinctly granular character. The texture of the drug, as defined by Pereira, is thus largely dependant on the degree of atmospheric humidity, obtaining when the capsule is being scarified. The ultimate manipulation does not materially affect it, if not subjected to any form of sophistication. The use of oil and saliva affects the aroma of the drug, the former especially so, while also giving it a waxy colour and texture; whereas the latter tends to lighten its colour, and in this respect improve its appearance. As disguising certain adulterative matters, *saliva*, as I will subsequently show, is an excellent adjunct in the sophistication of the drug.

5 The *natural and adventitious impurities* of the drug now call for a brief notice. The latter fortunately are never in sufficient excess to cause any serious or appreciable deterioration of the drug, in so far as regards its physical characters, but this much cannot be said as to the former class, which are the direct results of certain atmospheric conditions on the milk-juice. The most serious depreciating product is that familiarly and not inaptly termed *pussewah*—from the Urdu term *pussina*, purification—*i.e. opium sweatings*, if I may be allowed a literal translation. This we will first notice.—*Pussewah*, as naturally filtered from the drug, much resembles liquid tar, or the partially inspissated sap exudings from the stem of the '*Tal*' (*Borussus flabelliformis*). It is facilely soluble in water, the infusion affording a distinct acid reaction on litmus. Dr. Sheppard, Principal Assistant Opium Agent of Benares, very kindly made an analysis of two samples of pussewah, and also gave me the results of analyses by Drs. O'Shaughnessy and Eatwell, while Examiners of Opium in the Patna and Benares Agencies. They are as follows:—

Analyses of Pussewah.

	Consistence.	Extractive matter.	Morphia.	Narcotine.	
(1)	... 64·0	50·0	0·5	1·25	... O'Shaughnessy.
(2)	... 85·5	...	2·12	3·38	... Eatwell.
(3)	... 84·75	55·13	1·47	0·9	... Sheppard.
(4)	... 78·75	48·78	1·84	1·87	... Sheppard.

(*a.*) The first of the above analyses is by Dr. O'Shaughnessy, the second by Dr Eatwell, and the third and fourth by Dr. Sheppard. Besides the above (*i.e.* morphia, narcotine, and extractive matter), pussewah contains meconic acid, resin, and gum mucilaginous matters. The latter probably in higher proportion than pure opium, as Dr. Eatwell observes that "when opium contains much pussewah, the marc is diminished in bulk, loses to a certain extent its loose, granular texture, becomes more compact and viscid, and assumes a dark brownish-yellow colour." In good opium it varies from dull yellow to clear gamboge. As compared with opium, pussewah, judging from the above analyses is poor in morphia and narcotine, and though presenting a few degrees excess in extractive matter according to Dr O'Shaughnessy, the later results of Dr. Sheppard's analyses really show that the standard provision drug is the richer of the two in extractive.

(*b.*) In the absence of anything like an exhaustive analysis of pussewak, we can but crudely guess as to its true nature and origin. Humidity of the soil or atmosphere are the conditions favourable to its production, and this is doubtless correlated with some peculiar chemical condition of the milk-sap. For example, an excess of carbonic acid, or carburetted hydrogen, and ammonia or nitric acid. Segregated as it always is when respiration is low, it is probably directly caused by the accumulation of watery fluid in an undue proportion in the milk-sap. The results in this respect are very similar to what obtains in the milk and blood of animals (though in neither, as in the above, has any peculiar segregation been observed), in which it has been observed that water in undue proportion accumulates from diminished perspiration in a cold or damp atmosphere, as also by drinking it in excess and by refraining from accustomed exercise.

(*c*) The adventitious matters with which the drug is, practically speaking, unavoidably contaminated, are atmospheric matters, the outer coatings of the capsule, and the abradings of the drug-collecting scoop. These matters are generally present in the best commercial drug to the extent of from 2 to 4 per cent., and indeed, considering the frequently prevailing strong westerly winds and the dust-laden atmosphere during the collecting period of the Indian drug, the wonder is that it is not much more largely contaminated. As regards capsule impurities, those varieties of the poppy called by the assamees *subza* or green-headed of course afford the purest drug. The glaucous or white-headed—as due to a coating of fine powdery matter which is unavoidably collected with the drug—giving it of less purity. Pollen-grains of the poppy itself and other plants are always present less or more, as are also parts of the stamens which frequently adhere to the capsule. If a little care, however, be observed by the collector, the latter matters may be easily avoided. I will here but notice one other of the all but unavoidable adventitious matters found in the drug. This is *iron*. The presence of this metal in the drug is of course due to the wearing of the implements (the *nushtar* and *setwah*) used in scarifying the capsule and collecting the drug. The hard, silica-coated capsules in the course of a single season cause a very perceptible, and indeed frequently striking abrasion on the collecting-scoop or *setwah*. Obviously, then, such impurities as the above are really practically unavoidable, but fortunately they never occur to such an extent as to cause any appreciable deterioration of the drug.

6. We will now pass on to adulterations properly so-called. These are an extensive class, and I regret that I can but imperfectly illustrate them. Many of the ordinarily recorded adulterative matters are extremely clumsy and readily detectible by a merely mechanical examination of the drug, while others of them again, though troublesome to detect, are so extremely light, that I do not at all see how they can in any way recommend themselves to the adulterator. The above classes I will first notice. These are gravel, chips of pottery, sand, clay, cowdung, partially pounded or entire seeds of the poppy, and the like. A mechanical analysis will readily betray all such matters. For this purpose the only requisites in addition to those already supplied to the officers of the department for the examination of the drug, are *two sieves of brass-wire gauze, with meshes of one-fortieth and one-fiftieth of an inch respectively, in the side of the square.* The first will retain all the more bulky of the above, the second the finer grained, while the finest particles will pass in the solution, subside more or less

quickly, and form a residuum for examination. Each of the three *residua* are thus of easy examination with a microscope or magnifying lens. This would be found a more satisfactory process than that ordinarily adopted of filtering with Nepal paper, where all such matters get mixed together with gum, resin, &c., and are troublesome to examine. The process I recommend is simply this: prepare with boiling-water a solution of the suspected drug. Place the fine-meshed sieve on a common porcelain basin, with the coarser meshed sieve resting on the former; then see that the drug has been thoroughly broken up and all matters in solution or suspension; pour then the liquid into the upper sieve, allow the matter to strain a little from both sieves and remove for examination. This completed, the solution may next be decanted from the porcelain basin, and the residue examined under the microscope. It may consist of fine sand and mud, the bulkier matters being retained on the sieves. The pounded parts of the poppy and other plants will also be largely revealed amongst the matters retained by the sieves, unless they have been previously fermented or thoroughly macerated, when chemical reagents are alone of avail. With the exception of the latter matters, all the others above noticed are plainly very clumsy modes of adulteration, and, as I am inclined to think, *when present* are more likely to have been *accidentally* than *intentionally introduced.*

(*a.*) Much the same may be said of such light matters as pieces of paper, cotton, and other fibres; soot, charcoal, and burnt opium. Plainly, to give any appreciable return to the adulterator, these matters would need to be introduced in too large quantities for all but the veriest fool to use them, and in my opinion may be safely passed over as accidental adulterative matters. Anyhow, when present, all would be more or less perfectly revealed in the above filtering process.

(*b.*) Before proceeding further on the subject of adulterations, it may be as well to notice a few of the chemical characteristics of the pure drug. The odour, texture, colour, and fracture, are characters which readily betray the sophisticated drug to a practical examiner, though on these characters only, unless the adulteration be of a very gross nature, the drug should not be condemned without a chemical examination: carelessly prepared drug of low consistence having not unfrequently all the appearance of an adulterated article, though proving quite free of such when subjected to chemical tests. In *Farre's Abridgement of Pereira's "Materia Medica,"* opium is thus characterized:—"When fresh plastic, tearing with an irregular, slightly moist, chestnut-brown surface; shining when rubbed smooth with the finger; having a most peculiar odour and nauseous bitter taste." The watery infusion of opium acquires a deep red colour when treated with perchloride of iron, while nitric acid communicates a pale, almost carmine, red, though somewhat disguised if pussewah is present in any quantity, the infusion then acquiring a less or more distinct tinge of brown according to the degree of admixture. We will now pass on to the drug in its adulterated state.

First, for the *farinaceous* adulterations, comprising *starch, sago, tapioca, cassava, arrowroot, salep, and dextrine,* all of which are more or less used in the sophistication of the drug. . . . . . . Though the majority of the starch series are easily detected when mixed with opium in the normal state, they are, perhaps, more largely used by the adulterator than any other vegetable matters. Moreover they are of a most objectionable nature, as inducing fermentation, and thus rendering the drug perfectly worthless. Starch admixtures, however, are patent to the practised examiner by the fracture of the drug, which, relatively to that of a pure sample, is *smooth* and *stringy*, and but slightly, if at all, granular. Again, by placing a small portion of the suspected drug between a pair of microscopic slides, and rubbing them firmly together, the presence of starch is readily observed on placing one of the slides under the microscope. Many other adulterative matters are also readily detected by the microscope—gum and fatty matters, for example—by their different refractive powers. In the starch examination the usual mode, as described by Dr. Eatwell, is to weigh out one ounce of the suspected drug, place it in a copper saucepan, add three fluid ounces of distilled or rain-water, transfer to the stove, stirring constantly until the whole of the drug is broken up and the mixture boiling. It must be allowed to boil for five or six minutes. The decoction is then filtered, and, when cool, treated with tincture of iodine. From pure opium the precipitate will be of a light orange or orange-yellow colour, but should it form a green or blue compound, the presence of starch is indicated; the former colour being indicative of a weak adulteration, the latter of a stronger one.

The starch examinations might, as I think, be greatly facilitated by treating the watery solution with dilute sulphuric acid, instead of the comparatively tedious process of boiling the drug. By this means examinations could also be completed under the eye of the Sub-Deputy, and this is of great importance. Aside from the greater facility of the *sulphuric acid and iodine test*, the danger of neutralising the iodine test by the *over-boiling* of the decoction is obviated. Of course, in introducing the other mode of examination to sub-divisional practice, the degree of dilution of the sulphuric acid must in all cases be carefully tested by the Principal Assistant, otherwise the test might be much more effectively frustrated than is at all likely to be in the preparation of the decoction: sulphuric acid, as also solution of potash, as is well known, readily resolving starch into dextrine and sugar, and thus altogether disguising their normal re-action. This, however, can readily be obviated by the testing of the acid, as suggested by the Principal Assistant, before distributing it for district use.

We have seen that the iodine test altogether fails when starch is subjected to a degree of heat sufficient to change it into *dextrine*. Let us then treat of the examination of opium thus adulterated. Commenting on the farinaceous class of adulterations, Dr. Corbett observes "that even by the common boiling which such roots undergo in the hands of an ignorant cultivator previous to mixing them up in his opium, the iodine test may, in *nine* cases out of *ten*, be frustrated by the starch being thus changed into dextrine." Under such circumstances Dr. Sheppard, of the Benares Agency, continues:—"That the microscope is our only safeguard. When skilfully used, its results, taken with a marked diminution of the relative amount of alkaloid, are reliable."—What, then, it may be asked, is the nature or chemical constitution of *dextrine*? Now starch, as we have seen, is not chemically an individual substance, but consists of two independent substances (*isomeric*), one of which, *granulose*, is soluble in saliva, is tinted by iodine, and is dissolved by weak solutions of chromic acid; and the other, *cellulose*, is not affected by saliva or iodine, and is soluble in solution of cuprate of ammonia, but not in chromic acid solution. These two elements of starch exist in definite layers in the grain. . . . . . . *Dextrine* is composed of carbon, with hydrogen and oxygen in the same proportion as water. Its chemical composition is exactly that of starch, the difference between them consisting entirely in the grouping of their molecules. It is derived from starch by heating it to 400° Farenheit—that is, by converting starch into *British gum*, a well-known substance which is found to be identical with *dextrine*. Again, starch is insoluble in cold water, forming a pasty compound when boiled, whereas dextrine softens like gum in cold water. From the latter it is again readily distinguished by its conversion into sugar when treated with sulphuric acid, whereas gum is not thus convertible. Again, admixtures of *gum* and *dextrine* are readily distinguished by treatment with potash and sulphate of copper; the latter admixtures giving a blue re-action, and a precipitate of sub-oxide of copper on boiling the solution, while gum yields no such results. Opium, adulterated with dextrine, has also a smooth, stringy fracture, the solution filtering very slowly, or not at all, if largely adulterated. Again, a solution of opium adulterated with dextrine, heated with potash, acquires a light-blue colour on the addition of sulphate of copper. Dextrine as above, in the watery solution, is also separated by the addition of alcohol. It may here be observed that the adulteration of opium with dextrine is much less objectionable than starch—the former not fermenting, as the latter readily does when thus mixed.

Dr. Sheppard has well remarked (*vide* "Rules for the Guidance of Officers in the Opium Department," Appendix D), that, in entering at length into the nature of the adulterations of opium, the main object has been to show "that the cultivator is not always to be relied on to supply a pure drug, unless he knows that there is a searching examination. From the nature and variety of the adulterations, it will also be evident to any one that the cultivator is by no means the simple, uningenuous individual which he has been described to be by some who have visited India, and but imperfectly acquainted with him. He is, on the contrary, generally a very shrewd man, and, whether accidentally or intentionally, he can adulterate his opium in such a manner as to render detection in many cases difficult." As bearing on this, it is a curious and interesting fact that the native cultivators of opium, particularly those in Asia Minor, have a habit of working up their opium with *saliva*. It has only lately occurred to me that the use of saliva is not altogether objectless. Anyhow, it is a somewhat singular coincidence that starch thus treated gives little or no re-action with *tincture of iodine*, and it is curious to remark how frequently the discoveries of science have been directed or anticipated, or found to comprobate, with the intuitions of Nature. . . . . . . I can scarcely believe that the native cultivators are at all aware of the disguising nature of saliva on starch-adulterated opium, as it has only recently been observed by scientific men in Europe, the first of whom I believe was Nägeli. He showed that prolonged treatment with saliva removed the matter coloured blue by iodine, leaving the granule with its striæ more distinct and capable of resisting acids and alkalies—*vide Art.* "*Starch,*" *Micrographic Dictionary.* Again, physiologists have been long familiar with the fact that starch, when mixed with saliva and kept at a moderately high temperature, is rapidly converted into grape sugar, thus again utterly defeating the *iodine* test. I may remark in passing that, in my experiments with salivated starch, I have been much struck with the differences in the chemical re-actions of European and Native saliva. Thus, while starch mixed with European saliva, and treated with sulphuric acid, gives a less or more bright rosy tinge to the solution, that treated by Native saliva is of a pale dingy green. This is no doubt due to difference in the food-stuffs of Europeans and Natives. I merely allude to it here, as, not having observed it noticed in my limited physiological readings, and considering the functions of saliva in the animal economy, such distinctions must certainly have important pathological and therapeutical bearings.

Gums and vegetable mucilages are, I believe, largely used by the assamees for the adulteration of opium. The gums present themselves in two well-marked series, one of which, the *arabine,* as being soluble in pure water (as also in dilute acid, but not in alcohol or ether), and as being chiefly used by the opium adulterator is alone worthy of notice here. The following are a few of the more commonly used forms:—Gum-arabic, as procured from various species of acacia: that surrounding the seeds of the bael fruit (*Œgle marmelos*), and the gum kino, a product of the bark and leaves of the *Pterocarpus marsupium*; while of mucilaginous matters we have such abounding in various species of malloworts (for example, the *ramturay* or *dhenroos* and the *kal-kusturee)*—*Hibiscus esculentus* and *Hibiscus abelmoschus*—as also that of the linseed, the meal of which abounds in mucilage. The admixture of gums and vegetable mucilaginous matters with opium greatly increases its natural adhesiveness, and gives it a smooth and somewhat waxy texture and unnaturally stringy fracture. Gum-adulterated opium is readily detected by the sub-acetate of lead. Thus, prepare a watery solution of the suspected sample, add solution of sub-acetate of lead, and if gum is present it will be precipitated in the form of an opaque white jelly. Alcohol or spirits of wine in excess gives a flaky precipitate of gum: a distinct curdy precipitate of *arabine* and *protoxide of lead* is also afforded by treating solution of arabine (adulterated sample) with ammoniacal acetate of lead. The mucilages of *linseed, dhenroos,* &c., which also contain a considerable percentage of *bassorine* (a modification of *arabine,* insoluble in cold water, but forming a gelatinous mass when moistened), are, I suspect, largely used in the adulteration of opium, as they scarcely at all affect the physical characters of the drug. They are readily extracted from the seeds and seed-vessels by boiling water, and are then, probably in a concentrated state, mixed up with the opium. The presence of these mucilages is, however, readily betrayed by treating a decoction of the suspected sample with alcohol. If mucilage is present, this will at once give a flaky precipitate of white mucilaginous matter. As in the case of the gums, the sub-acetate of lead also gives a precipitate.

We may now pass on to that series of adulterative matters containing tannic acid, as the *pale* and *black catechu*, &c., the *Uncaria gambir*, and the *Acacia catechu*. The presence of catechu, or any other matters containing tannin, is readily detected by treating a solution of the suspected sample with *perchloride of iron*. Tannin, if present, gives a *deep black colour* to the solution. The presence of tannic acid in the solution may also be betrayed by treating it with strong sulphuric acid, the re-action with the tannic acid being a deep purply-black.

Saccharine matters, remarks Dr. Sheppard, "form a dangerous class of adulterations, inasmuch as they can be added in considerable quantity without materially altering the appearance of the drug to the eye—in fact, as Dr. Eatwell observes, its colour will improve if previously dark from *pussewah* admixtures." The latter authority, commenting on this, says that "a sample of opium containing *goor*, if dried on a plate in the manner followed in assaying opium, will emit a sugary smell, and the residue, instead of forming a yellowish-brown powder, will remain dark and sticky, and at last form a *hard cake*." An adulterated (sugar) solution of opium, when treated with strong sulphuric acid, gives a powdery precipitate of a blackish-brown colour. Under this head I may also notice the *wild liquorice-root*, the Rosary-pea of Europeans, and the *koonch* of the natives (*Abrus precatorius*). This is an extremely common plant in the opium districts as elsewhere in India, and much more likely to be used for sophisticative purposes than the pomegranate root and many other substances recorded in our opium adulterative treatises. It has long, slender, and branchy roots, which, by boiling, give a molass-like sweet and mucilaginous syrup. It differs from cane sugar in not crystallizing, nor fermenting when yeast is added to it, and unless specially examined for is not likely to be detected. In examining for this substance the solution may be treated as above for gums and mucilaginous matters. It is also precipitated from a solution by the addition of sulphuric or nitric acid.

Oils, ghee, and the like, though clumsy, do, it appears, form not unfrequent adulterative substances. Dr. Eatwell, treating of the examination for those matters, says:—"Dry a small portion of the suspected drug in a plate in the manner followed in assaying opium, and if either are present, the residue, instead of appearing as a dry powder of a yellowish-brown colour, is oily, or greasy, or almost black." The oily matter may also be readily extracted from the sample by treating it with *ether* or *bisulphide of carbon*, filtering the solution, and evaporating the solvent, when the oil or fatty matter will alone remain.

The milky juice of various common *Fici*, for example, the bhut or banian, the pippul, the pakoor, the goolur, representing, respectively, the *Ficus indica*, *Ficus religiosa*, *Ficus venosa*, and *Ficus goolerea* of the botanist. Another is the Mudar, or *Calotropis gigantea*. All of these, as it appears to me, are most unlikely adulterative matters; the latter particularly so, on account of its rancid and peculiarly offensive smell, which would at once betray its presence. If ever used, as containing tannic acid, it of course may easily be detected as above. As to adulteration of the drug with the milk-sap of the *Fici*, chemical tests are altogether unnecessary, this being readily detected by the extreme adhesiveness and stringy fracture of the drug. Moreover, adulterations with the juice of the *Fici* could only be made immediately or shortly after it was drawn from the tree, as it would be impossible to mix the drug with the caoutchouc when '*set*' in its watery solvent. This it does very rapidly when exposed to the air. From the very large percentage of water, the peculiar and strongly adhesive properties of this substance, I can scarcely think that any of the assamees would be so very foolish as to mix his drug with either this, or the preceding plant's juice.

Turmeric deserves a passing notice, as being used as an adulterative colouring matter. For this adulteration Dr. Sheppard recommends microscopic examination of the suspected drug. We have, however, a simple and effective chemical test: this is simply to treat a decoction of the suspected drug with boracic acid, and if turmeric is present, the re-action will be of a dull red colour, while a pure opium solution gives no re-action.

Earthy and silicious matter are thus referred to by Dr. Sheppard:—"This division comprises sand, powdered bricks, impure carbonate of soda, &c. These are detected by the alteration in the smoothness and translucency of the opium when spread out into a thin layer. The insolubility of all of them in water (except the soda salt) enables them to be separated and examined." With reference to these, I need only observe here that nearly all may be readily detected by a mechanical analysis, as suggested in a previous paragraph of this chapter. As to the adulterations with carbonate of soda, Dr. Sheppard continues:—"It is detected by the peculiar smell which it gives rise to in the opium, as also by incineration." It may also be readily enough detected by making a solution of the suspected sample and treating it with muriatic acid, when, if present, there will be a more or less tangible effervescence.

In concluding this *resumé* of opium adulterative matters and modes for their detection, I would specially recommend attention to the mucilaginous and albuminous or protein classes as the most likely substances to be used by the '*shrewd*' assamee. All abound in his commonest vegetable food-stuffs (as in the "dhenroos," and other mallows, linseed, &c., of the first group; and of the latter the sap of the yams or *aloos* of the natives; turnips—*selgums*; the radish—*moolees*; and the various species of the cucumber class—*torooee* or *torai*, the *kudoo*, *koomra*, &c., &c., easily expressed and reduced to an adulterative state by boiling; while again the solutions obtained from peas and beans—the *mutturs* and *seems* of the natives—are likewise rich in readily-available albuminous matters). These, as I have remarked, are the matters chiefly to be guarded against, and the first, as we know, is readily betrayed by treating suspected samples with subacetate of lead or alcohol; the latter by strong vinegar, diluted muriatic or nitric acid, which readily cause coagulation and precipitation of such matters from the solutions of adulterated drug samples.

CHAPTER XX.

THE SELECTIVE IMPROVEMENT, &c., OF THE POPPY, AND THE STORING OF ITS SEED.

In the improvement of the poppy as a drug-yielder, regard must first be had to the capsule, as the main reservoir and direct supplier of the crude opium. . . . . Now, as we all know, it is only by the strictest adherence to the principles of selection that such great improvements have been attained in the breeding of animals and plants. The breeder has an eye to the particular parts or qualities which he would wish to develop, and always selects from successive generations the most strongly characterized. It is thus that our cereal-growers get an increased size and improved quality of grain, and in attaining these objects they find it necessary to select the grains separately: they do not effect their purpose by simply choosing the best or largest ears. In wheat, for example, Mr. Darwin—commenting on the principle of selection—states that Colonel LeCouteur, in his persevering and successful attempts to raise new varieties by selection, began by choosing the best ears, but soon found that the grains in the same ear differed, so that he was compelled to select them separately, and each grain generally transmitted its own character. . . . . . The sugar-yielding varieties of the *beet* afford a most interesting example of improvement by the pedigree principle. Thus, Vilmorin (who has been the most successful improver of the beet), finding that the specific gravity of the root-juices indicated its richness in sugar, had a set of delicate instruments prepared for its exact determination in the roots of each plant set apart for seed-bearing. The roots were first selected according to the best ordinary rules, then a small portion of each was punched out in such a part of it as to injure as little as possible its future growth; the pieces were then reduced to pulp, and the juice was extracted. All roots not yielding juice up to a certain standard were rejected, and those which attained the standard were planted for seed. The roots produced from this seed were found to be constantly increasing in richness, and a few years' continuation of this selective process has, in certain instances, *trebled*, and on the average *doubled*, their yield of sugar. I will but give one other illustration of the application of the selective principle. It is afforded by the *cotton plant* . . . . . . The Sea Island cotton of Georgia is the most highly improved of the many cultivated varieties, and distinguished by the great length and silky softness of its staple. It is indispensable for the spinning of the finest sorts of thread. The filaments occasionally exceed two inches in length, and are very generally about three times longer than the indigenous varieties of India. Dr. Ure thus writes of it on its first introduction:—"The first samples of this cotton when sent to the market sold for *six dollars and seventy-five cents per pound*, while the ordinary Sea Island brought only about *thirty cents!* The growing of it was for some time kept a secret, and even in 1831, when Dr. Wardeman visited Madmalan Island, where it was originally raised, the fields in which it was grown were guarded in harvest time to prevent the stealing of the seed, *three quarts* of which have been sold as a favour for 150 *dollars*. It is chiefly distinguished by its large, bright, yellow flowers and lengthy staple. It is by the latter character that the best plants are recognized, and from which the best seed is selected for sowing the ensuing crop. It has been observed that, unless this selection be carefully made, the cotton readily deteriorates. It is also stated, on the authority of an eminent cotton-grower, that the top capsules of the cotton plant afford the finest seeds, and are selected, by the most skilful planters of the Sea Island districts, for the annual improvement of the staple. Thus, as I have elsewhere remarked, by a mode strictly analogous to that which I have recommended for the improvement of the poppy as a drug-yielder, do we find the cotton-grower raising and maintaining a high excellence in the varieties of the cotton plant. The wonder is to me that the principle should not have been adopted years ago in the produce of such a valuable drug as opium, and one which has had for years back an increasing annual consumption. Thus the demand for Indian opium in China alone has increased from 3,210 chests in 1817, to 9,969 chests in 1827, to 21,437 in 1846, and to 56,061 in 1866. I have, nevertheless, for three seasons past ineffectively urged the adoption of the selective principle, simple and inexpensive though the process is. I will now describe it.

2. Guided by analogy, it very naturally occurred to me, in observing the great variability in the drug-yielding quality of different plants in all the cultivated varieties of the poppy, that much good would result from a careful selection of seed from the most copious drug-producing plants. I at once put it in practice in the experimental gardens under my charge. Overlooking, however, the fact of variability of the several capsules on each plant, the results were not striking: indeed largely neutralised, just as in the case of our cereal improvers in beginning to select the best and largest ears, without attending to the individual grains. I have obviated this in practice now by grading the capsules on each plant: thus, my best seed is the produce of the primary or central capsule of each plant bearing a *minimum* of from *five to six copious* drug-yielding incisions. The second-class seed is the produce of lateral capsules bearing a *minimum* of *four* copious drug-yielding incisions, while the seed produce of the remaining—be they *central* or *lateral*—capsules, with a *maximum* of only three drug incisions, are utilised solely as oil-yielders. These, then, are the simple principles observed in the selection of the capsules; the general practice of which, I may remark, would not incur on the assamee more than a half hour's extra labour per beegha. Let us make this point clear. Thus, for each beegha of land, from three to four seers of seeds only are required, and this would on the average be afforded by from 50 to 60 capsules of 80 tolahs per seer, allowing 1,000 *grains* per capsule—a low average I may add. The labour, therefore, need scarcely be grudged. The above, or say 100 capsules selected for the seed-supply of each beegha, should be *exclusively the central or primary capsule of each plant*, these being invariably the best, and, in the case of the assamee, will afford all the seed he requires. In selecting the lateral and inferior capsules from my own crops as above, I do so to get a supply of seed (*superior* to the common or

unselected seed of the assamees) for district distribution. Again, considering the small number of capsules required to afford a sufficiency of seed, a *high minimum* of copious drug incisions should always be observed by the assamees in the selection of the capsules. In no instance should this fall below *five*; and in general, I do think that each assamee might easily obtain a sufficiency of seed for his requirements from *central capsules* bearing a *minimum* of from *six to eight copious* drug-yielding incisions. I will not dwell further on this, however, but only again strongly urge that, in the first instance, the practice should be slightly enforced on the assamees. They will soon learn to appreciate it, should it only be *honestly* observed by a few, and the trammels of a time-honoured practice will thus be most effectively broken.

(*a*)—We will now pass on to the seed.

The selection of the seed, as I would now recommend, is unfortunately not quite so practicable (considering the social position of the great mass of the assamees) as that of the capsule. It is none the less, however, well worthy of practice as an auxiliary to the selection of the capsules, which is unquestionably of paramount importance. In the experimental gardens under my charge the practice now is to sow chiefly those seeds (from even the selected capsules) that are retained by sieves, with meshes of the $\frac{1}{22}$nd of an inch on the side of the square. I should add that the *bulk* of the seeds of the several varieties now pass the above sieve, but I shall endeavour to get a sufficiency of such for my next season's sowing. For general use, *i. e.* where there may be a desire to try the experiment amongst the assamees, sieves with meshes of the $\frac{1}{27}$th or $\frac{1}{30}$th of an inch on the side of the square should, in the first instance, be used. So far as my experience goes, seeds—of which there are not a few—caught in sieves of the $\frac{1}{30}$th and $\frac{1}{40}$th of an inch are really of little or no value for cropping purposes.

3. It may occur to practical agricultural readers of this treatise that, in recommending mere *bulk*, I am overlooking a more important property, *i. e.* the specific gravity of the seed. Not so: I have made comparative trials, and find that the heaviest seeds (which, by the way, I may state are generally found amongst the smaller-sized class) are not a whit more productive than those retained by the $\frac{1}{30}$th of an inch sieve. Bulk of seed, and not its absolute weight, would thus appear to be the criterion of the seed in a drug-producing progeny of the poppy; such, at least, is my experience. Moreover, it is interesting to observe that the plants from the larger-sized seeds yield considerably more bulky capsules, and these yield relatively a larger quantity of drug. Thus, to illustrate: the results of experiments with *mixed seeds*, and the *large and small-sized seeds* of the same sample, were as follows:—

Large-sized 100 to 61·54 small-sized.
Ditto 100 to 76·92 mixed seeds.

It will thus be seen that the large-sized seeds give rise to a considerably higher productive progeny than either the smaller-sized or mixed seeds, the relative differences in the former being as 1·68 to 1, in the latter as 1·30 to 1. Plainly, therefore, the larger seeds afford the more copious drug-producing progeny; and this, again, is the result of the capsules being of a more uniform and decidedly larger size. It is worthy of remark, however, under this head, that the smaller-sized seeds germinate, as a rule, a few days earlier than the larger. As one of many correlative phenomena between the animal and vegetable kingdom, this is noteworthy as presenting an analogy with the process of incubation, it having been asserted that eggs of small size are hatched within a shorter period than those of a large size (*vide* "*Origin of Species*," *by C. Darwin, 6th Ed., p.* 213). I should add, however, that the small-sized seeds do not produce a more vigorous progeny; and, as regards opium produce, I have shown that they are really less productive than those of large size, inasmuch as giving rise to a progeny bearing smaller-sized capsules.

4. The comparative produce of seeds from selected and unselected capsules may now be specially illustrated. This, for facility of comparison, I present in a tabular form,—*vide* appendix, tables *A* and *B*.

The tabulated results in the case of the seeds from the selected capsules are from the gardens under my charge, whereas those from the unselected are from the neighbouring assamees, who, I believe, are among the best poppy-culturists in the Patna division. I have, however, thus limited my comparative statement, so that the results might not be affected by differences of soil or weather—both factors of the first importance in such comparative tabulations. Differences in the results are thus fairly attributable, as I think, to the quality of the seeds. Let us note them. Mould-blight caused serious injury to the crops early in the season of 1874-75, and consequently lowered much the normal outturn of the drug. The selected and unselected seed-crops, as being similarly affected, are however fairly comparable. Now, in the case of the Metapore gardens, I had as a general average from 13 *beeghas* 4 *seers* 7½ *chittacks per beegha*, whereas that of the neighbouring assamees was only 3 *seers* 4 *chittacks*. Again, in the tabular illustration of the produce of those lands, the returns are 5 *seers* 1¼ *chittacks per beegha*, which is 1 *seer* 13¼ *chittacks* in excess of the assamee average. The Deegah returns afford a still more favourable comparison.

The superiority of the selected as compared with the ordinary unselected seed crops is well borne out by this season's results—*vide* table *B* of Appendix. The general average of the 13 beeghas of land under my charge at Metapore was 9 seers 6 chittacks per beegha, whereas that of the 21 assamees on the surrounding lands was only 5 seers 7¾ chittacks. Again, the *maximum* produce of the assamees was 11 seers 13 chittacks, whereas I had in two instances over 15 seers, and others exceeding 12 seers. I need not dwell on the details, however, as all is clearly enough set forth in the tables. I will only add that, in making such comparisons as the above, certain important facts are too frequently overlooked. Let us note them: thus, an opium crop differs materially from all other ordinary crops in the amount of nicety or care required in its extraction and collection. Indeed, on this all depends; a careless scarifier may, as it happens, either cut too deep, and permanently injure the capsule, or, on the other hand, over-superficial, so that little or no drug exudes, and a collection is thus lost. Again, in the collecting, if every care is not observed, very great waste may occur. In both respects, I know from experience that very much does occur when performed by *hired labour*. The assamee and his family, on the other hand, have their heart and soul in the work; scarifying and collecting with the greatest care, until the last drop of drug in the plant is exhausted and collected. Little auxiliary labour is engaged, and when so, it is by those who, through their social position and relations, have sufficient moral control over their labourers to ensure an honest performance of the work. * * * Had the above operations been thus honestly conducted throughout the gardens under my charge during the past season, I feel convinced, from careful personal observation, that I would at the very least have had *one-third* more opium, and quite as high an increase in seed. An interested supervision of such works is, indeed, a trial to the temper; I have felt it; but with only a limited amount of labour, I could but ill afford to make examples by dismissal; even that, however, is wholly ineffective: the manipulation of the capsule and collection of the drug are plainly and altogether operations requiring a hearty subserviency on the part of the employé, otherwise, and particularly with European employers, there is really little chance of their being at all honestly performed by the available class of native agriculturists. This careless and even mischievous performance of the operations of tapping and collecting drug is, and will be, the grand difficulty in showing the normal drug-yield of my selected crops.

5. The interchange of seed deserves a passing notice. It is a general and apparently well-founded belief that the vigour and fertility of all annual plants are less or more largely promoted by occasionally exchanging the seeds of one locality or district with that of another, and, on the other hand, that the continued use of the home-grown seeds on the same plot of land has—even as *in-and-in breeding* in the animal kingdom—a markedly deteriorating effect. This is doubtless largely true under ordinary cultural conditions; but I am, nevertheless, strongly of opinion that, if the plant be adequately supplied with its mineral and organic constituents, it may be successfully cultivated on the same plot of land for an indefinite period. As it appears to me, the failing of any particular crop, in a locality where it has hitherto flourished, is wholly attributable to failing supplies in one or more of its essential food-stuffs. It may be asked how, on this assumption, can the well-known fact be explained of the perfect success of the same crop raised from seed imported from a different locality. The explanation, as it appears to me, is simply this: first, as to the failing of the indigenous crop. Well it will, I think, be readily admitted that comparatively few of our agriculturists or horticulturists—Indian of course—give themselves the slighest concern about the selection of seeds; those intended for the subsequent season's sowing being as a rule taken without discrimination from the bulk. Indeed, in the home garden the practice is only too common to reserve for seed purposes the produce of the weakest plants. Now, by such a practice we are plainly accelerating the deteriorating influence of the soil. Thus, assuming that the failing vigour and fertility of the crop is due to a failing supply of certain more or less essential food-stuffs in the soil, the *very fact* of selecting seeds from the *weaker plants* must intensify the evil, inasmuch as we thus *use seeds from plants least adapted to the changed and changing conditions of life*. On the other hand, it is easy to see that, by a careful selection of seeds from the most vigorous and highly fertile plants from season to season, we might successfully continue the crop for

many more years, inasmuch as we thus successively secure the progeny of those best adapted to the changing conditions of growth. Let us now have regard to the success of the same variety, from another district's seeds, on lands on which the hitherto flourishing home seed has gradually failed. The explanation, as I have elsewhere stated, is again clear: it is not of one or two, but many, substances that a plant builds itself up, one or more of which are of primary importance, the others less so, but nevertheless each having its own definite value in the vital economy of the plant. Let us take, as a special illustration, the poppy, which, as we know, is a *potasso-lime-loving* plant. Well, we can easily understand that where there has been for generations back a failing vigour from an inefficient supply of lime, that to again re-invigorate our crop we have only to place it in conditions where it is afforded a sufficiency of that food-stuff. Again, seeds from an adjoining district having had an adequate supply of lime would doubtless succeed on the above soil for a certain number of seasons, as being in full vigour, and not having hitherto suffered from its want. This is an extreme case, however, and such failures of crops as those under consideration is rarely due to a failing supply of one, but of many, of the mineral food-stuffs. It is thus easy to see how largely reciprocal exchanges of seeds from different districts may *temporarily* tend to promote the vigour and fertility of our crops. I have said that the vigour and fertility of our crops may be thus *temporarily promoted*; for it is well known that we must keep up a periodical exchange, there being a reciprocal deterioration of the crops, which can only be attributable to a deficient supply of certain mineral food-stuffs, and that these are different in the respective localities. For example, a *lime-potash* and *soda* plant finds in the locality an abundance of the two former minerals and a deficiency of the latter, whereas in another locality lime is the deficient mineral. Now under such conditions we can easily understand how crops may be benefited by reciprocal and periodical interchanges when thus sickening and deteriorating for a particular food-stuff in their own locality which is supplied in that to which they are transferred.

(*a*)—The assamees, as a rule, are somewhat chary in the mutual exchange of seed, each preferring the produce of his own lands, and having but little confidence in that from other districts. I have been surprised with this, as they have a simple, but really effective, test for the germinative quality of the seed. This is by simply sprinkling a sample of the seeds on embers, when, if good, they decrepitate freely, whereas if bad, or of low germinative quality, they simply deflagrate, or burn less or more slowly. This is an efficient and ready test. Local and divisional exchanges of seeds have been encouraged; and, indeed, seeds from year to year have been reciprocally and gratuitously distributed by Government in the agencies. As the *reported* returns, however, were rarely in excess of the average local produce, the practice has now been generally discontinued. The assamee, as a rule, is averse to sow other than his own seed, and I doubt if more than half the seed, in past years gratuitously distributed by Government, was really sown by the parties receiving it. The seed is useful to them for other purposes than sowing, and for such purposes I have reason to think they accept it, while using their own seed for sowing. As an illustration of this, an assamee came and asked me for a few seers of seeds to sow on his lands. I gave him them readily, and I frequently visited his *khet* to see how the crop progressed. All went on very promising, but to my astonishment, when the capsules made their appearance, I at once saw that the rascal had not used my seed at all: the variety being quite different from that which I had given him. It apparently had not occurred to him that I would distinguish the difference in the varieties. He had simply sown his own seed, and used mine for other purposes. I do not doubt that the returns, &c., of the seeds hitherto gratuitously distributed by Government have been thus largely falsified.

(*b.*)—While every encouragement, however, should be given the assamees to practice, *inter se*, local interchange with the seed of the poppy, it is well to be cautious in extending it to provinces, unless there is considerable uniformity of seasons. Thus, to illustrate, we have the results of the reciprocal changes of seeds between the Government agencies and Malwa. They proved most unsatisfactory, and this especially so as regards the Malwa varieties in Behar and Benares. The seeds sent from these agencies, on the other hand, succeeded much better in Malwa, though, again, they proved considerably less productive than the local sorts. The poppy, in so far as relates to drug-produce, is evidently very sensitive to changes in climatic conditions, though by no means nice as to the mere physical qualities of the soils on which it is cultivated.

6. The storing of the seeds may be briefly treated. This is a simple, but important operation, as the seeds require to be kept perfectly dry and in well-closed vessels during the rainy season. After the thoroughly mature capsules have been broken, the seeds separated and cleaned, they may at once be put into well-burnt earthenware vessels, and kept in a dry and airy verandah till the end of April, when they may be finally closed and stored for the approaching rains. In closing, all that is required is a close-fitting earthenware saucer for the mouth of the vessel. The rim of this being coated with plastic clay, the saucer is firmly bedded on it, and all covered with a thick layer of the above material. This is allowed to dry thoroughly, when it receives a second layer of fine clay, so as to fill up all cracks, and then carefully smoothed over. It rarely requires a third coating, the second forming a close, unbroken surface, quite impervious to moisture, which is mainly to be guarded against. The seed vessels may now be placed in dry and airy quarters, and require no further attention.

7. It is to be observed, however, that in simply closing them up as above, we find them very generally less or more seriously damaged by a few species of grain weevils and a member of the acarina or mite family. These will be more particularly noticed in the subsequent chapter. In the meantime, I may say that, prior to closing up the vessel, the surface of the seeds should be sprinkled over with pounded *camphor*, which is a complete preventitive to the attack of weevils and mites. The attention of the assamees should be drawn to this, as the weevils especially seem to be extremely prevalent in both agencies, and cause much injury to their poppy seed. I observed

this in my first season's experiment, having been supplied by the Agents with seeds from the assamees. Nearly all these vessels were swarming with weevils, and in many cases from a third to one-half of the seeds rendered quite useless.

CHAPTER XXI.

DISEASES AND INJURIES OF THE POPPY.

THE poppy, like many other of our fields crops, is liable to a variety of specific diseases: it has, however, its most serious enemy in a minute parasitic fungus, akin to those which for years past have so ravaged—the one the potato-crops, and the other the silk-worm nurseries. * * * It is, indeed, held by many botanical physiologists that cultivated crops, as a rule, are more subject to diseases, more liable to be infested with parasitic plants and ravaged by insects, than are those in a state of nature. Thus Professor Balfour, quoting from Schleiden, says:—"Plants in a state of high cultivation are all more or less in a condition predisposed to disease. There is an unnatural and excessive development of particular structures in particular substances, and thus the equilibrium being destroyed, the plants are liable to suffer from injurious external influences. The general morbid condition produced by cultivation is heightened into specific predisposition to disease, when the conditions of cultivation are opposed too strongly or too suddenly to those of nature."—"*Class-book of Botany.*" Dr. Hooker has well exposed the fallacy of such notions. Commenting on the phenomena of variation and reversion in our cultivated plants, he observes that "an artificially-induced condition of constitution is not necessarily a diseased or unnatural one; and, so far as our cultivated plants are concerned, all we do is to place them under conditions which Nature does not provide *at the same particular place and time.* . . . We have no reason to suppose that we have violated Nature's laws in producing a new variety of wheat; we may have only anticipated them; nor is its constitution impaired because it cannot, unaided, perpetuate its race. It is in as sound and unbroken health and vigour during its life as any wild variety is, but its offspring has so many enemies that they do not perpetuate its race. . . . Cultivated wheat will grow and ripen its seeds in almost all soils and climates, and as its seeds are produced in great abundance, and can be preserved alive in any quantity in the same climate, and for many years, it follows that it is not to the artificial or peculiar condition of the plant itself, and still less to any change effected by man upon it, that its annual extinction is due, but to causes that have no effect whatever upon its own constitution, and over which its constitutional peculiarities can exercise no control."—(*Introductory Essay to the Flora of Tasmania*, p. 9.)

The diseases and injuries of the poppy may be conveniently arranged under the following heads:—(1) Specific diseases of a functional or organic nature, "caused by an excess or deficiency of those agents which are necessary for the vigorous growth of plants", such as *soil, light, heat,* and *moisture.* (2) Injuries caused by parasitic plants (*a*) of the higher or flowering class, *e. g., the broom-rapes*; (*b*) of the lower or so-called flowerless class, and limited to the natural order fungi; (3) mechanical injuries of various kinds, chiefly caused by the attacks of parasitic and other insects. Diseases caused by changes in the atmosphere are often epidemic, and spread over extensive districts of country. Those which are due to parasitic fungi are very generally of a contagious nature, the minute spores being carried by the winds. Exciting causes operate with great intensity in cases where plants are previously predisposed to disease. Thus, if a plant is in an enfeebled or weak condition, it is much more liable to be affected with epidemic or contagious diseases than another in vigorous health.—*Balfour*.

(2.)—*Specific diseases.* 1, *a*, *Root-canker.*—In stiff clayey soils, in which there is an excess of the oxides of iron or manganese, poppy is frequently very seriously affected with the above disease. It also prevails even on the lighter class of soils when there is an excess of alkaline salts. Plants subject to this disease have the root variously affected: very frequently it breaks out in isolated patches, or again it extends less or more over the whole tap-root from the point upwards. I have frequently pulled up sickly-looking plants and found them thus affected; the softer outer tissues of the root being completely corroded, from the apex to a little below the neck of the plant, where, probably from some favourable change in the weather, or changed conditions in the surface soil, a less or more bulky *callus* (as such a development of cellular tissue is called), had formed, from which sprung tufts of rootlets. In most cases, however, the latter are abortive, rarely attaining sufficient vigour to supply the soil wants of the plant. The following are the more characteristic symptoms of this disease:—The leaves gradually wither from below upwards, and individually from the apex and circumference to the base, the central parts thus being fresh and green, while the margins are quite withered. All ultimately assume a pale brownish yellow with veins of a deeper colour, while the lower surface is generally less or more freely speckled with black resiny exudations. . . . . . In strong clayey soils, as also in those of a lighter nature, with an excess of saline matters, the young poppy frequently suffers much from a root injury akin to the preceding, though we can scarcely term it *canker*. In this case the root is less or more deeply *ringed* (as if by an escharotic application), immediately below the surface of the soil. The softer outer tissues are abruptly corroded, and this not unfrequently to the central woody cord. Below this ring the root presents quite a fresh and healthy appearance to its extreme points. It always, however, seriously checks subsequent growth, and indeed kills all the less vigorous plants: the more robust, on the other hand, gradully form a *callus* over the injured part whence spring adventitious rootlets, but these rarely acquire sufficient vigour to sustain a healthy vegetation, and thus even the survivors are to the last spare and stunted. . . . . The cause of this *ringing*, as it appears to me, is in many cases simply due to the abrasion of the softer outer tissues in a dry and baked soil. Thus, it may be indirectly due either to the natural shrinkage of the soil, or the irrigation of the crops in windy weather, thus giving the young plants considerable play immediately below the neck. Now the consequence of course is this, that as soon as the surface of the soil dries and cakes, the softer and exposed portion of the root are less or more regularly abraded in a circular manner, if wind prevail. In other cases, I have observed very similar effects in dry seasons, in light open soils, containing an excess of saline matters. In those cases the salts formed an efflorescence on the surface of the soil, and apparently caused the corrosion of the softer root tissues with which they came in contact. To remedy the evil in the latter instance then, means must be adopted to reduce or neutralise the excess of saline matters, whereas in the case where it is simply a mechanical injury, and indirectly due to the shrinkage of strong clayey soils, I would recommend for such the system of ridge and furrow culture, explained in a previous chapter of this treatise.

(2, *b.*).—*Sun-burning.*—This is the *moorka* or *joorka* of the assamees, a prevalent and seriously crop-depreciating disease, on light sandy soils in hot seasons. Poppy is especially liable to be thus affected immediately prior to the development of the stem. The symptoms are a gradual drying up of the upper or younger parts of the plant, the leaves becoming shrivelled and variously contorted, with the veins of a brownish or purply-black colour, while a longitudinal section of the plant shows a dry and shrivelled apex, with the pith less or more decayed from above downwards. It is, as I have remarked, simply due to *sun-scorching.* The poppy somehow, more than any other of our agricultural crops, seems to be susceptible to it, and that not only in poor sandy soils, but also in rich loams, when the weather is hot and the soil-moisture insufficient to enable the roots to keep pace with the transpiration from the leaves. As showing that this disease is simply due to drought and heat, we frequently observe partially-affected plants giving off lateral shoots immediately after their irrigation.

(2, *c.*)—*Scleriasis* (from the Greek *skleros*, hard).—The symptoms of this affection are a gradual drying and hardening of the whole tissues of the plant: it is evidently a congenital or constitutional affection. It appears to be rather a prevalent form of disease, and occurs indifferently in crops on irrigated and unirrigated lands, on dry and poor soils, as well as those which lack neither manurial conditions nor moisture. It would appear to be due to a partial arrestment of the vegetative function as the plant attains the flowering stage. The plants up to that period are, to all appearance, quite healthy, and usually the first symptoms are the slight persistence of the sepals, imperfect expansion of the petals, and the less or more complete persistence of the stamens. The latter may be observed for many days after the fall of the petals, and indeed until the capsule is fully developed, forming a withered fringe around the stem. The capsules also are always of small size, generally very numerous (from 12 to 20 or 30 on each plant), rarely yielding drug to more than two incisions, and even that scantily. Where prevalent, it thus seriously deteriorates the crop. . . . I also find, from experiments with the seeds of plants thus affected, that there is a strong tendency to the perpetuation of the evil: a considerable percentage of the progeny presenting the same deteriorative characteristic. Now, occurring as they do more or less in nearly every plot of poppy, and as the assamees take no precaution whatever in the selection of their seed, we have here another pregnant source of deterioration, distinct from that which I have previously pointed out—*i.e.* the use of seeds from healthy and vigorous plants which, from a poorly developed milk system, afford but a very scanty supply of drug. Scleriasis is a most obscure form of functional derangement, and one for which I can suggest no remedy. The fact, however, that it is strongly inheritable, should teach us to carefully avoid the use of seed from such plants in sowing. Indeed, by far the best plan would be at once to eradicate them when observed. In my last season's crops from selected seed, I observed only a very few plants, and I was careful to uproot them at once.

(2, *d.*)—*Petechia* (from the Italian *petechio*, a flea-bite).—In this affection the cuticle of the leaves becomes more or less densely covered with specks or spots, somewhat resembling those caused by the bite of the above insect. In moist seasons plants thus affected are far from uncommon in our poppy-fields. The first sign of the disease is shown by the leaves acquiring a pale, dull, yellowish-green tinge, and soon after the whole surface becomes studded with specks and patches of purply-black. The affection is much less developed on the lower than the upper surface of the leaf; the latter ultimately acquiring a nearly uniform purply-black colour, and then presenting all the appearance of a plant affected with *purpura*—literally, the *purple* or *livid disease*. The discoloration is mainly confined to the leaves, and very rarely accompanied by any external exudations from the tissues, though all parts of the plants are soft and juicy; indeed in a quasi-dropsical condition. In many cases, as I believe, this disease is *largely attributable* to the overcrowding of plants in low and damp soils. It appears, anyhow, to arise from an excess of moisture in the soil or atmosphere, or both, accompanied with a low temperature, which, lowering the vegetative processes while the tissues are gorged with fluids, causes the rupturing of all the finer vessels of the leaves: the peculiar colour assumed is probably due to the oxygenation of the exuded sap. Plants thus affected may and do bear flowers, and even perfect seeds, but, as might be expected, they yield little or no drug. The fact, however, of their perfecting seed, and this being indiscriminately collected with that from unaffected plants, will no doubt tend to perpetuate and extend the disease, on the principle that affected plants have a more or less pronounced tendency to transmit it to their progeny. I would thus strongly recommend the eradication of all such plants from our crops as they make their appearance.

(2, *e.*)—*Gangrene* (from the Greek *graino*, to eat) is so-called from its eating away the tissues which it affects. The soft or herbaceous parts are most liable to it. It frequently breaks out on injured parts of the plant, and is then more or less local, while, again, when due to an excess of moisture and low temperature, the whole plant may be affected and destroyed. Indeed, cold and damp are pregnant sources of this disease; and under such conditions I have frequently observed large patches of hitherto apparently healthy plants, suddenly affected, droop and wither after a short exposure to the sun. Affected plants are easily recognized by their curved, depressed, and less or more rigid shoots and drooping leaves folded backwards, or even somewhat revolute. The flowers also expand very imperfectly, and the stamens are always more or less persistent and drooping, forming a long, persistent, dry, and shrivelled fringe around the base of the capsule. The latter—the capsule—is generally arrested in an early stage of its growth, and very rarely indeed do plants (poppy, I mean, affected with gangrene) perfect their seeds. As the disease progresses, the stem, leaves, and capsules, are all less or more freely spotted with black, resiny exudations. Such, briefly, are the more marked external symptoms of a gangrened poppy, and of which the first to betray it are the general flaccidity of the foliage, and the pale-yellowish green colour of the leaves which it so rapidly assumes. Very generally the largest and apparently the most vigorous plants are the first to succumb to gangrene. On cutting such plants over, we find the whole pith of the plant in a more or less advanced stage of decay or rot. Thus, in a longitudinal section, a plant killed with gangrene exhibits from below upwards the pith dry and shrivelled, adhering in cords to the surrounding woody zone, and becoming more abundant upwards, until it again quite fills the central axis, but still throughout in a pulpy, putrid state. The affection as a rule, in the case of the poppy, originates in the pith immediately above the neck of the plant; thence it extends upwards, as we have seen. It is worthy of note that, in inoculating healthy plants of the poppy with gangrene—which is easily done by inserting a small portion of the affected tissues into that which is to be the subject of experiment—the disease makes scarcely any downward extension, while rapidly invading the pith zone upwards. This would seem to indicate that the flow of the sap is only from below upwards in the latter zone. For the above disease in the poppy there is really no remedy, all the softer inner parts of the plant being in an advanced stage of decay before any external symptoms present themselves. In softer tissued plants—cucumbers, melons, &c.,—where the inner and outer parts are almost simultaneously affected, its progress may be arrested by carefully cutting out the diseased portion, and dusting the fresh cut with sulphur. From the nature of the disease, it will be readily understood that when young poppy, of soft and vigorous growth, are affected with gangrene, its extension, and the ultimate destruction of the plant, will be much more rapid than in the less vigorous, or more fully-developed and harder structured plants.

3.—*Injuries caused by parasites : the Broom-rapes.*—(*a*)—The higher or flowering class of parasitics. Of this class, the poppy is the *nurse* of two species of the *root-parasitic, Broom-rapes.* One of these is very common, and causes serious injury to the crop. This is the *Orobanche* (*Phelipœa*) *indica.* It is very generally diffused through both agencies, as in many other parts of India, making nurses of various plants, though its special favourites in our fields are *tobacco, brinjal, rape, mustard,* and the *poppy,* on the roots of all of which it is parasitical. It forms a bulky tuberoid stem, from which spring up numerous flower-stalks from six to twelve inches high. These are stout, erect, hairy, and scaly (and, like all other root parasites, void of true leaves), bearing numerous pretty, blue-coloured flowers on the upper half of the scape. The other species is the *Orobanche cernua,* a more robust plant (attaining a height of from 12 to 18 inches), but with much smaller flowers of a purply-blue colour. It affects the tobacco plant more than the poppy, giving rise to massive tufts of flower-shoots to the destruction of its nurse. Those root-parasites, when at all frequent, cause much injury to the crops they affect. Unless very extensively affected with the broom-rape, however, the poppy attains its full development, the evil effects only appearing in the post-floral or drug-yielding period. Then, depending as the parasite does on the assimilated juices of its nurse, we find the excretion of drug suddenly arrested, the seeds ripening prematurely, and the whole plant drying up. It thus seriously reduces the yield of drug. We frequently observe plants thus parasitised affording one or two copious excretions from the central and secondary capsules, and then with the younger capsules suddenly drying up. This I wholly attribute to the *broom-rape.* The assamees are fully alive to the injury it does their crops, though careless in its eradication. This is simple; and with very little extra labour—if not altogether banished from their fields—it might be greatly suppressed. Unfortunately the assamees, I observe as a rule, instead of entirely detaching the tuberoid stem from the root of the poppy, are satisfied with merely cutting off the flower-stalks below the surface of the soil, and thus only increase and perpetuate the evil; the result being that the tuberoid stem only further increases in bulk, and in a short time gives off other and more bulky tufts of flower-shoots. District officers should draw the attention of the assamees to this, as the broom-rape plant is easily enough wholly detached from the poppy root: thus by merely catching the stalks by the base, and having loosened the soil somewhat with the weeding root, it may be readily twitched off. By thus eradicating the plant prior to its attaining the flowering stage, these broom-rapes would, in the course of one or two seasons, be of rare occurrence in our poppy fields.

(*b*) – *The lower or flowerless class of the poppy plants' parasitic foes.*—These are all comprehended in the natural order of the fungi, and chief of them is that evil-famed mould—*Peronospora arborescens*—which peculiarly affects the poppy: it is thus a member of a genus which, as Mr. Cooke observes, "no other can parallel in the number of species injurious to the field or the garden, or in which the injuries inflicted are so great and irremediable."

(*b*, 1.)—*Peronospora arborescens.*—The poppy-mould has been long known to the mycologist as affecting the crimson-flowered corn-poppy,—an agricultural weed—rarely, however, affecting the opium poppy in Europe, and never known to have caused any injury to that species. It was only after the serious failing of the opium crops in India, in February 1871, that this mould—being detected by the Rev. M. J. Berkeley on the specimens sent him for examination—began to be regarded as another agricultural pest of that already evil-famed genus. As to this there can now be no question. Indeed, but that in the opium poppy it finds a nurse-plant of annual duration only, I do not doubt it would prove quite as serious an enemy to that crop as are its allies (*P. infestans*, and *Botrytis bassiana*) to the potato and silk-worm: periodically, in fact, it has proved itself quite as virulent a foe as either. But that the opium season of 1874-75 was unusually dry, I am strongly of opinion, from the mould so abounding on the crops, that its blighting effects would have been quite as striking as any on record of the potato. As it was, the drug returns were seriously reduced, the later-sown crops suffering the most. This, however, will be fully illustrated in a subsequent paragraph.

(*b*; 2.)—The poppy-mould, like all its kin, is, I need scarcely say, one of those minute forms which can be studied only by the aid of the microscope. To the unassisted eye the fertile filaments are alone visible, forming white, dust-like patches on the lower surface of the leaf. An ordinary pocket lens exhibits these patches as bundles of silky-grey, thread-like filaments, with the extremities of their branches studded with minute, globular and pellucid spore-cases. I annex the specific description of the poppy-mould from Mr. Cooke's admirable little treatise on the British "*Microscopic Fungi*":—"*Fertile threads, slender, erect,* 7–10 *times dichotomous above; branches more or less flexuose, squarrose, spreading, gradually attenuated; ultimate ramuli shortly subulate, more or less arcuate; acrospores very small, subglobose; membrane scarcely violaceous.*" On the corn-poppy in Britain the mould is in full fructification in June; in this country, where the poppy is a cold season's crop, we find it making its appearance on the young poppy about the close of November, and attaining its full development early in February. With the increasing heat—which altogether checks its development—of the latter part of February and March, scarcely a trace of mould can be found on our late crops, and this only on the lower and least exposed leaves.

(*b*, 3.)—I will now give a brief description of the vegetative and reproductive organs of the mould, as the technical terms used in the following paragraphs may otherwise be unintelligible to many of my readers. The *spawn*, or *mycelium* of fungi, is the analogue of the root and stem of the higher plants, fulfilling their several functions. In the moulds under consideration it consists of colourless filaments, either in the form of a continuous canal, or it is partitioned, and has then the appearance of a septate tube. It is developed in the interior of the substance of the plants, which foster or nurse it, and in the case of the poppy it is mainly, if not wholly, confined to the inner tissues of the leaf: I have at least in no instance observed it breaking out on any part of the stem, on the flowers, on capsules. The filaments bearing the reproductive organs spring from the *mycelium*, either solitary or in bundles, and are either continuous, as in the *poppy* and *potato-moulds*, or chambered, as in that of the allied species, which is the cause of that disease known as the *muscardine* in our silk-worm nurseries. The *spores* or *conidia*—the seeds or reproductive bodies—in the poppy mould and its allies are various in form and function. They are simple or compound, borne on the extremity of a filament, or inserted on special organs called *basidia*, and then supported on stalks which are technically called *sterigmata*. The *spores* vegetate by producing one to four filaments, and these are the rudiments of the *mycelium*. *Oogonia* are other spore-like, female organs, of considerably larger size than the *conidia*, and are seated on the *mycelium*, from which, however, they are separated by *septa*, and hidden in the tissues of the foster-parent: they have not as yet been observed on the mould of the opium poppy. These organs—*oogonia*—are large ovoid or globose cells, consisting of a thickish membrane, which is filled with a granular mass of *protoplasm* (the first formative matter, or that from which the cell—nuclei originate), which ultimately and after fecundation by a filamentous tube, which shoots out from the *antheridia*, or male organs (subsequently to be described), divides into several reproductive bodies called *oospores*. The *antheridia*, or male organs, are simple, obtuse, or obovate cells, smaller than the *oogonia*, or female organs, and borne on branches of the mycelium, from which they are separated by a septum, and very generally rest on, or are applied to, the female organs to effect their fecundation. They contain a finely granular *protoplasm*, and ultimately produce a filamentous tube, which perforates the wall of the *oogonium*, and thus, as is believed, effects its fertilization. . . .

(*b*, 4.)—I first observed living specimens of the mould on the opium poppy in a field at Ranchee, in the Chota Nagpore division. This was in January 1873. Later samples also of mould-affected plants were sent me from the sub-divisions of Jaloun, Mynpoorie, and Etwah, in the Benares Agency. Throughout both agencies, however, that season the mould seems to have been most sparingly diffused or developed, and nowhere, I believe, could any of the local failings of poppy be attributable to it. In the ensuing season of 1873-74, on the other hand, it abounded on the poppy in both agencies. I first observed it on plants in the Government experimental gardens at Deegah in December 1873. It was then confined to the lower and matured leaves of the plants. Early in January 1874 it had much increased, being then prevalent on all the more advanced crops, but, it is to be observed, in all cases *confined to the matured leaves of the plants*, the younger and developing leaves showing no trace of it. This is an important correlation. I was much alarmed with this general diffusion of the mould and, much to the horror of my sirdars, I ordered them at once to strip all the mould-affected leaves from the plants on several of my experimental plots. I adopted these measures with a view to prevent as much as possible the further diffusion of the mould by its spores, which I then mistakingly regarded as the organs by which the mould contagion was diffused. It was evidently useless work in so far as related to the existing crop, though it is likely to have served a purpose in lessening the number of spores which await the crops of the following or subsequent seasons; as it is difficult to say how long, under favourable conditions, such vitalized germs may sustain a dormant existence. It has, indeed, been held by not a few mycologists that these spores—the *conidia*—lose their vitality or germinative power very rapidly; but this, of course, is the result of experiments with such under artificial conditions, and it is rash to assume on such purely negative evidence what may obtain in their own natural economy. In the higher plants, for example, we are familiar with many kinds of seeds which are kept with difficulty under artificial conditions, and yet when left to nature, and as it would appear to us in the most adverse conditions, they nevertheless retain a vigorous vitality and reciprocate at once to the return of their season of growth. . . . . . But to return to the extension of the mould on the plants. This was quite a periodic phenomenon (as I will subsequently describe in detail), and extended from about the middle of December to the middle of February. At the latter period fully more than half the leaf surface of every plant was invaded and discoloured by the mould. The invaded portions of the leaf are readily distinguished by their dry, escharotic appearance, and dull-brownish colour. On examining the lower surface of these in February 1874, I found every patch crowded with spore-bearing filaments. The mould had apparently exhausted itself in this high reproductive fertility: it made no further extension, and the invaded parts dried up and withered, without causing rot or further injury to the uninvaded parts of the leaf. From the result of that season's observations of the mould, I had concluded that it was not at all likely to prove a serious enemy to the poppy. The less succulent structure, as compared with that of the potato, as I then wrote, "is evidently unfavourable to any rapid or general extension of the *mycelial processes*, and out of the many thousands of poppy plants which I have now seen, with their whole leaf surface teeming more or less with the *fertile* shoots of the mould, I have not seen a single plant succumb to it: all have flowered, yielded drug,—*I am indeed not prepared to say in undiminished quantity*,—and borne their normal quantity of good seeds." Well-founded, apparently, though the above view was, the following season's observations proved it to be anything but true; and the escape of the crops from a virulent blight, proved simply to be due to the mode of development, as I will now attempt to show in the following *resumé*, of the mould's extension and morbific action on the poppy crops in the season 1874-75.

(*b*, 5.)—The first appearance of the mould on the poppy in the experimental gardens for the above season was towards the close of November 1874, and, as in the previous season, I found it entirely confined to the lower and mature leaves. It had again a periodic extension from the lower to the upper cycle of leaves, and by the middle of February the whole leaf series presented patches and streaks of a dark-brown colour, indicative of mould invasion. Hitherto it had given me no anxiety, my observations on extensively-affected specimens in the preceding season having afforded me grounds for the belief that the drug-yielding qualities of the poppy would not be sensibly impaired by the infection, nor did it appear in any marked way to have weakened the plants, as even those with the older leaves very extensively affected (the *mycelium*, as I should here observe, being *fertile* or *spore-bearing*) continued in good health. . . . Each mould-patch *fructified copiously*, and thus, as it would appear, utterly exhausted the *mycelium* or *spawn* in the inner tissues; so that the latter and its fostering matrix simply dried up, without communicating disease or rot to any uninvaded portion of the leaf tissues. On the other hand, in the season 1874-75, the inner tissues of the leaves appear to have been wholly interwoven by a *sterile mycelium*, the decay of which caused their discoloration and death. Again, the fungal discolorations and disease of the leaves were communicated to the *nodes*,—*i. e.* the points of union of the leaf and the stem,—thence extending upwards and downwards from each as a centre, until the whole stem not unfrequently assumed a nearly uniform glaucous bluish-black. At this stage all subsequent growth is arrested, and the plant sooner or later dies. The cuticle, or skin of the stem, shrinks and dries, but unlike that of mould affected potato-stalks, it continues firmly adherent to the dry woody layers beneath. This close adhesion of the epidermal layers to the woody zone tends, as I think, to show that neither the cambium layer nor liber, or inner bark, has been actually invaded by the mould; otherwise one might have expected a separation of the epidermal or upper layers on the death of the *mycelium* and softer tissues investing the wood. . . . The pith of plants affected with mould acquires a brownish-green colour, and in the earlier stages of the disease becomes gorged with sap. As this is exhausted—apparently in the supply of the capsules, which frequently continue green and soft, and even mature their seeds after the leaves of the plants are dry and withered—the pith also dries up, and the whole plant dies. . . . The weather during the period of this mould-invasion was upon the whole dry, with only light, occasional showers of rain. I do not doubt that with cold, foggy, or rainy weather those mould-blighted plants would have become so surcharged with sap, that all their parts would have become soft, and instead of withering and drying as they did, would have become a pulpy, rotten mass. This I now strongly suspect has been the case in the poppy blight of 1871-72, as it appears to have been everywhere preceded by cold, foggy, and rainy weather. We have now shown that, under certain unknown conditions, there may occur either a merely vegetative extension of the *spawn* or *mycelium* in the tissues of the poppy leaves, or, on the other hand, the development of the vegetative system may be in abeyance, and have the reproductive correspondingly exalted, to the complete exhaustion of the mycelial processes. Now, in the latter case, we have a comparatively *harmless parasitism*, the injury to the tissues of the foster parent being local, and limited to those in immediate contact with the *mycelium;* whereas in the other case, with the reproductive function in abeyance, and a purely vegetative development in force, the results are most mischievous: this, as it appears to me, is due to the decay of the *unexhausted mycelium* in the tissues of its nurse. In all circumstances the spawn is but short-lived, decay fast following development; and it is thus that the soft, almost sebaceous tissues of the *mycelium*, full as they are of protoplasmic matter and juices, cause alterations in the cellulose and cell contents of the surrounding tissues, and generate a *quasi*-fermentive process, which being communicated to the surrounding tissues, the whole organ, or indeed the entire plant, undergoes decay. Now, it is easy to see that if this should occur in cold, wet, and cloudy weather, when transpiration is checked, and the tissues consequently less or more gorged with juices, the plant will present all the symptomatic appearances of *moist gangrene;* the leaves becoming soft, flaccid, and drooping with the first break of the sun, while the softer tissues of the stem will speedily rot. In a dry and hot atmosphere, on the other hand, while transpiration is increased, and the absorption of moisture from the soil impeded, by the decay of the mould in the tissues, and the functional derangements thereby occasioned, the fluid contents of the cells being nearly exhausted, the several parts of the plant, as might be anticipated, do simply wither and die. Thus, in the first instance, we have one of those *virulent rot-blights* which ruined the poppy-crops in 1871-72; and in the second it assumes the dry and less striking form as exemplified in those of 1874-75. The latter, its development and effects, we will now briefly notice.

(*b*, 6.)—In the beginning of March 1875 blight, in a truly epidemic character, first made its appearance, as I learned from reports and specimens sent me from the different districts of the agency. About the middle of February suspicious symptoms of some secret blighting influence had presented itself in the experimental gardens. This was, in a considerable percentage of the most advanced plants ceasing to yield drug, though to all appearance in vigorous health and far from mature. Now, it is to be observed that the leaves externally betrayed no symptoms of the mould's renewal of vegetative activity. The old blight spots and patches did not increase in size, nor were there any fresh eruptions of mould. I now suspect, however, that certain obscure chemical changes had then taken place in the maturing plants, as indicated by the sudden exhaustion of the opium fluids, and that this had stimulated to fresh action the dormant mycelial particles, which were doubtless present in the leaf tissues. It would appear that certain changes in the juices of the plant are somehow peculiarly favourable to the development of the vegetative system, or spawn of the mould, and that thus, as in the case of many common terrestrial plants which draw their nutriment from the soil, under certain conditions continue for longer or shorter periods to vegetate vigorously without producing seeds, so with the parasitic mould, revelling, so to speak, in juices suited to its vegetative wants, we need not be surprised at the temporary suppression of the reproductive functions, and the exclusive exercise of those of a purely vegetative character. I am, indeed, convinced that we are thus afforded a satisfactory explanation for many of those epidemic mould-blights which, with such fearful rapidity, lay waste our crops. Again, assuming that this virulent, or vegetative mode of development of the mould, is wholly dependent on certain obscure conditions of the cell-contents, or, we may add, the watery fluids by which they are more or less bathed, we can easily understand how, under the most opposite meteorological or other physical conditions, a mould-blight may, with alarming rapidity, devastate our crops.

(*b*, 7.)—I will now pass on to another phenomenon of much interest in the natural economy of the mould—this is its periodicity, individual and specific. In illustrating the periodic evolution of the mould on the poppy, it will be desirable, in the first instance, to indicate the mode of arrangement of the leaves of the latter, inasmuch as I will show that the periodicity referred to is specially correlated with the leaf cycles: in other words, that the invasion of each spiral cycle of the leaves comprises a distinct period of the mould's evolution. Now, the leaves of the poppy are alternately disposed on the stem, so that in following their course from below upwards, we must move in a spiral or corkscrew-like fashion. It need scarcely be remarked that, in our ordinary illustrations of the leaf-arrangement, or *phyllotaxis*, as it is technically called, the respective cycles have no definite physiological value, any particular leaf forming the base of a cycle. This, however, is not the case in the subject of our present illustrations: here, we must be guided by the serial order of development, and assign to each cycle its morphological position and limits—its organic individualisation—as the relations of the phenomena in question to the functions of the living plant can thus only be properly understood.* With this view we must take, as the initial or base of the cycles, the first true leaf, that is, the one immediately succeeding the cotyledonary or seed-leaves, and thence proceed upwards in the spiral line of arrangement. Each cycle is, of course, limited by the disposition of a leaf directly above that whence it originated. Now, in the poppy we have to make two turns of the stem, and pass six leaves, before the cycle is completed. Such a disposition of the leaves is technically termed pentastichous, the leaves being disposed over the stem in five rows—an arrangement indicated by the fraction $\frac{2}{5}$ths, of which the *numerator* denotes the number of turns round the stem, and the *denominator* the number of leaves in the cycle. Now, as I have above remarked, the life history of the mould is not, as is generally supposed, one of uninterrupted development and extension; on the other hand, it has distinct alternating periods of activity and rest, and, as I have remarked, the former have a definite physiological relation with the leaf cycles: the invasion of each cycle comprising a distinct period of mould evolution. With these explanatory remarks, we will now proceed to lay before our readers an account of the development and extension of the mould as carefully observed on a few of the plots in the Government experimental gardens under my charge in the season 1874-75.

(*b*, 8)—First of all, then, the mould appeared on the cotyledonary or seed-leaves, and as the stomata are considerably more numerous on the upper than the lower surface of these organs, so correlatively the mould was more copiously developed on the upper surface. It is interesting to observe, in connection with the elaboration and circulation of the juices of the plant, as generally understood, that this minute mould—fastidious to a nicety though it is as to the nature and quality of the juices it feeds upon—was equally as flourishing and as perfectly fertile on those incipient leaves and crude juices, as on those of the maturing plant and its highly elaborated juices. As in the case of the latter, however, it is important to observe that it only breaks out on the perfectly mature cotyledons: in no instance have I observed it prior to the development of one or more cycles of

---

* Following out Goëthe's beautiful idea of Nature's archetypal plant—*vide* his book entitled "The Metamorphosis of Plants," and regarding the leaf as the type of all the lateral organs—the sepals, the petals, the stamens, and carpels—I would particularly draw attention to the construction and arrangement of the several parts of the flowers, as well illustrating the above-noted organic individualisation, or rather, as I should say, physiological integration of the leaf-cycles and their homological relations with the leaves. This, I think, is very strikingly brought out. Thus, for example, we have *trimerous*, *tetramerous*, and *pentamerous* flowers associated with, and corresponding to, a *ternary*, *quaternary*, and *pentastichous* arrangement of the leaves. True, there are many apparent exceptions from alterations in the regularity and symmetry of flowers, due to inheritance of ancestorial variations, but these, if carefully studied, may be generally shown to be due to the abortion, union or adhesion, and ultimate irregular development of parts which, in their earliest observable stages, are alike regular and symmetrical. The physiological limitation of the leaf-cycles (as connected with the above-noted periodicity in the development of the poppy-mould), and the homologies of the leaf and the parts of the flower are thus strikingly illustrated by the number and disposition of the floral organs. This, it may be observed, is a most interesting and importan branch of vegetable morphology, though hitherto almost entirely neglected.

normal leaves. The crowded radical leaves are seriatically overrun with the mould, and the careful observer will also find even of these (of which there are, as a rule, three complete cycles) the lowest series covered with mould blotches, while the upper and younger series are unaffected. Poppy, germinating in the beginning of November, usually exhibits the mould blotches on the lower series of leaves ere the end of the month.......The above observations, it may be as well to remark, were chiefly made during the last season (1875-76). To return now to the preceding season. I observed that from the period of the moulds having overrun the lower series of root leaves about the beginning of December, it made no further progress until the middle of that month; it then almost simultaneously appeared in insulated specks on all the upper series of radical leaves: at first small, they gradually extended, forming by mutual confluence large patches, and thus ultimately gave a considerable portion of the leaf all the appearance of having been daubed with an escharotic. It is noteworthy that those mould spots were always clearly defined, and not unfrequently limited to the interspaces between the secondary and tertiary veins: these forming clear and sharp lines of demarcation between the mould-invaded and uninvaded tissues. The under-surface of those mould patches was, as a rule, covered with copiously spore-bearing threads. The extension of the mould was in this instance arrested in some six or eight days: this was the beginning of the *second resting* period (Normally, as I find from the last season's observations, this should be considered as the *fourth resting period*—thus: the *first* after the cotyledons are infested; the *second*, succeeding that of the first cycle of radical leaves; the *third*, the second leaf-cycle; and the *fourth*, as above the upper cycle of radical leaves.) With reference to the weather during this period of the mould's activity, we had light east by south-easterly winds, no rain; the sky clear; heat moderate; the night temperature unusually low (the average temperature for the week being 34°·7),* and the plants in the morning dripping from their own exhalations in the cold atmosphere. This, it may be remarked, is quite a common phenomenon in the cold weather here, and due to the plants maintaining a higher temperature than the atmosphere; so that the *dew* under such conditions, instead of resulting from the condensation of atmospheric vapour, as explained by Dr. Wells in his classical essay, is, on the other hand, the result of condensation of the warmer, moisture-laden exhalations from the plant by the colder atmosphere.

(*b*, 9.)—Passing, then, the *fourth* periodic rest of the mould (during which I should state there was a continuation of the previously noted light easterly winds, a moderate day temperature, and an increase of 1·31° to the mean of the night temperature), it again resumed its activity in the first week of January, and as it so happened, immediately after a light fall of rain—0·10 of an inch—with a westerly wind. On this occasion the mould attacked and overran in about eight days the lower cycle of the true cauline leaves: this closed its *fifth periodic* evolution, and was succeeded by another period of rest.

---

* *The temperature in the above instance, and indeed throughout the treatise, is according to the thermometer of Farenheit.*

Light south-westerly winds prevailed, the sky clear, the maximum temperature 78·5; the average night temperature still low—viz., 35·5. There was no rain, though the atmosphere was moist and favourable to vegetation.

(*b*, 10.)—This, the *fifth* periodic rest of the mould, continued from about the middle of January to the beginning of February. In this interval rain fell on three occasions, the total quantity being *one inch*: light east and south-easterly winds continued throughout. The mean day temperature was 78·3; the atmosphere moist and favourable to vegetation. In the beginning of February the mould resumed its vegetative activity, and in this instance its prey was the second cycle of stem-leaves. It made a very active invasion, and in a few days the many brown and seared patches on each leaf of the series, showed that all again had been simultaneously and very similarly affected. During this period of activity there was 0·20 of an inch of rain. The vegetative activity of the mould having nearly run its course as the rain fell, it had, however, no appreciable stimulative action on the mould, no previously unaffected leaves were subsequently invaded, nor was there any marked extension on those already infected; indeed, in some two days more, the mould again resumed a quiescent state. The average night temperature for the period had increased to 40·8°; the maximum day temperature was 79·3°: westerly winds prevailed; and, though the sky was clear, the atmosphere was, upon the whole, moist.

(*b*, 11.)—This, the *sixth* period of vegetative dormancy in the mould, and its *seventh* and last invasive action, occurred about the middle of February. There was no rain in the dormant interval of the mould: easterly winds prevailed; the mean temperature for the night was 41·0 and for the day 77·3 (as compared with the average temperature for the day in the beginning of the month, the decrease was of course due to the change from *westerly* to *easterly* winds): the atmosphere continued humid and favourable to vegetation. The mould now invaded the upper cycle of cauline leaves, the plant being nearly fully developed; the primary or central capsules having attained their full size, and yielded drug some ten or twelve days previously. The leaf injury caused by the mould on the upper cycle of leaves was very similar to that on the lower, and in no instance did it appear to have impaired, in any marked way, the normal functions of those organs. The flowers attained their normal size, the sepals and petals falling off in the usual time, and the capsule afforded a fairly copious supply of drug. Now, it has been remarked in a previous paragraph that immediately after this invasion of the mould in the comparatively harmless or spore-bearing form, that apparently from some obscure changes in the juices of the plant, peculiarly favourable to the vegetative functions of the mould, the previously uninvaded leaf tissues were overrun with barren mycelia, which at once arrested the secretion and exudation of drug, and soon after the death of the entire plant.

(*b*, 12.)—From the above summary of a series of careful observations, there can, I think, be no question as to the correlation of periodicity in the development of the mould and its fosterer, each periodic invasion of the former being strictly limited to a single leaf cycle of the latter. In its limitation to the fully mature leaves, and in presenting well-marked periods of rest and activity, the poppy-mould appears to differ altogether from its ally, the potato-mould, in which, so far as I am aware, no such phenomena have been observed. It is also important to observe that the poppy-mould does not necessarily extend wherever a green leaf matrix presents itself. This, as it appears, is a clear proof that atmospheric influences have really little to do with the extension of the mould, but that, on the other hand, it is largely, if not wholly, dependent on the degree of maturation of the matrix; that is to say, on certain peculiar chemical changes which occur in the juices of the nurse plant at that period, and that these are alone favourable to any high degree of vital activity in the mould. This is a matter of high importance. Hitherto, it has been customary to correlate the sudden appearance and rapid extension of various fungoid-blights to certain peculiar atmospheric conditions. Now, there may be some such relation in the spread and extension of the truly terrestrial or even epiphytal species; but I do think that careful observations will show that this scarcely, if at all, holds in those of a truly parasitic character, and especially such as the poppy and potato-moulds, which are wholly dependent for their development on a supply of the juices afforded by these plants in the period of their vegetation. As regards the poppy-mould especially, I am convinced that its development and extension are largely dependent on certain changes in the juices of the maturing leaves, though I admit that there are grounds for the belief that the particular mode of development—that is, the dominance of the reproductive or vegetative function—may be partly due to certain obscure atmospheric conditions. This, of course, is an important influence, inducing, as I have shown, in the one case a comparatively harmless, in the other a most mischievous, parasitism.

(*b*, 13.)—We will now pass on to the phenomenon of the reproduction of the mould, or its annual recurrence and extension. Now, it is to be observed that what are regarded as the true resting spores of the poppy-mould—the *oogonia* or *oospores*—have not hitherto been detected in this country. In the case of the potato-mould, organs somewhat resembling them were observed many years ago, and described as a new genus under the name of Artotragus. Later observers, however, have failed to detect either those organs, or true *oogonia*. The presence of the latter for the perpetuation of the mould in the potato, however, would appear to be unessential, as portions of the mycelium are known to hybernate in the tissues of the potato tubers, and resume vegetative activity with their nurse. Now, it is altogether different in the case of the poppy—an *annual herb*—of which all that remains to perpetuate it from year to year is a very minute seed. That these—the seeds—really are the nurses of the mould from year to year I certainly have no positive proofs; but for reasons to be given in the sequel, I strongly suspect that they do perform that function, and this probably in the following manner:—From the progressive development of the mould on the various cycles of leaves from below upwards, I believe that minute particles of the mycelial processes are diffused through the tissues of the stem, thence pass into the seed, and there in a dormant state await its germination; or, again, we may assume that protoplasmic granules from the spores are diffused through the tissues of the plant, remain dormant in the seed, and ultimately effect the inoculation of the germ. Indeed, in the absence, as far as is yet known, of *oogonia* and *oospores*, there is much likelihood that the poppy-mould is thus very largely reproduced, though I am inclined to believe that the *conidia* are also largely effective, and not, as is generally supposed, merely *spore-buds*—if we may so term them—specially adapted for the seasonal diffusion of the mould. . . . Let us then have regard to the latter organs—the *conidia*. Well, as I have already stated, an opinion prevails that they retain their vitality for very short periods; that they are, in fact, not annual recurrent or resting sporés, but of fugitive vitality when detached from their living matrix, and specialised for the immediate diffusion of their kind. Now, placing in abeyance for the present the question of the special function of these organs, it may be observed that they are generally produced in immense profusion by the *Peronosporæ*; and moreover that in certain species, when placed in water, the *zoospores* which they emit vegetate in a few hours. Thus, in the case of the potato-mould, for example, the *zoospores* if placed on the shoot or leaves of that plant emit germ-tubes, as they are called, which at once enter the stomata (or respiratory pores), rapidly extend their mycelium in the inner tissues, and in a very few hours give rise to the fertile or spore-bearing filaments. Now, as every square line of the potato leaf may give rise to some *three or four thousand conidia*, each of which contains some *half dozen* or so of *zoospores*, it is easy to understand how alarmingly rapid the spread of that mould may be on our potato crops. There can thus be no question as to the contagious nature of the potato-mould. The *conidial* contents of several other of the potato-moulds' allies, I may here observe, are also known to vegetate immediately, when placed in favourable conditions, and are thus a source of rapid diffusion from affected to unaffected crops. In the case of the poppy mould, however, this does not hold; it would appear to be altogether different, and, even though an undoubted species of the same genus as those, I cannot regard it as thus contagious. In other words, that there is no diffusion of the mould by the *conidial* spores as in the case of the potato and allied mould pests. As it appears to me, the periodicity and regular evolution of the mould on the leaves, cycle by cycle, from below upwards, strongly supports the views above suggested, and are quite opposed to the idea of contagion by spore-diffusion. Again, the very equable diffusion of the mould on the leaves, and its almost simultaneous eruption on each leaf of the cycle, are phenomena favourable to the view of the existence of dormant mycelial gemmæ or particles in the tissues. No such regulated phenomena could possibly result, as it appears to me, if the diffusion depended on the external contact of the conidial spores with the leaves. Again, as regards the vegetation of the *zoospores*, water is admittedly an indispensable adjunct. Now, throughout the past season 1874-75, though the atmosphere was upon the whole moist, we had very little rain, and though the upper surface of the leaf was frequently dew-besprent in the morning, the lower was dry, and thus alike unfavourable to the adhesion of the *conidia* and the vegetation of their *zoospores*. I would, therefore, explain the original infection and individual extension of the mould in the following manner:—Granting, as before suggested, that certain protoplasmic granules or mycelial germs of the mould hybernate in the poppy-seed, and that these either directly inoculate the embryonic-germ, or simply adhere to it and resume their vegetative activity simultaneously with the parts of the nurse-seed, and through the cotyledons or seed-leaves infect the inner tissues. It is easy to see how these vitalised particles may be distributed by the circulation of the sap, and thus uniformly burst out from its vegetative nidus—the leaves. Its periodicity and uniformly progressive march from below upwards are really only explicable by some such mode of transfusion. Again, in the cotyledonary stage, the young plant may readily contract mould-taint from the *conidia* in the soil, as I am convinced that, under the natural economy of the mould, these spore-buds do retain for one, or it may be for many years, their vegetative functions, and, under favourable conditions, give rise to germ-tubes or *zoospores*. At this stage the conditions of growth of the young plants are highly favourable to extraneous infection from the *conidia*, inasmuch as in the first and second irrigation, the tiny crops are quite submerged, and the *conidia* are thus buoyed into direct contact with the germ-plants.

(*b*, 14)—While admitting, however, the possibility of extraneous infection of the cotyledonary plantlet by contact with *conidia*, I am, nevertheless, of opinion that the reproduction or recurrence of the mould from year to year is mainly dependent on the transmission of protoplasmic granules, or mycelial particles in the tissues of the seed. Moreover, I am convinced that, in the case of the poppy-mould, an *affected crop* can possibly form a centre of diffusion and extension to surrounding and previously *unaffected crops*. I have attempted to show this in previous paragraphs, and I will now add a few experimental observations as further supporting it. *First*, it has been shown that by subjecting the seeds of certain plants—cereals, &c.,—affected with mould to special alkaline steeps, and subsequently washing them that they will not produce diseased crops. Steeps of sulphate of copper for example are said to kill the spores of the *bunt*, *rust*, and *smut* moulds, without causing any injury to the seeds to which they are attached. Now, during past seasons I have subjected poppy-seeds to various alkaline steeps, afterwards placed them on fine sieves, and exposed them for some time to a stream of water, which must, I would suppose, have washed off all extraneous matter. I have also immersed them in weak alkaline leys, washed them as above, then soaked in the strong copper sulphate solution, dried in quicklime, and at once sowed them. For the sake of comparison, in an adjoining plot I also sowed wholly untreated seeds. The results briefly were, that the mould almost simultaneously appeared in all the plots; nor was it in a single instance a whit less prevalent on the steeped than the unsteeped seed-crops. (The only apparent exception, as I have subsequently ascertained, is, as I shall explain below, in a *camphorated-water* steep.) *Secondly*, I had the surface soil to the depth of from six to ten inches carefully removed from two beeghas of land in the jail enclosed garden, Deegah. This heap of surface soil was thoroughly *charred*, and shortly prior to the poppy-seed being sown, was again equably spread over the same surface. The two beeghas, thus treated, were sown up in due course with poppy, but the mould from its *first appearance* on the crops that season was *quite as prevalent* on the charred, as on the wholly untreated lands. This certainly ought not to have been the case had contagion been communicated by spores in the soil, and thus, as it appears to me, favours strongly the view I have advanced on the inoculation of the embryonic poppy by the mould-germs or particles contained in the seed: these, as I believe, forming from year to year the *chief hibernacula* of the mould. . . . . *Thirdly*, I made another series of comparative experiments on the above charred and uncharred lands. Thus, on one plot I used seeds which had been steeped in a strong solution of Glauber's salts (*soda-sulphate*). One portion of these I subjected to a severe washing in a fine sieve, the other was immediately dried in quicklime, and sown on the charred-soil plot. The steeped and washed seeds were also dried in quicklime, prior to their being sown, on another charred-soil plot. In each instance, however, the precautions were utterly futile; the crops from the saline steeped seeds on the charred soil, being from the first, quite as seriously infected with mould as those from the wholly untreated seeds on the uncharred lands. All this, I think, goes to justify the conclusion that *germ cells*, or *mycelial gemmæ*, do exist in the inner tissues of the seed. . . . . . . *Fourthly*, as illustrating the reproduction of the poppy-mould from other than the *oogonial* or *oosporal* organs, I have the following case in point:—Thus in the season 1873-74, I had the prison lands in the jail enclosure at Deegah broken up and sown with district seeds of poppy. Now, it is to be observed that these lands are wholly enclosed by a masonry wall 13 feet high, and had been under no cultivation for more than thirty years. Moreover, for a considerable radius around them there is no poppy cultivation. These lands, one may safely assume, could not possibly contain either *oogonia* or *oospores*, nevertheless, even as on the old poppy lands, were the first season's crops overrun with the mould. It should also be observed that the season was an exceptionally hot and dry one, and thus highly unfavourable to any form of extension by *zoospores*. . . . . . . As bearing on the question of non-affection by *conidia*, I have remarked with interest the following observation by Mr. M. C. Cooke.—(*Vide* "*Microscopic Fungi*," *p.* 159) Mr. Cooke, commenting on the *Peronorporæ*, observes with reference to the spinach mould—*P. effusa*—"that he had lately seen a bed of spinach utterly destroyed by it, whilst on another bed, not twenty yards distant, not a spotted leaf could be found." This observation, as it appears to me, goes to confirm my views as regards the *non-diffusion* of the mould by *conidia* in the poppy-affecting species, and thus that, in the absence of seed, or cotyledonary inoculation, the crops will not be affected by the mould. It is to be regretted that Mr. Cooke gives no history of the plots for the previous year, or of the origin of the seeds used on the respective plots. I can give no parallel case from my observations on the poppy, as throughout both agencies the mould is everywhere present on our crops. . . . . . It is not at all improbable, however, that the assumed immunity, in Mr. Cooke's case, may be rather apparent than real, and really due to comparisons of nurse-crops at different stages of maturity. For example, in the case of the poppy, we find that the mould is confined to the leaves at a certain stage of maturity; so in the case of spinach, a comparison may have been made on successional crops, the later of which had not attained that stage of maturity favourable to the development of the mould.

(*b*, 15.)—This, perhaps, is as suitable a place as any to introduce the results of experiments with *camphorated seeds*, as related to the mould infection. In a previous chapter I have alluded to these results in treating of the stimulative effects of the practice of seed-steeping, and of course in experimenting with camphor I had simply that end in view. I had no idea of its proving in any way a preventive to mould in the poppy; such, however, it would appear to be In Chapter VII I have shown that, while the steep of alcohol and camphor much retarded germination, and so weakened the plantlets that not one of them survived the cotyledonary stage, the camphorated water, on the other hand, not only greatly accelerated germination, but also invigorated the young germs I was also struck to observe, as the patch of poppy thus treated grew up, that while all the other experimental plots treated with alkaline and other matters were more or less seriously affected with mould, the foliage of those camphorated seed-plants scarcely presented a trace of it. The experiments, of course, are on much too small a scale to warrant our concluding that in camphor we really have at last found an effective preventive to the *peronosporoid moulds* on the crops which they affect; but they are so far satisfactory, and will form the subject of more extensive experiments next season.

(*b*, 16)—We will now pass on to a consideration of the hereditary predispositions of the poppy—in other words, the greater liability of certain plants than others to the mould affection. Well, in the course of my observations on the blight during the past and previous seasons, I was much struck with the frequent occurrence of individual plants and patches, of more or less extent, seriously affected with the mould, and surrounded by others but slightly affected; while, again, even in the seriously-blighted patches, it was not unusual to observe solitary plants which had well withstood the blight. I also observed that certain varieties possessed considerable immunity from the mould. Now, such phenomena can only be attributable to certain hereditary predispositions: individuals naturally presenting greater liability to, or comparative exemption from, the mould; and this, let it be observed, concomitant with healthily constitutioned subjects. I may here briefly specialise a few of the cases that have come under my observation. In one instance a plot of plants raised from the same variety of seed (and all under the same conditions as regards soil, moisture, and general treatment) exhibited the curious phenomenon that, while all were really affected with the mould, individual plants and small isolated patches here and there presented themselves, in which the mould had so overrun them as to cause very serious injury. Instances also were not unfrequent in which solitary, and but slightly parasitised, plants appeared amongst patches extensively affected. Such cases are very striking, and clearly indicate some sort of hereditary immunity to the infection. Again, we have a constitutional idiosyncracy, correlated with the decoloration of the leaf, entailing comparative immunity from the mould. Thus, the *white* portions on plants with variegated leaves (as we will illustrate fully in a subsequent paragraph) suffer comparatively little from the mould, while the adjoining *green portions* of the leaf are quite as liable to the infection as are those of plants of a uniform green colour. This comparative immunity of the *white portions* is very striking, and alike interesting, theoretically and practically, as we shall hereafter see. . . . . In another instance a variety picked up in the gardens here, and well distinguished from others by its setigerous flower-stalks, is but little liable to the attacks of the mould. Doubtless this immunity must have relation to certain peculiarities in the chemistry of the plant's juices, as the structure and texture of the leaf afford no exemptional characteristics. . . . In a third variety the comparative immunity to the attack of the mould is apparently due to the denser texture of the leaf, and the smaller size and comparative paucity of *stomata*, which, of course, are the only means of egress for the fertile or spore-bearing filaments. This variety—the *kutila*—as I have previously stated, differs from the others in the thicker and denser texture of its leaves, which are also deeply divided into several lobes, and all less or more cut into narrow segments. I particularly observed, in the season 1874-75, that it was very much less seriously affected with the mould than any other of the generally cultivated varieties, and gave nearly twice as much drug as any of those on the adjoining plots, though in all respects similarly conditioned and treated. Now, this relatively increased yield of drug could only be due to the milder infection with the mould, as the variety is not naturally a more copious drug-producer than the others. It has thus, however, evidently the advantage of all those in seasons when blight prevails. . . . The above illustrations, then, as it appears to me, conclusively prove the existence of varieties of the poppy but slightly liable to the mould infection, as also individual predispositions, involving greater liability to its attacks, and this concomitant with unimpaired health and vigour.

(*b*, 17.)—We have now to consider the process of decarbonization as correlated with comparative immunity from the mould in the case of the poppy. This is a subject of much interest, and one which, I may here state, was suggested to me by the following casual observations,—*first*, that plants with foliage blotched, or variegated with white, were never seriously affected with the poppy mould; *second*, that plants growing less or more under the shade of trees had also considerable immunity; and *thirdly*, that those infected with certain root parasites—*broom-rapes*—had a very similar immunity. Now, dissimilar though these illustrative observations are, it is to be observed that they have at least one quality in common; this is the disengagement of carbonic acid with nitrogen in small quantity, and the absorption and utilisation of oxygen. This, then, entailing as it must important changes in the chemistry of the plant's juices, may be anticipated to have a marked influence on the tiny, delicately-structured parasitic moulds which live thereon. The effects are apparent, as we find plants under this decarbonizing process much less liable to the attack of the *peronosporoid* moulds, than plants performing their normal respirative functions, *i.e.* giving off oxygen and assimilating carbonic acid. Let us now specialise the instances.

(*b*, 17*) – First, for plants with *white blotches* or *variegations* on the leaves. In illustrating this class, it may not be deemed superfluous to introduce here a short account of the phenomena of variegation, as explained by Dr. Morren. From his observations, then, we learn that variegation in leaves is either due to an alteration of the *chlorophyll*—as the green colouring matter is technically called, or the presence of air or gas in the intercellular passages. He thus explains the general phenomena of variegation, the subject of illustration being a discoloured leaf of the common lilac (*Syringa vulgaris*) :—" In this plant, as with many others, there are several hues which constitute that form of variegation which we call '*marbled*,' Some of these tints are pale green, others greenish-yellow, or here pure yellow abounds, and there we have pale or clear-yellow, with at last pure white and a brown colour indicative of a decarbonisation of the tissues. Now, whence these varied tints proceeding from the green to the white by numerous intermediate shades? We have dissected such a portion, and the anatomy explains the phenomena. We find that the discoloration of the *chlorophyll*, and the secretion of the air between the cellules—the *emphysema*, from the Greek *emphysao*, to inflate—only affects the cellular tissue of the superior *mesophyll*—*i.e.*, the *parenchyma* or cellular tissue between the upper and lower epidermal layers—layer by layer. It thus follows that the *first layer* diseased is the *superior*; the *second*, that which comes below it; the *third*, that further down, and so on. We may therefore perceive why the pale green tint is only the index of a slight superficial *emphysema*; why the greenish-yellow tint indicates *emphysema* of several layers; in short, why the total discoloration of the leaf is only the result of a *general emphysema*, which has affected all the leaf tissues." Reflecting, then, on the important physiological changes involved in the process of discoloration of a leaf, we need not be surprised to find such tissues, or rather their contents, no longer a congenial matrix for that class of true parasitic moulds which are wholly dependent for their sustenance on the cell-contents and juices of living plants. Now, of this class is the mould which causes the poppy-murrain. As affecting the food-stuff then of this mould, what, it may be asked, are the special chemical changes entailed in the processes of respiration and assimilation as performed by *decoloured* leaves? Well, we all know that, under the influence of light, the green parts of plants assimilate carbonic acid and give off oxygen; whereas in darkness the obverse largely obtains, oxygen being retained and carbonic acid rejected. This is also the case with all white or decoloured parts of plants, hence the practice of blanching plants to expel bitter or noxious principles from the stem and leaves, the secretion of which depends on the assimilation of carbonic acid. The parts of plants under such conditions usually contain an excess of water—sap, and it may be assumed that, in the non-assimilation of carbonic acid, the cell-contents will be considerably enriched in the acidifying constituent—*oxygen*. In the process of decarbonisation, then, oxygen is absorbed and assimilated, and the carbonic acid, mixing with the sap of the plant, is evaporated along with its watery matter through the leaves, and such are the respiratory processes which obtain in the case of the poppy with white-blotched leaves, and as it would appear, delimit the extension of the mould. The diminution of carbonic acid, and the increase of oxygen in the tissues entailing, it would appear, conditions unfavourable to the development, or even the life, of the mould.

(*b*, 17.**)—The next topic which we have to illustrate is the effects of tree shade on the poppy as affecting its physiological relations with its specific mould—*Peronospora arborescens*. Well, I may at once state that even under light shade. the poppy is but little affected by the mould, and under somewhat dense shade it altogether repels it, the leaves then maturing and drying up of a uniform strawy-yellow colour, thus strongly contrasting with those of the mould-infested plants, which are daubed with blotches of brownish-black on the above ground . . . . The altered chemico-vital processes of plants thus environed no doubt explains the correlation between plants growing under a diffuse light and their comparative immunity from mould. Thus, De Saussure has shown that plants even in cloudy weather, as in darkness, inhale oxygen and exhale carbonic acid gas, if long continued in such obscure conditions; whereas when exposed to the sun the process is reversed, oxygen being then given off and carbon retained for the plant's nourishment. Again, everybody knows that the leaves of plants in shady or dark places become pale, etiolated, or blanched. It is thus that starch-yielding plants are so poorly productive when grown under the shade of trees, &c. Common starch, of which carbon forms so large a part—consisting of 36 parts by weight of *carbon* and 45 of *water*—is developed *only* under the influence of light. "For this reason," observes the late Dr. Lindley, "when orchard ground is under-cropped with potatoes, the quality of their tubers is never good, because the quantity of light intercepted by the leaves and branches of the orchard trees prevents the formation of carbon by the action of the sun's rays upon the carbonic acid of the potato plant." . . . . . . Again, light retards germination by causing the decomposition of carbonic acid, thus reversing the normal processes by giving off oxygen and storing carbonic acid; whereas in healthy germination—as in the obscurity of the soil—the seed assimilates oxygen, and gives off a considerable quantity of carbonic acid. After germination, and as soon as the cotyledonary leaves emerge from the soil, the phenomena are reversed; the plant then exhales oxygen from its green surfaces, absorbs carbonic acid, separating and assimilating its carbon. That the process of decarbonization is consequent on the natural or healthy germination of the seed is of prime importance, as correlated with the parasitism of the mould, inasmuch as presenting conditions unfavourable to the vegetation of the latter. Were it otherwise, and all the conditions of mould-growth afforded by the embryonic germs, there would be great danger of its then utterly destroying the tiny germlets . . . . Again, the coloured parts of the flower—the petals, the stamens, and the styles—all absorb in considerable quantity oxygen, and give off in exchange carbonic acid. This respiratory process in the floral part goes on during the night as well as in the day. Hence remarks Decaisne:—"The noxious quality of the air in a room full of flowers, which is greatly increased by the exhalation of carburetted hydrogen, contributed by the volatile oils, to which the perfume of the corolla is due." The large white petals and numerous stamens of the opium poppy must thus assimilate oxygen in large quantities, and it need not thus surprise us to find that the mould never penetrates their tissues. There can thus, as I think, be no doubt that the comparative mould-immunity of variegated poppy plants, as also those growing under shade, is wholly attributable to the respiratory phenomena as above explained: the highly oxygenised juices and cell contents of plants thus conditioned, presenting a *nidus* altogether unsuited to the requirements of the parasitic mould.

(*b*, 17.***)—Our next and last topic for consideration, under the above head, is the comparative mould-immunity of poppy infected with the common, root-parasitic, *broom-rapes*. This, it must be confessed, is no great gain to the poppy, inasmuch as those broom-rapes, though never causing the devastating blights consequent on the extensive invasions of its tiny congener, the *Peronospora arborescens*, yet depending as they do on the assimilated juices of their fosterer, they so exhaust the latter in the post-floral stage, as to more or less suddenly arrest the excretion of drug, and cause the whole plant to dry up and ripen prematurely. It is to be observed, however, that poppy, even seriously infected with *broom-rapes*, may, and indeed generally do, vegetate quite as vigorously as do unaffected plants: the evil effects of the parasite appearing only in the post-floral or drug-yielding period. The species which affect the poppy, as I have previously stated, are the *Orobanche—Philipœa indica* and *O. cernua*: the former prevailing less or more generally over the opium districts of both agencies; the latter nowhere, I believe, common on the poppy, though proving a very general and often serious enemy to the tobacco plant throughout the above districts. It may be worth while to give a short account of the development and parasitism of the *broom-rapes* on the poppy. . . . . . . The seeds are extremely minute and produced in very great abundance, each plant, when in full vigour, producing several millions . . . . The germination of the seed is peculiar, but I have yet had few opportunities to study it carefully. The following outline is thus but very imperfect, and entirely from my own observations, as I do not know of any published account from which I can glean further information. The seed, as I have remarked, is extremely minute; the *testa*, or skin, thick and neatly reticulate, enclosing a copious fleshy albumen: at the base rests a minute embryo, which, from some arrest in development, simply consists of an ovoid knob of cellular tissue, alike destitute of cotyledons and radicle. The earliest stage of germination—or I should rather say of vegetation—observed as yet by me, presented the seed with a minute cellular knob protruding, and giving off from its base a slender radicular process. The knob is void of scales or anything resembling leaves. I have not observed it undergo any further development. The thread-like radicle, on the other hand, extends frequently to some little distance, in search, as it would appear, of the roots of a nurse plant; this found, it readily affixes itself, it may be on the very neck of the nurse, lower down on the main root, or on some of its ramifications. In either of the first forms the parasitism is severe, the parasite—having then direct access to the main nutrient store of its nurse—growing with great vigour: on the other hand, if on the branches of the root, it rarely acquires much vigour, and indeed, if at all distant from the main root, it really causes no great injury to the poppy. It may be as well to remark here that the parasite cannot form any attachment with a dry or hardened portion of the root; it is only on the soft developing parts that it fixes itself. At the point of contact between the rhizomoid process of the parasite and the root of the nurse plant there is an enlargement of both, and the apex of the former becomes quite fixed and partially embedded in the latter; the radicular connection with the seed now withers and dies. The base of the rhizomoid process enlarges and forms a tuberoid body, from which proceeds a slender stem, or rather scape, and a few abortive root-like processes. This primary scape-like process never apparently acquires much vigour, being generally arrested in an early stage of development by the stronger shoots which spring out from the tuberoid base. The active or absorbent root-processes of the parasite, it is important to observe, lie in and never penetrate beyond the cambium layers. Those found in the interior woody layers having simply been embedded by the exogenous enlargement of the root; just as occurs, for example in the case of the mistletoe suckers in its fosterer. As the old roots, however, are thus successively embedded, new ones spring out, invade the cambium layer, and thus afford a continued and copious supply of nutriment. The tuberoid rhizome of the parasite often acquires a large size, and gives off numerous scapes of from six to twelve or more inches high. These begin to flower about the same time as the poppy, and as I have said, when the parasitism is severe,—that is, when the attachment is on the main root,—cause a considerable reduction in the yield of drug. With this sketch of the development, &c., of the parasite, we will now illustrate the physio-chemical correlations of this mode of parasitism with the nurse plants comparative immunity from its leaf-parasitic enemy, the mould—*Perohospora arborescens*. Now, it has been shown by various authors that those *root* or *brown parasites*, as they are called, vegetating in atmospheric air, produce on that air very different modifications from those of *green plants* in analogous situations: in fact, they promptly vitiate the air, either by absorbing oxygen to form carbonic acid at the expense of the carbon of the vegetable, or, again, by directly disengaging carbonic acid in various ways. "In every stage of their vegetation," remarks Lory, "all the parts of these plants, whether they are exposed to solar light, or whether they are in the dark, absorb oxygen and give out carbonic acid in its place." This, as suggested by Dr. Lindley, probably explains the fact of brown parasites and fungi (which are characterised by like respiratory phenomena), being so universally destitute of green colouring matter, which we know results from the decomposition of carbonic acid gas. . . . . . . Now, in reflecting on the physiological relations of those root-parasites to their foster-parent, it is obvious that they must seriously interfere with the normal functions of the latter, by the continued withdrawal and waste of carbonic acid, which they can only derive from the nutrient sap of their nurse. Well, in the way above explained, this excessive extraction of carbon, as leaving a proportionate excess of oxygen, will induce very similar alterations in the chemical composition of the nutrient juices to those already recorded, as obtaining in plants with white variegated leaves, and those growing under the shade of trees. Obviously, then, there is a complete concurrence in the evidence of the above illustrations, and this confirmative of the view that, while the normal respiratory processes of the leaf are favourable to the development of the poppy-mould, those of an abnormal character, entailing the exhalation of carbonic acid, and the absorption and assimilation of oxygen, are, on the other hand, highly unfavourable to its extension..

(*b*, 18.)—Relations of the poppy-mould to the morbid appearances of its nurse-plant. "Fungi," observes Mr. Berkeley, "were long regarded as the mere creatures of putrescence, and therefore the *consequence*, *not* the *cause*, of *disease*. A more intimate acquaintance with their structure and habits has, however, removed much of this prejudice, and almost everyone now is ready to acknowledge what a weighty influence they have in inducing diseased conditions, both in the animal and vegetable organisms. . . . . Though, like other minute bodies, they may obstruct the minute cells of the lungs, there is no reason to believe that they induce epidemic disease, such as cholera or influenza, according to a once somewhat prevalent opinion, whatever their abundance may be, or however easily they may be collected, as some assert, at the mouths of sewers, or in other situations likely to induce miasma." The parasitism of those microscopic pests assumes two very distinct modes—*first*, the *endophyllous* and *endocauline*, terms respectively indicative of the invasion of the *inner tissues* of the *leaf* and *stem* by the *mycelium* of the mould; *second*, the *epiphyllous*, the *hypophyllous*, and *amphigenus*, of which in the first and second the *mycelium* spreads respectively over the *upper* and *under surface* of the *leaf*, and in the last indifferently over the *outer surface* of all parts of its fosterer. Now, the *second class* (which includes, amongst many others, the now too well-known mildews of the vine, the hop, and the rose) may in most instances be mitigated, if not always suppressed, by simply dusting the affected plants with sublimated sulphur. *Smut*, *bunt*, *rust*, *&c.*, *e. g.*, as belonging to this class may, as we have seen, be less or more effectively suppressed by simply steeping the seed-grain in solution of mineral salts, and drying with quicklime immediately before sowing. The whole of the *epiphyllous* series are thus, indeed, less or more amenable to the remedial or suppressive measures adopted by the agri-horticulturist. The other series, however—the *endophyllous* and *endocauline*—have hitherto run their course of destruction in spite of all so-called remedial or suppressive applications, invading, destroying, or at least permanently injuring the inner tissues of their fosterer, ere they emit their aerial or spore-bearing shoots: the ordinarily prescribed remedies have thus proved altogether useless. Obviously, then, we have hitherto been greatly at fault in the treatment of the latter class of fungoid affections, and this in not directing ourselves to the chemistry of the fostering or nurse-plants, and by special applications (*acid*, *saline*, *or alkaline*) to the plant, induce, if possible, such chemical or constitutional changes as will render them no longer favourable to the development of the mould. I have illustrated the effects of chemical changes in the cell-tissues and contents of the poppy in correlation with its mould, and I have no doubt that a series of judicious experiments, from this point of view, would enable us to contend successfully with the most inveterate and hitherto irrepressible forms of fungoid affections.* I would here specially direct attention to those of the *potato* and *silk-worm*, the former as being unquestionably caused by the *Perenospora infestans*, and the latter—the well-known *muscardine*—by a species of a cognate genus, the *Botrytis bassiana*, a fungus not confined as it would appear to organisms with an *ærial respiratory system*, but even affecting those of an *aquatic* character, as *gold-fish*, *frogs*, &c., in their different stages. The *gold-fish* fungus was formerly regarded as an *algæ*, and best known as the *Achlya prolifera;* but, according to one of the highest mycological authorities—the Rev. M. J. Berkeley—it is nothing more than an aquatic form of *Botrytis bassiana* of muscardine notoriety. . . . . As regards the potato and its mould, observations have been largely directed to the selection of varieties constitutionally unsuited to the mould, and this certainly with some little temporary success. By directing attention, however, to the chemistry of the plant, and in the first instance making careful observations on the effects of the mould on plants with variegated foliage, I do think a more permanent success might be attained. It is indeed highly probable that the tubers of such plants would, in the first instance, be very watery from the diminished secretion of starch, but I do not doubt that, if the mould could thus be driven from its old nurse, a careful and continued selection of the most copious starch-producers of the new race would again redeem the *quondam* starch-yielding quality. . . . . . . If I am not greatly mistaken, we have in this correlation of the processes of oxygenation and decarbonisation on the one hand, and the degree of infection by the mould on the other, an explanation of the following phenomena remarked upon thus by the late Professor Johnston: Commenting on the peculiar qualities of different varieties of the potato, he says:—"These varying proportions of starch are of much moment to the practical farmer at the present time, inasmuch as *the certainty of the growth*—exemption from murrain being, I presume, implied—*of the potato, when used as seed, appears to be the greater the smaller the percentage of starch.*" . . . . . A passing suggestion on the *silk-worm* and its *mould-pest*: the *poppy*, the *potato* and the *silk-worm moulds*, as we have seen, are all very closely allied, and we may thus, as I think, safely assume a considerable similarity in their chemical propensities, *i.e.* their *likes* and *dislikes*, as in the case of the poppy-mould. We have, I think, afforded unquestionable evidence of *its* particular likes and dislikes. Reflecting then, on this, and the great and continued ravages of the mould-muscardine in one or other of the many silk-rearing districts—in all parts of the temperate and tropical zones—from season to season, it is certainly desirable that experiments should

* In the above mode of suppressing the Peronospora tribe of moulds by artificially inducing alterations in the plant's chemistry, we have an analogy in the therapeutical treatment of various skin-diseases which are primarily due to the attack of parasitic fungi. Commenting on the relation of fungi to certain cutaneous disorders, Mr. Berkeley observes that "a few spores rubbed into the skin, or inserted in it, soon produce the disease known by the name of *Porrigo lupinosa*, and experiments have lately been made which tend to show that this immediate influence is greater than has been generally suspected Dr. Lowe has induced skin-diseases by inoculation with the granules of yeast, and he is inclined to attribute a great deal more to the agency of fungi than has hitherto been allowed.—(See *Lancet*, 17th September 1859). An exact knowledge of their influence, whether externally or internally, meanwhile is producing a better mode of treatment, such *salts* being administered with good effect as are fatal to fungal growth.—"*Outlines of British Fungology.*"

be made on the effects of feeding the silk-worm on leaves of the *variegated* mulberry, or the younger, inner, and less or more *blanched* leaves of the lettuce. It would be an inexpensive experiment, and may probably afford results of high importance to the silk-grower. Other herbaceous plants, with perceptible acid qualities, might also be tried as 'food-stuffs.' I need not dwell further, however, on these topics in this treatise, though I do hope the suggestion will not be altogether lost sight of by any of my readers at all interested in the above branch of industry. . . . . . . Let us now pass on to a consideration of the *relations of the mould to the poppy-blight*. The influence of parasitic fungi to induce disease in perfectly healthy tissues is now a well-known, and indeed generally admitted, fact, and of this I have unquestionable evidence in the case of the poppy. The following instance will serve to illustrate:—In the season 1874-75, prior to the outbreak of mould in my experimental plots, all the more advanced crops were in good health and vigour. They also continued in fair health even after the mould had bespeckled less or more every leaf; but during that period the *mould*, it is to be observed, was *copiously fertile*. Now, as I have already explained in this mode of development, the mould-parasitism is comparatively innocuous: the spawn or *mycelium*, apparently exhausted of its juices by an excessive fertility, simply dries up with its matrix, transmitting no infection to the environing or uninvaded tissues. Subsequent to this, however, the mould assumed a decidedly virulent form of development; it ceased sending out its fertile or spore-bearing branches, and a *barren mycelium* appears to have invaded the whole leaf-tissues, which, in its decay, caused the death of the whole leaf. In many cases I have observed plants comparatively healthy one day, thus suddenly overrun with a barren mycelial growth, withered and dead by the close of the following day. Under such circumstances, had the weather been cold and damp, I feel convinced that the blight would have rapidly assumed a very serious character. As it was hot and dry, however, the plants simply withered and dried up.

(*b*, 19.)—Presumed periodical recurrence of the mould affection on the poppy in a virulent form. This is an important topic, to which my attention was first drawn in looking over a table drawn up by Mr. Abercrombie, as an appendix to Mr. Money's memoranda, on the opium conference at Patna in July 1873. In this table the average drug returns of the Gya and Tehta divisions are shown—from the season 1851-52 to 1872-73—by way of comparison with those from three districts to which opium culture had been only lately introduced. In going over these, I was struck to observe that they exhibit very regularly a minimum (beginning with the unquestionable blight season of 1870-71) return of drug every third or fourth season. The apparent exceptions would, I am sure, be fully explained by a comparative examination of local weather conditions, which, of course, are most important factors in such deductions as the above. . . . . . I lay the more stress on these periodical minimum returns in the Gya and Tehta divisions from the following observations:—Thus, taking as a starting-point the season 1870-71, when we know that blight seriously devastated the poppy—this was in the latter end of February and

March—I pass on to the following season, in which, from personal inspection of the crops generally throughout the Behar Agency, I know that mould was rare in the extreme on the poppy. In 1872-73 it was locally prevalent, but nowhere caused any damage to the crops. In 1873-74 it was everywhere abundant in a *highly fertile* form, but, as I have remarked, it did not even then cause any perceptible decrease of drug. We now pass on to the season 1874-75. This season I observed that mould was very prevalent on all the crops which I had visited, but assuming as it did a highly fertile mode of development until the close of February, it did not at all alarm me as in the preceding year; it did not in any tangible way detract from the vigour of the crops. About the beginning of March, however, it assumed a different and decidedly virulent form of development. This was in producing a barren *mycelium* only, the results of which, as I have already shown, were the sudden arrestment of drug-secretion, and ultimately the premature death of the whole plant. This resulted in a decreased average return of 1*s.* 7¼*c.* per beegha on that of the preceding year; and I am strongly of opinion that, but for the prevailing drought, it would have fallen quite as low as that of 1870-71—that is, 3*s.* 12*c.* per beegha. From these personal observations I was thus rather prepared for the periodicity in the mould attack, of which we are afforded unmistakable evidence in the Gya and Tehta returns, for the last quarter of a century or so. In conjunction with my own observations, these crop statistics indicate intervals of from three to four seasons in the appearance of the mould in a more or less severe blight form. Admitting, then, the operations of a law of periodicity, I would explain the apparent *triennial or quadrennial recurrence of mould in a virulent form*, thus:—*First*, I am led to assume, on a careful reconsideration of the results of all my observations and experiments, that the degree of virulence, or at least the particular form—*i. e.* the *dry*, or *humid*, and *rotting*—is to a certain extent modified by prevailing atmospherical conditions during the latter stages of the mould's maturity, which, as a rule, is from about the close of February until the middle of March. Again, however, in seasons when the mould has attained a very extensive development on the crops, it, irrespective of the weather, tends to induce certain obscure chemical changes in the cell-contents and juices of its fosterer, which would appear to entail an active resumption of the *vegetative function* and the *complete abeyance of the reproductive*. Now the *mycelium* or spawn is the sum total of the mould's vegetative system, and on this its organizing forces are concentrated, until it exhausts itself by completing the invasion of all the previously uninvaded leaf tissues. At this stage, then, as I believe, the weather largely affects the results. Thus, should dry and hot weather prevail, as it did in 1874-75, the parasite and its fosterer will less or more quickly dry and wither up, and, according to the stage of maturity of the fosterer at which this may occur, will the mould be less or more prevalent in the following season's crops. Again, should a low temperature prevail with damp and cloudy weather at the above stage, the probability is that we will have a most virulent blight: the mycelium then rotting and exciting a *quasi*-fermentation in the leaf-tissues, so that the whole parts of the plants suddenly become soft and putrid. This appears to have been the case in 1870-71. Now, it would appear in those virulent and moist modes of development a very large proportion of the protoplasmic granules, or mycelial particles (on which the recurrence of the mould from season to season mainly, as I believe, depends), are doubtless destroyed by the premature death of the foster plant; hence we may anticipate that the following season's crop will be but very sparingly affected with the mould. Again, on the foregoing hypothesis, as the mould attains its periodical crisis, so to speak, under dry and hot—or the converse, a moist and low—temperature, its triennial or quadrennial recurrence in a really virulent form may be predicted. That there has been such periodical fallings off in the average drug returns is, I think, clearly enough shown in column 16 of my table (*vide* Appendix, table L.) of the average returns of the several divisions ot the Behar Agency for the 24 seasons ending 1874-75. This column gives the average of the five divisions south of the Ganges. I have excluded all the north Gangetic divisions as comprising a considerable proportion of naturally irriguous lands, and the returns from which, as might be expected, are extremely variable, the crops being of course so largely dependent on season and weather Again, in column 13 of the above table, I have given the general average of all the divisions of the agency, and in column 14 those of the three north Gangetic divisions, in which the lands nearly all retain sufficient natural moisture for the maturation of the poppy—these are Tirhoot, Motiharee, and Bettiah. By a comparison of the returns from these divisions with those of the two succeeding columns, it will be seen at a glance how poorly and irregularly productive they are. . . . Column 15 shows the average of the three north Gangetic divisions, in which considerably more than half of the lands require regular irrigation. It will be observed that, relatively to those of column 14, there is a considerably higher rate of production, while at the same time they do not attain that of the universally-irrigated districts on the south of the Ganges, the results of which are shown in column 16 of above table.*

(*b*, 20.)—I will now briefly notice a few other parasitic fungi, less or more common on our poppy crops, and the opium itself, in the godowns.

(*a*)—*Sporocybe.*—A genus affecting the decaying parts of plants, and usually forming a blackish stratum thereon. The species have erect, simple, or branched peduncles, terminating in a capitate head studded with spores. The species found on the poppy much resembles the *S. bulbosa*, chiefly distinguished by its rigid, erect peduncles, slightly inflated at the base, and ending in a globose head of brownish-coloured spores. As affecting only the dead organs of the poppy, it is, of course, quite innocuous, and only alluded to here as being of common occurrence on the decaying parts.

(*b*)—*Helminthosporium.*—The species of this rather extensive genus of dark threaded moulds affect rotten wood and the decaying parts of plants generally. They have a gelatinous or indistinct mycelium, from

* I regret to state that the mould abounds in all the more advanced crops this season, even now—December—but this in the fertile mode, so that it is not likely to cause much injury to the crops. From its past history, however, we may almost with certainty anticipate its development in a *dry* or *moist* blight form, according to the state of the weather, next season.

which spring up erect, rigid, fertile filaments, terminating in large less or more elongated, often club-shaped, many-septate spores of a brownish-black colour. The species occurring on the poppy has erect septate filaments, with oblong and club-shaped, 6 to 10 septate spores.

(c)—*Macrosporium.*—A genus affecting similar habitats to the preceding, and distinguished from it by its large, transversely and vertically septate spores. Species of this genus are very abundant in India, but are perfectly innocuous to vegetable life, springing up only on the rotten or decaying parts of plants. The spores of this and the preceding genus are among the most abundant of the organic products found in the examination of the air at Calcutta.

(d)—*Cladosporium.*—A genus affecting both decaying animal and vegetable substances, and found in nearly every habitable part of the globe. *C. herbarum* is the species found on the poppy, forming thereon olive-green patches, which consist of jointed microscopic threads more or less varicose, simple, or branched, and bearing on their sides oblong or elliptic spores of an olive-colour, with one or two transverse divisions. It is very common on the older gummy exudations of the poppy, and also frequent on the injured capsules; indeed, on all injured or decaying parts.

(e)—*Aspergillus.*—A genus found everywhere on decaying substances and accelerating decomposition. A well-known species is the *A. glaucus,* which forms the *blue mouldiness* on cheese. It is distinguished by its necklaces of spores, rising from a less or more globular head, and supported by erect, septate, microscopic threads.

(*f*)—*Dactylium.*—A genus of thread-moulds found on the decaying or living tissues of plants and animals. The species are distinguished by their erect, jointed, and branched hyaline threads, bearing at their tips septate spores. *D. roseum,* the species found on the poppy, is thus described by the Rev. Mr. Berkeley:—"It consists of a creeping mycelium, from which arise short erect threads, crowned above with a few obovate uniseptate spores. The mass is first white, but at length acquires a pale rose colour, by which it is readily distinguished. The plant grows very abundantly on various objects, whether dead or living, and is sometimes highly destructive to cucumber plants, forming broad patches on the leaves and stems. It occurs also not unfrequently in closed cavities, as in nuts, to which it must have made its way from without through the tissues. A solution of *bisulphide of soda,* or indeed anything which contains sulphuric acid, will facilitate the destruction of this mould when requisite." The pale rose-coloured patches of this mould are very common on the poppy in moist, warm weather, occurring alike on the leaves and stems, and in the interior of the capsules, then densely webbing the seeds. It is very common in capsules which have been injured by grubs. In the opium godowns, indeed, as on opium everywhere, when exposed to a moist and high temperature, it evidently finds a favourite *nidus,* covering the surface with its rosy web, when left for any time undisturbed. Dr. Durrant, the present Principal Assistant in the Behar Agency, however, informs me that it does really no injury to the opium. His only fungoid dread is the black-mould—*Mucor mucedo*—which will be subsequently described.

(*g*)—*Sporotrichum.*—A genus of obscure thread-moulds, affecting decaying vegetable substances. They have tufted, jointed, ascending threads, with spores at first concealed, simple, and scattered. A species apparently belonging to this genus is found on the roots of the poppy. It occurs in oblong or roundish patches of a strawy colour, the threads forming a closely woven web, and bearing numerous minute subglobose spores. Plants with their roots affected by this mould have been sent me by the Sub-Deputy Opium Agent of Chuprah. The plants had withered in the ground; the roots were covered with the above mould, and had assumed quite a dry and woody texture. I suspect this mould had been the main cause of the destruction of the plants.

(*h*)—*Trichoderma.*—A genus found on decaying wood and other parts of plants. It is characterised by a roundish peridium, composed of interwoven, branched, and jointed filaments, at length disappearing in the centre; spores minute and spread over the disc. *T. viride* is not at all unfrequent on the base of the stem and roots of the poppy, but generally confined to diseased or injured parts. It forms roundish, intertangled tufts of snowy-white threads, on which rest numerous globose spores of a dusky-green colour.

(*i*)—*Mucor.*—The typical genus of the mucorinous moulds, characterised by a globose sporangium, into which the tip of the stem often enters in the guise of a clavate columella, and indefinite sporidia produced irregularly in the cavity: the spores are mostly elliptic.—(*Berkeley.*) . . . . *M. mucedo* is the blackish-coloured mould so frequent on the opium shells during moist weather. It has a dense cobweb-like mycelium, consisting of tubular, jointed, simple threads, which bear at their apex a roundish membranous spore case, at first white, but which ultimately with the spores assumes a brownish-black colour. Dr. Durrant, the Principal Assistant in the Behar Agency, refers to it as the only serious cause of injury to which the China opium cakes are liable. It appears to destroy the aroma and other physical qualities of the opium if allowed to affect it seriously. With regard to the conditions favourable or otherwise to this mould on the cakes, Dr. Durrant remarks :—"I am much inclined to attribute it to the use of an undue proportion of lewa, as it is a well-known fact that all adulterated opium of the kind and quality generally confiscated as unfit for use, if kept for a short time, will generate this fungus to any extent. This fungus also may be seen to perfection during the rainy season on the surface of all contraband opium classed as fourth quality, which, as a rule, is chiefly composed of foreign extracts, and is kept in large wooden boxes until destroyed. The only remedy for infected cakes is to strip off at once all affected parts of the shell, and to replace it by a new one well smeared with fresh lewa." A moist and hot atmosphere is peculiarly favourable to its devlopment and rapid extension, and really the only practical mode of suppressing it, for example, in our opium godowns, as in other closed structures, is to supplement free ventilation with a perfectly dry atmosphere—conditions which, throughout the rainy season at least, could only be secured by introducing hot air pipes or other heating apparatus into the godowns. The black mould is of that class technically called *hysterophytes*, which chiefly affects dead or decaying matters, and, like many others characterised by a high selective power, absorbing and assimilating nutritious and rejecting noxious matters, so as to flourish amongst the most poisonous of chemical substances, if not of a corrosive nature. It is thus useless to attempt its suppression by the artificial application of mineral salts, &c., to its *nidus*.

5. *The injuries caused by insects.*—The following are the most destructive of the insect pests with which the poppy has to contend in one or other stage of its growth; some of them attacking the plant in the field, others infesting and causing much injury to the seeds in the rainy season in their store-pots.

(*a*)—*Noctua.*—The caterpillars of two species of dart-moths, apparently belonging to the genus *Noctua*, are rather serious enemies to the poppy. The caterpillar of the first species is somewhat cylindrical and depressed above, from 1¼ to 2 inches long, and rather stout in proportion to its length. It is of a dull greyish-brown colour, with two lateral stripes of a pale lilac colour. The head is horny, with the eyes and jaws black. When fully mature it buries itself in the soil, forms an oblong cell of earth, about 1¼ inch long by ¾ of an inch deep, and therein, in due course, changes to a rusty-brown-coloured chrysalis. The upper wings of the moth are a glossy greyish-brown, marked somewhat like the *gamma-moth;* the under wings ash-grey, the horns pectinated, the head and collar greyish, the body similar to the upper wings, or rather darker. The caterpillars of this species prove especially destructive to the young crops in dry seasons; then often so abounding as to strip beegha after beegha of plants in a few nights. Their ravages, however, may be very effectively checked by dusting the young crops over with quicklime, or a mixture of that and finely-powdered charcoal. In the *common crow* and the *mynas* these caterpillars have serious natural enemies. During the day they rest in their burrows, but are readily dislodged by irrigation, and even appearing on the surface in moist cloudy weather. It is curious to observe that, while a dry westerly wind prevails, the *crows* and *mynas* (ever vigilantly haunting the caterpillars), follow the tract of the irrigator, whereas with a moist easterly wind they are indifferently dispersed over the field, well aware that their caterpillar prey are then everywhere near, or on the surface.

(*b*)—*Noctua sp.* 2.—The caterpillar of this species varies in shade from dull-green with transverse brownish bands, to ash-colour, with central and lateral stripes of ashy-brown. When full grown it is from an inch to an inch and a quarter long. It then bores its way into the stems and capsules of the poppy, and changes into a reddish-brown-coloured chrysalis, from which it emerges in from six to eight weeks as a moth. The individuals of the latter differ considerably in colour: *one series* having both upper and lower wings of a pale brownish yellow colour, with a broad intramarginal band of dull-brown; a *second series*, have both upper and lower wings of a dull silvery-grey, with a mouse-coloured intramarginal band; whereas the *third series* have the *upper wings* of a pale clay-colour, the lower tawny-grey, with an intramarginal band of smoky-brown extending over both pairs. In repose the wings are horizontal; and, from tip to tip, about 1¼ to 1¾ of an inch. The caterpillars of this species attack the maturing poppy, feeding alike on the leaves and seeds. The young caterpillars are of a nearly uniform dull-green colour, and these may be found on the lower surfaces of the leaves. With the maturing plant they gradually acquire a dull-ash colour with lateral stripes of ashy-brown. They then chiefly affect the maturing capsules, selecting only the drug-exhausted class, which they quickly bore through, quartering in the interior and feeding on the seeds. A single caterpillar will eat, or at least render useless, the whole seed contents of a full-sized capsule ere attaining its full maturity and changing to the chrysalis. It is interesting to observe that the caterpillars carefully avoid the younger and drug-containing capsules: the milky juice of which, as I know from experiment, has a strong narcotic influence on them, that being for some little time preceded by quick convulsive-like twitchings. . . . In the caterpillar and chrysalis state this moth is vigilantly hunted by the "*Ab-lak Myna*" of the Hindoos, the *Sternopastor contra* of the ornithologist. The caterpillar, affecting as it does the lower surface of the leaves of the advanced plant, and the interior of the capsules, can only be kept artificially in check by hand-picking.

(*c*)—*Acheta.*—The crickets, as this familiar genus of saltatorial orthopterous insects are popularly called, are closely allied to the *grasshoppers* and the *locusts*—those periodical scourges of the vegetable kingdom in all tropical and intertropical countries. One species of this genus, much resembling the common field-cricket of Europe, *A. campestris*, often commits sad havoc on the young poppy crops, its ravages extending from about the middle of November to the beginning of January. This insect carries on its depredations chiefly during the night, and secretes itself in the soil during the day. It is of difficult suppression, and ever tends to increase in all tracts of country where there is an absence of forests to harbour their natural suppressors—insect-feeding birds. This cricket has, however, also vigilant foes in the *sand-wasps* and the *chrysida* or *golden-wasps*. The only simple and really practical mode of mitigating their ravages is to dust the young crops with a mixture, in about equal parts, of finely-powdered charcoal and quicklime, repeating as may appear necessary, until the young plants have got beyond the stage of the cricket's attack.

(*d*)—*Gryllotalpa*, the technical name of the genus to which the well-known *mole-cricket* belongs, also familiarly known in England as the churr or jarr-worm, and the eve-churr or earth-crab. It is the "*oo-chingrah*" of the Bengalees and the Hindustanees; the *Gryllotalpa vulgaris* of the entomologist. "It lives chiefly under ground, and is perpetually on the move, burrowing like the mole, and, even like it, throwing up heaps of soil from its tunnels. The full-grown insect measures fully two inches in length and four lines in breadth. The female forms a nest of clay about as large as a hen's egg, and deposits therein upwards of 150 ova, in the preservation of which it takes the greatest care. Wherever a nest is situate, avenues and entrenchments surround it; there are also numerous winding passages which lead to it, and the whole is environed by a ditch, which present an impassable barrier to most insects. In the evening it issues from its retreat and continues producing less or more throughout the night a shrill jarring note. It is a night-feeding insect, and of a most destructive nature, cutting indiscriminately the stems of any plants which may be near its burrow, and carrying portions of them into it for daily consumption. By far the best plan to catch the mole cricket is to flood its burrow, which usually forces it to the surface, where it may be caught and destroyed. Failing a simple application of water, a little cocoanut or linseed oil poured on the top of the water will effect the purpose, inasmuch as, when the oil-bearing water reaches and subsides upon them, they must at once come to the surface or die in their burrows; in either case, the oil is thus fatal to them.

(*e*)—*Thrips.*—A genus of minute hemipterous insects, and a serious enemy to nearly all forms of vegetation in dry and hot seasons: it is, however, extremely impatient of moisture, revelling in drought and heat. I quote the following remarks on the genus from the "*Gardener's Chronicle*" *of* 1841, *p.* 228:—"The species of this genus vary much in colour, some being black, others have wings branded with white, but the general tint of the larvæ and papæ is yellow ochre. Their bodies are much depressed, and much broader than any other part in the female; the mouth is placed under and at the hinder part of the face, and forms a short conical rostrum, lying when at rest close to the base of the fore-legs. The eyes are rather large and coarsely granulated, and there are generally three ocelli. or simple eyes, on the crown of the head; the horns are eight or nine jointed, often appearing to be united, when they look as if only six or seven jointed, especially in the larvæ state. They are either wingless or have four wings, which are narrow and lie down the centre of the back, the edges being ciliated with long hairs; the legs are short, the feet being formed of two joints with a vesicle or little bladder at the apex, but not any claws. The larvæ resemble the perfect insect in form, but are often of a totally different colour; their bodies are soft, and they have no ocelli. The papæ are also similar, but the wings are sheathed, and the horns are generally thrown over the head. Some of the species are very active when they have arrived at their perfect state, running fast, skipping, and flying well; and they are able to walk about in their previous stages." The *T. adoidum* is apparently the species which attacks our poppy, often causing considerable damage to the crops in dry seasons: it is the "*Lhi*" or "*Lehi*" of the natives. Its injuries are due to its habit of piercing and imbibing the juices of the leaves. If the insects are observed, a globule of blackish fluid will be seen to exude from the abdomen, which is soon deposited on the leaf, and as this is given off many times a day by numberless insects, the whole leaf surface soon becomes so speckled with this glutinous matter, that the pores of the leaves are stopped, and the leaf ultimately destroyed. I know no practical mode of mitigating the injuries of this class of insects in the field. The syringing and sulphurating affected plants, as practised in hot-houses, is, of course, simply impracticable in our poppy-fields.

(*f*)—*Acarus.*—A genus of arachnida, commonly called mites, and with certain members of which everybody is familiar; for example that occurring in old cheese—*Acarus domesticus*—the cheese-mite (or *Acarus longior* upon Gruyére and Dutch cheese) in *flour*, *Acarus farinæ*, the flour-mite and even upon preserved cream, *Acarus* *lactis*—the cream-mite. Some also occur on the skin of man and animals, causing those disgusting diseases known as itch and mange.

A. telarius, the *scarlet mite*, or *red spider* as it is usually called, is the species affecting the poppy, the tea, coffee, and cotton plants, indeed more or less the whole train of our domesticated plants; such is the omnivorous habit of this minute but destructive mite. It is thus described in the *Gardener's Chronicle* for 1841, *p.* 164:—"The red spider, if magnified, looks like a crab of an oval form, with the legs so arranged that two pairs are directed forward and two pairs incline backward; it has a few long scattered hairs, and is of a somewhat transparent yellowish-white, more or less inclining to orange, with a blood-coloured dot or spot on either side of the thorax. The larger specimens, which appear to be females, have a bright chesnut-coloured body, the forepart of the thorax being ochreous, while the smaller ones have a lead-coloured patch on each side. Unlike spiders, the thorax and body are so united that they form one mass. The head is narrowed and rounded, and from under the nose projects a short rostrum, composed, I believe, of two lateral valves, enclosing two fine bristles, which can be thrust out at the pleasure of the animal . . . . The female is viparous and exceedingly prolific: the eggs hatch in eight days; and it is very remarkable that, when first excluded, the young red spider has only six legs, the third pair being wanting; this pair is acquired when the insect changes its skin." As in the case of the thrip, the injuries of this mite are most serious in hot and dry seasons. It then spins for itself a delicate closely intertangled web, which overlies the surface of the leaf and absolutely suffocates the plants, while underneath it is at work piercing and imbibing the plant's juices, causing little yellow spots on the upper surface, which spread and give to the whole a seared and yellow look, and thus ultimately causes the death of the plant . . . . . . It is extremely impatient of cold and moist weather, and is thus only to be dreaded on the poppy in dry seasons. Like the thrip, its attacks are scarcely at all mitigable in the field.

(5, *a.*)—These, then, are the chief insect foes of the poppy in our fields, and we will now pass in brief review those that attack and feed upon the seed in our store-rooms.

(*a*, 1)—*Tipula.*—A considerable genus of insects, the grubs of which are serious enemies to the products of our fields and gardens. The larvæ of one species specially affects and often causes much damage to the poppy-seed in our store-rooms. The grubs are about three-fourths of an inch long, slender, and tapering, and of active movements, though destitute of feet. The papæ are rather shorter, but stouter than the larvæ: they differ in colour, the latter being white with a brown head, the former a nearly uniform pale dirty brown. The gnat is about 3-8ths of an inch long, the wings grey and iridescent, with brownish-coloured nervenes; the body black, with white hairs indicating the segments of the abdomen: they have six long slender and tapering black legs, with base of thigh and shanks pale brown. The larvæ are ravenous, and where abounding destroy large quantities of seeds, leaving their outer coverings adhering together in pellets.

(*a*, 2)—*Bruchus.*—A specimen apparently of this genus is very common, infesting the poppy-seeds in our store-pots and causing much damage. It completely shells the seeds, leaving them matted together in masses, with a mould which springs up on their excrements. This beetle is about two lines long; body pale-brown, the clytræ or wing-covers blackish-brown with longitudinal striæ of a darker shade. The larvæ of this species are apparently more destructive than the perfect insect.

(*a*, 3)—*Phaleria and Haltica.*—Two minute beetles, apparently members of the above genera, frequently abound amongst the poppy-seed in our store-pots. They cause much damage, penetrating and completely shelling the seeds. The females also deposit their eggs in the interior of the seed, thus affording the tiny grubs a readily available supply of food. The Phaleria much resembles, but is somewhat larger than, the *C. comuta*, or maize-weevil, well-known in Indian granaries from its destructiveness on the grain of that plant. The Haltica species is smaller than the above, ovate in outline, about one line in length, the wing covers of a clear metallic brown.

(*a*, 4)—*Calandra.*—One species of snout-beetle is not unfrequently found in company of the above in a few of the store-pots; in no case, however, have I found it abundant. It is smaller than the *rice*-weevil (*Calandra oryzæ*), of a dull reddish-brown colour, with furrowed wing-cases. It appears to be destructive in both the larvæ and perfect state.

(*a*, 5)—*Tetranychus.*—A genus of *Arachnida*, or spiders, of the order *Acarina*—mites—and family *Trombidina*. I am unable to determine the species specifically, but, as abounding amongst our seeds for two seasons past, I may temporarily distinguish it as the poppy-seed mite. It is an extremely pretty little animal of a deep-red colour, smooth and shining, about one line in length. In outline and size it much resembles *Tetranychus cristatus*, but unlike it, its body is smooth and destitute of hairs. Its eggs are enveloped in cocoons, about an eighth of an inch in diameter. These little mites cause much injury to the poppy-seed in our store-pots and granaries, reducing the seeds to dust and chaff, and further damaging them with their copious glutinous excretions which, in drying, glue the seeds together in pellets or more or less bulky masses. Like the other members of its tribe, it multiplies with great rapidity, so that, though there may not be a single specimen visible when the seed-pot is closed, we need not be surprised to find them swarming in it when opened, *i. e.* four months later. Fortunately for this, as indeed for all the above noted pests of our granaries, we have a simple, effective, and perfectly practicable remedy in *camphor*. All that is necessary is to take a small quantity of this in a powdered state and sprinkle it freely amongst the seeds immediately before the pots are finally closed for the rainy season's storage. By adopting this practice, the pots on being opened will be found quite clear of one and all of the above pests.

6. *Birds.*—Of this class, the poppy has, as above noticed, its friends or protectors in the common crow, the minas, and other insectivorous species; *but it has also a very inveterate foe in the common rose-ringed parrakeet, the "totha" or "soogha"* of the Hindustanees.

It attacks the maturing capsule of the poppy, feeding, of course, on the seed. When undisturbed it lights on the flower stalk, breaks open the capsule, picks out the mass of the seeds, and passes on to another; on the other hand, if disturbed, it will dart suddenly from a considerable height, dexterously cut off a capsule, and carry it off to some neighbouring tree, where it may consume its contents at leisure. Abounding as these parrakeets do in many of the poppy districts, they cause much damage, if not sharply looked after in the early mornings and evenings.

7.—*Opium-consuming insects.*—According to Kirby and Spence (*vide* "*Introduction to Entomology,*" *7th ed.*, *p.* 135), "opium is a dainty *morceau* to the white-ants." This remark has its foundation in the following reference quoted as a foot-note in the above work:—"In examining ninety-two chests of *opium*, part of the cargo saved from the *Charlton*, previously to reshipping them from Chittagong for China, thirteen chests were found to be full of *white-ants*, which had almost wholly devoured the opium."—(*Article from Chittagong, November* 1812, *in one of the newspapers dated* 31*st July* 1813.) The above statement requires confirmation, or at least some qualification. On no occasion have I observed white-ants attack fresh and good opium, though quite open to them. I also know from experiment that in closing white-ants in a finely perforated box with a piece of fresh opium, that though they crawl over it, they never eat it, and are quickly narcotised. Again, while in this narcotised state, if allowed to remain in the box with the opium they never recover, though they generally do so if taken out before the narcotism is complete. It may be, however, that they really will attack and consume opium exposed for some little time to the action of salt water, as doubtless that in the chests under notice had been—which very quickly destroys its odour and bitter and pungent taste: it will no doubt also materially reduce its narcotic qualities, and may thus render it an innocuous diet, for those all but omnivorous insects.

APPENDIX.

Introductory remarks to Appendices A, B, and C.

The general results of my experiments and observations on the poppy have formed the subject of a Minute by the Lieutenant-Governor of Bengal, permission to publish which, in the appendix of this book, has been granted by His Honor. This is highly satisfactory to me, inasmuch as the difficulties I have to contend with in introducing new modes of culture, &c., are fully appreciated, and detailed in this Minute. Moreover, that these have been correctly anticipated by His Honor, is well shown in the following summaries—submitted subsequently to the drafting of the Minute—of the Sub-Deputy Opium Agents' reports, on the selected seed distributed by me last season. The first report is by Mr. H. W. Alexander, Opium Agent of Behar. From this it will be observed—where any opinion is expressed—that five only of the twelve sub-divisional officers are more or less favourable to a continuation of the experiments. In the report from Benares, the Agent, Mr. H. Rivett-Carnac, supplements the summary of his Sub-divisional Officers' reports by a concise and excellent critique, in which, while remarking that the results are not so conclusive or satisfactory as could be wished, he expresses himself as strongly in favour of a continuation of the experiments.

APPENDIX A.

Prolongation of the experiments in Behar in respect to the growth of the poppy and the production of opium.

Minute by the Lieutenant-Governor of Bengal, dated 13th September 1876.

Having recently had under consideration the reports received through the Board of Revenue regarding the enquiries and experiments made by Mr. John Scott during the last three years at Patna, respecting the culture and growth of the poppy and the production of opium, and having fully conferred with Mr. Scott himself, I desire to record the following remarks :—

This investigation was commenced by my predecessor's orders, and has been continued during my own time. The proceedings, conducted as they have been with much care and perseverance, and these reports, elaborated as they are with much knowledge and research, seem to me to show—

(1)—That by sowing seeds selected from the best plants, the poppy plant can be much improved in productive power as regards quantity and quality.

(2)—That by a further selection of seed, those varieties of the poppy can be grown which enjoy a comparative immunity from blight, fungoid, or other disease.

(3)—That by drilling of the soil, the early sown crop can be better secured, and the growth of the plant can be much promoted.

(4)—That by judicious use of irrigation during the time when the plant is flowering, and the skilful treatment of the opium-yielding capsule, the period of production may be prolonged, and the yield consequently increased.

(5)—That if manure of the right sort be applied a still further improvement may be effected.

(6)—That if the first four matters, as above mentioned, which are all within reach of the peasantry, at some trouble perhaps, but without any appreciable expense, be duly attended to, the yield of opium per acre may be much augmented beyond that of the ordinary average crop.

(7)—That if the fifth measure above mentioned which, as involving some expense, may not be so readily practicable, were adopted, then some additional improvement would be attained.

The establishing by practical and scientific proof of the fact, that the adoption of certain measures quite within our reach, so greatly augments the produce of opium per acre is very important.

If the knowledge of this could be brought home to the ryots, so as to be applied by them, then either a much greater quantity of opium would be produced from the present area, or else the present quantity could be produced on a less area. In either case the result (which would depend on the fiscal policy of Government at the time) would be of much consequence.

Even if the full augmentation of produce, as now anticipated by Mr. Scott, after actual experiment, should not be realized, still if some large degree of augmentation were attained, the result would be important, and the experiments worth continuing. I gather from Mr. Scott, however, that the experiments are year by year showing a probability of more and more augmentation, and that he now believes that it might become nearly double the present average yield—*vide foot-note.*

But it is one thing to establish a possibility, and quite another thing to ensure the possibility being so applied as to be realized. In other words, there is only the first step made when we show that if certain selected seed be used; if a certain culture of the soil be adopted; if a certain treatment of the capsule be carried out, all which may be done by the ryot with trouble only, and without expense, there will be a much larger produce; but the second step remains to be made, namely to gradually induce the ryots to adopt these measures for their own benefit as well as for the fiscal interest of the State. I say nothing here regarding manure, because however beneficial it may be, it cannot but cost something, and consequently the ryot will have some difficulty in procuring it. Though we may persevere in experiments in manuring, we can hardly hope that they will have immediate results. For the second of the two steps above mentioned, namely teaching and inducing the ryots gradually to sow the selected seed, to drill the soil, to treat the capsule, it is absolutely necessary that Mr. Scott should remain for the present in Behar. Otherwise the experiments, if not watched by their author, will be forgotten, the seed distributed among the ryots will be either thrown away by them, or be allowed to fail (so distrustful are they of new methods), the other improvements suggested will be spoilt, and the lessons learnt during the past three years at some cost and trouble will remain a dead-letter. Doubtless the Opium authorities will afford all the co-operation they can; but with their other duties they cannot adequately observe the trials and the results; indeed they can hardly be expected to possess the requisite scientific knowledge. On the other hand, their zealous co-operation will be required, for without that aid all Mr. Scott's skill and knowledge will not avail to overcome the *vis inertia* which the peasantry in this country always oppose to improvements in the first instance.

Already, that is, during last season, some small quantities of the selected seed have been sent to some of the opium divisions in the interior of the districts (departmentally called sub-deputy opium agencies), and have there been distributed among the ryots with some good effect. I am glad to hear favourable reports of the assistance in this matter specially rendered by two of the Sub-Deputy Agents, Mr. Peppe (Chota Nagpore), and Mr. Masters (Hajeepore). The season is now at hand when further quantities of seed will be obtained from Mr. Scott's fields at Patna. These should be distributed, under the general direction of the Board of Revenne, by the two Opium Agents (at Patna and Ghazeepore) among those Sub-Deputy Agents who may be chosen as having more than ordinary aptitude for introducing improvements. At the same time, there should be sent to them any directions which may seem expedient respecting the drilling of the soil and the treatment of the capsule.

The Sub-Deputy Opium Agent to whom this duty may be confided must carefully choose the ryots who are to be taught and induced to try the desired improvements; he must take proper measures to make them desirous or contented to make the attempt faithfully and earnestly, offering them some moderate and reasonable inducement with this view, according to circumstances. He must himself see that the selected seed is actually sown, that the soil is duly drilled, and, if possible, he should see the capsules, or at least some of them, manipulated. If he does not see all this personally, it will not be fully done by the ryot, and there will be more or less of failure, which failure, instead of being attributed to the true cause, will probably be ascribed to some defect in the new method. Such notoriously has been the fate of many attempted improvements in this country, and such might be the end of these experiments also, if we do not adopt due precautions.

If, then, the selected Sub-Deputy Agent feels himself able to undertake this sort of supervision, and really to see to the trial being made, then let the duty be entrusted to him. But if there be any doubt on this point, then it will be better that he do not undertake it at all. It is greatly preferable that a trial should not be made at all than that it should be made ineffectually or with any degree of efficiency short of the highest. For, by such half trials undeserved discredit would be brought on methods in themselves excellent, and more harm than good would be done.

But, however unwilling a ryot may be to try a new method, however sceptical he may be of its merits, and however much inclined he may be to discard it without proper trial; he is quick and willing enough to adopt it as soon as he sees it actually used and practised by others with undoubted success and profit. If, therefore, the Sub-Deputy Opium Agents, to whom the above duty may be confided, shall succeed in displaying before their opium ryots certain fields cultivated also by ryots, with a productiveness greatly exceeding that of ordinary fields, and this, too, with the application of care and trouble only, and without any extra expense, then we may be sure that other ryots will begin to follow the example more and more, and so by degrees the system will spread over the whole opium-producing area.

But I cannot repeat too often that if this result, or anything approaching to it, is ever to be attained, there must be care, patience, and perseverance exerted by our officers during several years.

The thanks of the Government are due to Mr. Scott for the good service rendered by him in this affair.

I rely much on the supervision to be exercised in this matter by the Opium Agents, Mr. H. Alexander and Mr. Rivett-Carnac, and upon the exertions of the Sub-Deputy Agents whom they may select to carry out the experiments. I shall always be glad to receive a separate report of service rendered by any Sub-Deputy Agent in this respect.

And I know that the Government may confide in the general direction to be maintained by Mr. A. Money, C.B., the Member of the Board of Revenue in charge of the opium department.

RICHARD TEMPLE.

APPENDIX B.

His Honor the Lieutenant-Governor of Bengal lately requested me to recapitulate the grounds for the belief that, by adopting the mode of seed selection, &c., as suggested in my annual reports, the average returns of opium might be fully doubled. This I did in a memorandum, which it may be as well to introduce here.

In the tabular statements comprised in my annual report for 1874, I have shown how greatly deteriorated the poppy crops are by the predominance of scanty drug-yielding plants, the average proportion of *scant* to *copious*-drug-produces being no less than 2·25 to 1! Now, it is clear that by eliminating all the scanty productive plants, and securing a uniform crop of the more copious producers, we would proportionately increase the drug returns: this is, I believe, perfectly practicable. Let us, however, in the meantime see as to the proportions of copious and scant drug-producing plants in the ordinary unselected crops of the agencies. I will allow, then, 27,225 plants per beegha (*i. e., one square foot* to each, though certainly a fairer average would be *six* or *nine inches* only), of which, according to the proportions above stated, 4,537, or *one-sixth* only, are of the copious drug-yielding class, the great bulk—22,688—of the plants thus consisting of the scantily-productive class. Now, for the comparative fertility of the superior and inferior class. To illustrate this I collected separately the drug from 50 capsules of both classes. Thus, in each instance, be it observed, the collection of the second incision on the capsule was taken as the average for the following estimate, and moreover in the *inferior class* this was confined to the *central and most productive capsule*, whereas in the superior class from two and three capsules on each plant were included. By confining the collection, as in the former class, to the *central capsule*, the contrast, which I will now show, would have been considerably increased.

The crude drug from 50 capsules of the inferior class weighed only 23 *grains*, whereas that from an equal number of the superior class was 140 grains, *i. e.* fully six and-a-half *times more crude drug*. From these data, then, the comparative fertility of one beegha under a selected and unselected crop may be thus shown in a tabular form:—

		Number of plants per beegha.	Crude drug, produce of 3 and 5 collections.	Assumed average of capsules on each plant.	Prepared drug in lbs Troy.
1—Unselected crop	Superior class	4,537	44·12	4	11·37
	Inferior „	22,688	21·76	4	7·25
2—Selected crop	... ...	27,225	264·44	4	88·14

It should be observed that *three* drug-collections, as given in the above table, is rather a *high average* for the inferior class, whereas, on the other hand, for the superior class, *five* is decidedly a *low average—vide* comparative tabulations in my annual report for 1874; seven collections would indeed have been a fairer average for the latter class. Even as above stated, however, the differences in the relative fertility of the selected and unselected crops is very striking, being nearly as 4·75 to 1. I do not think that I have here in any way over-estimated the results of a careful and continued selection of seeds from the most productive capsules for a few years, the basis of my belief being simply, as stated above, the practicability of *eliminating* the scanty from the really copious drug-yielding plants, and securing an unmixed crop of the latter only. The *improvement* of these again by selection will of course, as in all analogous *cases*, be the slow work of years. I have no doubt, however, that by attention to the above principle, even the most copious of our drug-producing plants now will ultimately prove as inferior to the improved races of the future, as are the former to their wild progenitors.

APPENDIX C.

Dated Bankipore, the 23rd August 1876.

From—H. W. Alexander, Esq., Opium Agent, Behar,

To—The Secretary to the Board of Revenue, Lower Provinces.

I have the honor to submit the information asked for in regard to the plants raised this year from the experimental seed supplied to the several Sub-Deputy Opium Agents by Mr. Scott.

2. The Sub-Deputy Opium Agent of Tirhoot reports that only in one case was the produce of the selected seed greater than from the ordinary seed, and this is accounted for by the failure in the land sown with the indigenous seed being much greater than in the other. The plants themselves were strong and healthy, and the cultivators were generally pleased with their appearance, but the yield of the drug did not come up to their expectations. Mr. Drake is anxious to make further experiments this season.

3. The Sub-Deputy Opium Agent of Hajeepore reports that no conclusion can be drawn from the average yield per beegha given in the statement furnished by him, as in his opinion they are unreliable, more especially when the average yield per beegha tells against the experimental seeds, as there appears to be a general impression that a low yield from experimental seed, compared with that from ordinary seed, will be made good to the cultivators in whose fields the

experiments are conducted by pecuniary compensation, equal in value to the difference between the two outturns of the drug; on the other hand, where the average yield per beegha tells against the ordinary seed, the fact may be taken as evidence strongly in favour of the success of the experiment. In twenty-four sowings the average produce per beegha was in six cases only in favour of the experimental seed.

4. The Sub-Deputy Opium Agent of Chuprah writes that, in the statement submitted by him, in nearly all cases the average yield from ordinary seed was higher than that from the experimental seed. He wishes, if any further experiments are to be made this year, to be supplied with the seed in September or early in October.

5. The Sub-Deputy Opium Agent of Alleegunge states that the plant from both seeds appeared equally strong, but that the produce from the local seed was far in excess of that from the selected seed.

6. The Sub-Deputy Opium Agent of Motiharee reports that, owing to the small scale on which experiments are made at present, no reliance can be placed on the results, as the cultivators mix the produce of their fields, and are not disposed to encourage any change being introduced. The plant raised in Mr. Cooper's own garden from selected seed was stronger and healthier in appearance than that raised from the ordinary seed. In the statement furnished by him, in fifteen out of eighteen cases the produce per beegha from the local seed was in excess of those from the experimental seed.

7. The Sub-Deputy Opium Agent of Bettiah has given no opinion on the subject, but has shown in a statement that in thirty-eight out of forty-six cases the produce from local seed was more than that from experimental seed.

8. The Sub-Deputy Opium Agent of Shahabad reports that, except in three instances out of fourteen, the ordinary seed had yielded better than the selected seed, and that in these three instances the excess produce was so very small that it could be considered only the result of accidental circumstances and not attributable to the superiority of the seed used. The plants raised from the selected seed at no time showed any perceptible superiority over those raised from ordinary seed, and Mr. King is of opinion that the selected seed, when subjected to the same influences as the seed ordinarily used, cannot yield a better crop to such an extent as to render it advisable to incur the expense and trouble which would necessarily arise by the general use in the department of selected seed of kinds, the ordinary seed, moreover, being much preferred by the cultivators themselves.

9. The Sub-Deputy Opium Agent of Gya states that the plants from the experimental sowings was not seen by him, but that the gomashtas report that the plants raised from the different kinds of selected seed did not differ much in healthy appearance or size from the plants produced from country seed: four of the selected varieties gave a greater and three a smaller yield than the ordinary seed.

10. The Sub-Deputy Opium Agent of Tehtah reports that no perceptible difference was found between the plants and produce of the two kinds of seed (selected and ordinary).

11. The Sub-Deputy Opium Agent of Patna gives no opinion in the matter, but from a statement submitted by him, it appears that in three out of twelve cases the experimental seed gave better results.

12. The Sub-Deputy Opium Agent of Monghyr writes that the outturn from the ordinary seed was in excess of, and better than, that from the selected seed, but that no absolute trust can be placed on the experimental sowings, as, although ordered to do so, it is impossible to say whether the cultivators keep the outturn from the experimental and ordinary seed quite separate.

13. The Sub-Deputy Opium Agent of Chota Nagpore reports that he watched the experiments this year carefully, and although the season was an unfavourable one in many respects, there could be no question of the superiority of the selected seed. The ordinary seed gave 2 seers 5½ chittacks, and the selected seed 2 seers 14½ chittacks per beegha, or 9 chittacks in excess: had the two been sown at the same time (the former having been sown on the 6th of November and the latter on the 2nd December), the results in his opinion would have been still more favourable to the selected seed.

APPENDIX D.

Dated Ghazeepore, the 21st August 1876.

From—H. RIVETT-CARNAC, ESQ , Opium Agent, Benares,

To—The Secretary to the Board of Revenue, Lower Provinces.

THE season having closed, I have now the honor, to report on the experimental sowing of selected poppy seed received from Mr. Scott.

In October last 23 maunds of selected poppy seed were received from Mr. Scott. This quantity was distributed amongst the several Sub-Deputy Opium Agents for experimental purposes as per margin. The Sub-Deputy Agents were desired to distribute the seed at their discretion amongst the cultivators, keeping a record of the quantity and description given to each cultivator, and watching as far as possible the plant from such seed. The following is a summary of the reports the Sub-Deputy Agents have now submitted on the result of the experiment.

	Mds.		Mds.
Ghazeepore,	3	Futtehgurh,	3
Azimgurh ..	2	Bareilly ..	2
Gorruckpore,	2	Lucknow ...	3
Basti ..	3	Fyzabad ...	3
Futtehpore,	2		
			23

2. *Ghazeepore.*—Mr. Turnbull reports that the seed germinated freely everywhere, and that the plant was healthy throughout the season, the capsules were of usual size, stood lancing from four to six times, the exudations were pretty free. The average produce ranged from three to 18 seers per beegha, and contrast favourably with the returns obtained from indigenous seed. He is, however, of opinion that any further distribution of foreign seed would not be appreciated by the cultivators, as they themselves are alive to the importance of selecting good seed for sowings. Their seed is selected from capsules which are most productive, and the indifferent return is not attributable to indifferent seed, but to indifferent soil.

3. *Azimgurh.*—Mr. Mendham states that, from a comparison between the plots sown with Mr. Scott's seed and adjacent indigenous seed plots, the return from the former would appear to contrast favourably with that obtained from the latter, but that the foreign seed is unfavourably received by the cultivators, and difficulty is experienced in getting them to sow it. The general average of the experimental sowing of Mr. Scott's seed is six seers six and a quarter chittacks, whereas that of adjacent fields, sown with ordinary seeds, is 5 seers 15¼ chittacks.

4. *Goruckpore.*—Mr. Matthews reports that the plants germinated freely and looked healthy. The capsules, however, were small, and did not yield juice to more than two or three incisions. The general average from Mr. Scott's seed was three seers, nine chittacks, three kanchas, per beegha, as compared with about six seers from indigenous seed. The cultivators do not like the foreign seed, and are not inclined to undertake a further trial.

5. *Basti.*—Mr. Ridsdale states that the plants germinated freely; their growth, however, was rather slow, they having suffered from heat and the extreme dryness of the season. The results were encouraging, the average was high, as being 8 seers 16 chittacks per beegha, but the average from indigenous seed, sown in a similar area of lands adjoining, was at the same time nine seers two chittacks per beegha. There was no marked superiority in the drug obtained from Mr. Scott's seed, the plants were similar in habit, and were chiefly distinguishable by the darker green of the foliage and stems, and the leaves being more serrated than the common plant. The cultivators are averse to the exotic plant, they consider the acclimatized native seed is more suited to the damp climate and soil of Basti. Some of the cultivators are of opinion that this foreign seed, when acclimatized, will be superior to the indigenous.

6. *Futtehpore.*—Mr. Campbell states that the results of the experiment were far from satisfactory. The plants from Mr. Scott's seed germinated well and looked promising, but the yield was much less than that from ordinary seed. Mr. Campbell, therefore, recommends that the experiment be given up: the cultivators are not in favour of it. This officer's report is meagre, general, and unsatisfactory, and further explanation has been called for.

7. *Futtehgurh.*—Mr. Anderson states that the seed was sent to him rather late in the season, and the consequence was that poor lands generally were secured for experimental purposes. There was no perceptible difference in the plant, except as to the colour of the pods. Generally the selected poppy seed plant was not finer than that from local seed. The result was far from satisfactory. The general average of experimental seed was three seers three and-a-half chittacks per beegha, compared with seven seers three-fourths chittacks per beegha indigenous seed. Mr. Anderson is of opinion that these repeated failures from experimental seed do more harm than good.

8. *Bareilly.*—Mr. Pratt states that the seed was sent to him rather late in the season, and that its general inferiority, as compared with the indigenous seed, was attributable to this cause. The general result was fairly good, and in some instances the average was higher than that from indigenous seed. Mr. Pratt recommends a further trial, and begs that the seed be sent earlier.

9. *Lucknow.*—Mr. Nicholson, officiating for Mr. Armstrong, states that the average yield from Mr. Scott's seed in all the four districts of his division was greater than that from indigenous seed, but he is of opinion that if the seed had been sown indiscriminately over the four districts, instead of only in a few good fields in each, the results would probably not have been so good as they now appear.

10. *Roy Bareilly.*—Mr. Luard, Assistant Sub-Deputy Agent of Roy Bareilly, procured a small supply of hill seed from Simla. The plant from this seed did not germinate so rapidly, but when once above the ground, grew so quickly that it flowered ten days before the plants from indigenous seed. Six chittacks of seed were sown in three and-a-half biswas of land, and gave an outturn of four seers nine chittacks, on an average 26 seers one chittack per beegha. The plants from this seed were small in height, but the stems were thick and capsules large. The cultivator to whom the above six chittacks of seed was given is extremely pleased with the result, and intends sowing the same seed this year again. The quantity of seed obtained was 20 seers.*

---

* The results of experiments with seeds of Simla poppy in the plains, recorded by the Sub-Deputy Agent of Roy Bareilly, have surprised me much The experiment, unfortunately, has been entrusted to an assamee, and at the most only casually looked to by Mr. Luard. I thus cannot help thinking that he has been misled—intentionally or unintentionally—and that the results are really those of carefully-selected plains grown seed. The observations of Mr. Luard on the general character of the plant are indeed opposed to the seed being of hill origin, particularly so the relatively tardy germination; hill seeds sown in the plains (of any particular plants), germinate relatively more quickly than do those of the same species grown in the plains: so, also, the dwarf habit and stout stems—appearances the obverse of well-ascertained results. Again, we all know that, as regards the *secretion of opium*, the poppy is extremely sensitive to changed conditions of growth. This is the case even when the plant vegetates with fair vigour. Take, for example, the case of the Malwah poppy in Behar and Benares, and *vice versâ*. Now, certainly the reciprocal changes in these instances is very much less marked than that of the Simla seed experiment in the plains of India. Altogether, I must confess that I have grave doubts as to the correctness of the experiment. Moreover, all hitherto recorded experiments of Simla poppy-seeds in the plains have been anything but successful. The following are two in point. The first is by Mr. W. Peppe, at present Sub-Deputy Opium Agent of Chota Nagpore. "In receiving the seed," he observes, "I had it divided into several parts and distributed amongst experienced cultivators; I also had it sown in my garden at different times, but in every case in conjunction with Patna seed. The first plot was sown about the 25th October, the seed germinated, but the young plants died off. The local seed, on the other hand, did not germinate so profusely, but the plant stood and grew vigorously: the same result followed with the ryots, and not *a plot of the first sowings of hill seeds survived.* The next sowings were made about the 25th November, as the weather had by that time got quite temperate, the plants arrived at maturity, and gave a very good yield of opium, *but the capsules were very small, and the ryots did not give a satisfactory report of them.* I thought that the small size of the capsules resulted from the non-irrigation of the plant, but I had afterwards an opportunity of examining a plot which had been regularly watered, and in this also the capsules were small, both in comparison with the Patna seed and also with common seed of the neighbourhood. Here, then, we find that sowings of hill poppy seeds in the plains failed, even when sown so late as the 5th of November, and I venture to say that the *very finest selected poppy-seed will not yield 20 seers of opium if sown later.* It should also be observed that the hill poppy is naturally as suited for late as early cropping (I mean, of course, that when it suffers from the comparatively low temperature at the close of October, so will it in the still higher temperature of March). Now for the other report which is by Mr. Armstrong of Ghazeepore. "Here," he remarks, "is a little statement showing the average yield *per beegha* from land sown with *local, Patna,* and *hill seed.* The land in which the experiments were made is much of the same kind, not far apart, and cultivated by eight assamees. The results *are*—from *local seed* 10 *seers;* from *Patna seed seven seers thirteen and-a-half chittacks;* and from the *hill seed one seer fourteen chittacks only.*

11. *Fyzabad.*—In all the four sub-divisions of Fyzabad the imported seed was sown. The return from Mr. Scott's seed in the Fyzabad, Gonda, and Baraitch districts was better than the general yield from indigenous seed, but in Barabanki and Sultanpore the result was not so good. The plants in all the districts germinated well and progressed speedily. On reaching maturity the plant was healthy, with abundant foliage. The capsules also were promising. Mr. Gennoe is of opinion that it is unfair to draw any conclusion until the imported seed is acclimatized and sown a second year. He, however, admits that the introduction of foreign seed, which has been going on from the last three years has decidedly led to improvements in the capsules and the yield therefrom.

12. The results are doubtless not so conclusive or satisfactory as we might wish them to be; but, nevertheless, I am strongly in favour of giving the experiments a further trial, and Mr. Scott has been requested to send up some more seed at once.

13. The experiments have not had quite a fair trial in all cases. Thus in Futtehgurh and Bareilly the seed arrived late, and was sown late. This is quite enough to account for failure, and steps will be taken to prevent any delay this year. Then the experiments are much weighted by the apathy and, in many cases, the actual dislike of the cultivators to the experiments. Attempts to improve the cultivation of opium have to contend with the same difficulties which beset attempts to improve the seed of cotton and other crops. The cultivators are distrustful of the experiment. They know they can depend on a fair crop from their own seed, and they think it is likely, as not, that the new seed may prove a failure. These experiments carry with them a certain amount of trouble: that is, the inspection of it by the Government official and perhaps some of his hungry hangers-on. The produce has to be kept separate, and enquiries regarding the result necessitate visits to the tehsildar or gomashta's cutcherries. So experiments are always unpopular with the native; and in a village to which seed is distributed, the villagers always go on the principle of "*fiat experimentum, in corpora vie,*" and the most wretched creature in the village is, if careful supervision is not exercised, forced to undertake the sowing. Everyone, too, is anxious to prove the experiment a failure, in the hope of preventing, for the future, the vexations which accompany the trials, and the result is often to be attributed to the result described in the "*Old Pindaree*"—

> "There came the settlement-hakim to teach me to plough and to weed.
> ("I sowed the cotton he gave me, but first I boiled the seed.")

This shows the hill poppy to be a failure. The plant germinated pretty well *where it did grow*, but when some four or five inches high, the leaves began to turn yellow. The hill poppy grown here had not sufficient strength to remain upright, but *trailed most part of its stem on the ground*. (This, I may add, clearly shows its unfitness for plains cultivation.) "I think that, as the experiment has been made here, it is sufficient to condemn the introduction of the hill poppy."

Subsequently to the writing of this note, I received (November 25th) from the Opium Agent of Benares, a copy of a letter from Mr. Luard, on the origin, appearance, growth, &c., of the above seed. It is there stated that "the seed in question was procured from a village some long distance north of Simla. . . . . . . The name of the village, the distance and *proper* direction from Simla, I cannot now remember, the distance, however, must have been great, as it took the man—a pahari—nearly three weeks going and returning." It would thus appear that Mr. Luard really knows nothing of the true origin of the seed; he states emphatically—as shown by the italicising of the word "*proper*," which is not the author's—that he is even unacquainted with the direction whence the man sojourned for no less than *three weeks*—of itself a suspicious circumstance, and I have known my '*pahari*' plant-collectors, when thus sent out to distant localities, lounging in their '*basti*,' and in due course making their appearance with a load of plants from the neighbouring jungles. Who, then, can say whence the seeds were really got? Mr. Luard evidently cannot. Well, one seer of seed was got, which Mr. Luard on his return to Dalamow "made over to a Kaioli Lumberdar, who sowed them on, *I think*, four biswahs of ordinary soil." The italics are mine, and throw no little uncertainty over the whole experiment. Moreover, it does not appear from the letter that Mr. Luard either saw the seed sown or even the plant in this field.

The Agent also favoured me with a copy of Dr. Sheppard's analysis of the opium, which shows an increase in *extract* and narcotine, as compared with the general average samples of Behar and Benares. It would have been much more satisfactory if the comparison had been made with drug from the same locality, as there is not a little local variation in the extractive and alkaline qualities of opium.

14. I am not quite confident either that the officers of the department are always quite so enthusiastic regarding the experiments as they might be, and unless they take a real interest in the matter, and watch the trials with some intelligence and care, much success is not to be expected: measures will be taken this year to ensure a fair preparation of the fields sown with the experimental seed being visited by European officers. A few fields only—and these representing every class of soil—will be sown, and these will be selected in positions near the head-quarters of a European officer, so that they can be easily supervised.

15. I am in favour, too, of a small experiment with the selected seed being carried on by each European officer on a piece of ground to be rented by him near his head-quarters, and, in anticipation of the approval of the Member in charge, I have sanctioned the necessary expenditure for this purpose. The expense should eventually be recouped by the produce. I hope also to arrange with the Director of Agriculture, and commence to undertake an experiment on the Government model farm here.

16. *Primâ facie*, I am strongly in favour of the importation and exchange of seed, and that, too, of selected seed. The two processes are quite separate, and Mr. Turnbull, in deprecating further experiments on the grounds that the cultivators in this agency select the seed of the poppy plant, has lost sight of the circumstance that one of the objects of the experiment is to see the result of introducing *new* seed (selected, too, it is true), *i. e.*, seed grown at a distance, which, in regard to the cultivation of other produce, is supposed to have the same beneficial results as the introduction of new blood in stock-breeding.

APPENDIX E.

Addenda to Chapter IV., Sections 4 and 5.

With reference to the long-sustained fertility of the poppy lands under shallow tilth and the most sparing manurial applications (which I confess I have hitherto been at a loss to explain in any satisfactory way), it now occurs to me that it may be thus satisfactorily interpreted. In the first place, then, it is to be observed that by far the major proportion of the land is artificially irrigated, and that most copiously, every beegha during the poppy season having on an average estimate from 80,000 to 100,000 gallons thus applied. Reflecting, then, on the fact that nearly one-third of this water is again withdrawn from the soil by evaporation, and that every drop contains one or more molecules of the soluble, fertilizing constituents of the soil, which it brings up (from zones far beneath the range of the plant's roots) and ultimately deposits on and near the surface as it passes from the soil. This, it is easy to see, must have a highly fertilizing influence on the soil. . . . . I do not think *that four or five feet* is an over-estimate of the quantity of water thus evaporated: *fifteen feet* is Captain Maury's estimate of the annual evaporation from the tropical zones of the Atlantic—(" *Physical Geography of the Sea,*" *11th edition, page* 37). . . . . . Commenting on the origin of ocean currents by the process of evaporation, Professor Ansted observes that "*its* effect in a long narrow sea is to be found in the Red Sea, whose surface is an inclined plane, owing to the enormous quantity of water removed from it into the atmosphere. The quantity thus removed at a moderate estimate is half an inch per day during summer. It is thus not extraordinary that, in spite of a strong current that sets inwards from the Arabian Sea at the rate of nearly a mile per hour (20 miles per day), the water at the head or northern part is some two feet lower than at the foot. As the Red Sea is 1,000 miles long, the water entering takes fifty days to reach the land, and in doing so loses .25 inches of height"—(" *Physical Geography,*" *page* 144). From these results then, and considering the large quantity of water annually evaporated from our poppy fields, and its high fertilizing influence, we need scarcely, as it appears to me, be surprised at the long-sustained fertility of those soils, in spite of *shallow tilth* and sparing manurial applications. We have here an agent, quite as effective in bringing within reach of the plant the enriching constituents of the lower-zoned soils, as the deep subsoil ploughs which are absolutely necessary sooner or later in the agricultural economy of all temperate countries, where evaporation is low, as also in tropical countries where the rainfall is light and consequently the evaporation small. Another important fertilizing source to large tracts of arable land in India is the annual overflowing of rivers. These waters are literally saturated with matter in suspension and solution. Now, these are largely brought down from the mountain-sources of the rivers, which in India are largely composed of those old rock formations rich in potash, lime, phosphates, and the like; all of which are more or less soluble in one or other of their forms in water, and anyhow carried down with facility in a state of suspension in the waters. The waters from such sources are thus highly impregnated with richly fertilizing matters, and these, in their turn, are again withdrawn from them by the comparatively impoverished soil-admixtures taken up in the lower drainage lands of the rivers. Altogether, it is easy to see that these suspended matters, borne down by the river, must ultimately form a rich deposit on the lands overflowed in its lower basin. In this, then, as I have remarked, we have another most important sustaining or renovating agent of the soil's fertility. Thus, reflecting on the bulky annual deposit from those mud-laden rivers, on all their lower basins, on tracts subject to their overflow, we need scarcely be surprised at their sustained, though comparatively low, fertility. . . . . . I can scarcely doubt that the two sources of fertility above noted are the real mainstay of very large tracts of the arable lands of India. It is to be observed, however, that *these sources of fertility are by no means perpetual.* They are limited, as are the richest of agricultural soils, and disastrous indeed will it be to a country when such sources of fertility fail, as they inevitably must sooner or later. We have an example of it in parts of Central America, long famous for the high fertility of the soil, and now, through an exhaustive and unrenovating system of culture, reduced to a hopeless sterility. The same practices are being followed in the general agriculture of India, and there can be no doubt that it is a mere question of time to reduce them to the zero of fertility. Alarming indeed are such prospects when we confront ourselves fairly with the conditions of a soil's fertility, and observe how sparing and scant are the applications of extraneous manures even in the most advanced agricultural districts of India. . . . . . I have thought it desirable to express my opinion on this question, as it might otherwise be thought, from the forestated views, that I am of those who believe in the inexhaustibility of a soil under the most spoliative culture. I thus conclude in the words of Baron Liebig, "the law of compensation, which makes the recurrence or permanence of effects dependent upon the recurrence or permanency of the conditions which produce them, is the most universal of the laws of Nature; it governs all natural phenomena in their various phases, all organic processes, all the productions of man's industry. The European husbandman has for centuries past been in the habit of taking away the produce of his fields without making compensation for the mineral matters removed, and his fields have accordingly been continually diminished in fertility. On the other hand, the Chinese husbandman has for thousands of years past made it a practice to restore to his fields the mineral constituents removed from them in the produce, and the fertility of his land has accordingly kept pace with the increase of population"—("*Letters on Modern Agriculture,*" *page* 254).

I may in this place take the opportunity of briefly drawing attention to an interesting fact in the natural economy of vegetal life as related to the chemico-physical properties of soil and water. It is this. In the foregoing treatise, we have illustrated the remarkable powers of the soil as regards the withdrawal of the salts of lime, potash, and the phosphates from their watery solvent. Now, the soda-salts, which are also highly soluble in water, are but sparingly withdrawn from their solution by the soil. Thus, the same sample of soil which will *utterly exhaust* a watery solution of *chloride of potassium,* will scarcely withdraw *one-half* of the *chloride of sodium* (*i. e.*, common salt) from its watery solvent; so also does soil withdraw ammonia, phosphoric, silicic, and carbonic acid—all most important vegetal food-stuffs. This property of the soil has been carefully illustrated by Thompson, Huxtable, and May in England, and Liebig in Germany. From this peculiar affinity of the soil for the above mineral substances, it is interesting to observe that they form some of the most essential food-stuffs of land plants; whereas those growing in, or in the neighbourhood of the sea, largely reject the above, and freely absorb and assimilate the soda-salts. "*Potash*," observes Liebig, "is found in all our land plants, but *soda* forms only an exceptional constituent." It—*soda*—is on the other hand especially the *alkali* of the animal kingdom. I have been much struck with these correlations between the plant and the soil, and especially so in reflecting on the richness and plenitude of form of land as compared with marine vegetation. The latter are almost wholly represented by the comparatively low and simple forms of algoid plants, whereas on the land there is an exuberance of all forms—from those simple and lowly forms which inseparably unite vegetal and animal life, to those highly-developed and bulky forms represented by the trees of our forests, &c. Connected with this comparatively low development of the marine forms of vegetation, it is not a little remarkable that the zoology of the sea should be so rich—nearly all the great classes being represented by various more or less unwieldy and grotesque forms; while other and simpler forms are perhaps more variedly and numerously developed than on the land: indeed, there are great classes which are wholly peculiar to fresh and salt-water. The correlations here indicated—be they *causal* or *casual*, it is for others to determine—between those alkaline elements and the degree of representation of the higher forms of animal and vegetable life, are indeed very striking, and this more especially when we reflect on the fact that *each*—*sodium* in the one, *potassium* in the other—is so to speak pronouncedly the alkaline basis of both kingdoms. It is anyhow a subject well worth the attention of experts in organic chemistry, as I do think this unquestionable difference in the degree of structural development of animal and vegetable forms in the waters of the globe, and on its dry surface, may have no unimportant bearing on that well-termed "mystery of mysteries," the origin and development of the two kingdoms.

From these peculiar correlations of the soil and its mineral constituents, we would appear to have a satisfactory physical explanation for an old teleological stand-point, namely, the nature and cause of the saltness of the sea; the teleological explanation, as is well known, being that the water of the sea is salt, because it would otherwise putrify, or simply that the Almighty so willed it. Thus would those who still cling to the time-honoured doctrines of teleology place the question altogether beyond the bounds of legitimate enquiry. Professor Ansted, with no sympathy in their views, in commenting on the nature and cause of the saltness of the sea, observes that "much has been said as to the cause of this condition of so large a part of the water on the globe, and certainly to very little purpose. It would be as *reasonable* and *profitable* to enquire why *silisa*, *alumina*, and *lime*, constitute the important bases of all soils and rocks, as to seek to discover a reason for the saltness of the ocean." No doubt, continues the Professor, "it is an adaptation full of uses and full of meanings; but what in the whole economy of Nature is not so? It seems almost impertinent to single out one contrivance of Nature, if it can so be called, and magnify it as a special interposition of Providence"—("*Physical Geography*," *page* 132). Quite a new light, however, is afforded us in the later advances in agricultural chemistry, which, as it appears to me, really satisfactorily explain the origin and cause of the saltness of the sea. I think there can be no doubt that the large percentage of *chloride of sodium*, or common salt, in the sea is due to the comparatively low chemical affinity between it and the soil. It alone, of all the other alkaline and earthy salts, is allowed to pass from the soil in a watery solvent, and we need not thus be surprised at its accumulation in the sea, whither our rivers are continually carrying and hoarding it. Moreover the beds of the seas and oceans are themselves plenteous suppliers of those salts which are being ever variously concentrated, according to the amount of evaporation. It is interesting to observe, from this point of view, that while the waters of the ocean contain on an average 2·700 of *chloride of sodium*, they only contain 0·830 of the salts of potash, magnesia, and lime—constituents for which, as we have seen, the soil has a great affinity. As it appears to me, then, the chemical relations of the soil and the alkaline salts affords us a satisfactory explanation for the excessive accumulation of the *chloride of sodium* in the waters of the ocean: that in short the saltness of the sea is wholly attributable to the soil's rejection of *its* characteristic salt in the waters which feed the rivers and disgorge themselves in the oceans.

APPENDIX F.

Addenda to Chapter XII.

I HAVE thought it desirable to append the following table by way of illustrating the relative oil-yielding value of the seeds of lanced and unlanced capsules. The first column gives the quantity of seed; the second the quantity of oil extracted; the third (to facilitate comparison) gives the calculated produce; and the fourth and fifth columns the actual and calculated produce of oil-cake:—

A.—Lanced Capsules.

	Seed.		Oil.				Oil-cake.			
	Srs.	C.	Srs.	C.	Srs.	Srs.	Srs.	C.	Srs.	Srs.
Benares poppy, large capsules ..	3	8	0	15	100	26·79	2	9	100	73·12
Patna „ small „ .	2	9	0	13	..	31·70	1	12	...	68·29
„ „ large „ ...	29	3	11	4	...	38·54	17	15	...	61·24
Average produce ...	11	12	4	3	...	32·34	7	6	...	67·58

B.—Unlanced Capsules.

	Seed.		Oil.				Oil-cake.			
	Srs.	C.	Srs.	C.	Srs.	Srs.	Srs.	C.	Srs.	Srs.
Benares poppy, small capsules ..	7	4	2	3	100	30·17	5	1	100	69·82
„ „ large „ ...	31	0	11	7	...	36·89	19	9		63·10
Patna „ small „ .	44	13	16	5	...	36·40	28	8	...	63·50
„ „ large „ .	3	10	1	4	..	34·48	2	6		65·50
Average produce ...	21	10	7	12	...	34·48	13	14	..	65·50

C.—Unlanced Malwa Capsules.

	Seed.		Oil.				Oil-cake.			
	Srs.	C.	Srs.	C.	Srs.	Srs.	Srs.	C.	Srs.	Srs.
Lukria variety	40	4	14	7	100	35·87	25	13	100	64·13
Uggarya „	2	5	0	11	...	29·72	1	10	...	70·27
Average produce ...	21	0	7	9	..	32·79	13	11	...	67·21

D.—Lanced Capsules.—New seeds.

	Seed.		Oil.				Oil-cake.			
	Srs.	C.	Srs.	C.	Srs.	Srs.	Srs.	C.	Srs.	Srs.
Patna poppy	36	0	13	1	100	34·72	22	15	100	63·71

In undertaking the above experiments, I naturally anticipated a considerable increase of fatty matter in the seeds from the unlanced capsules. Indeed, the results of the oil-extraction from the local varieties of poppy do show an increase of about two per cent. in favour of the unlanced capsules, but I am inclined to attribute this to the seeds not having been sufficiently pressed in one of the samples from the lanced capsules. This was in the case of the large capsuled Benares seed (*vide* table A), which yielded less than 27 per cent. of oil, with a proportionate increase of cake. The latter was unfortunately mixed with that of the other samples before I had made any comparison of the results, and I thus could not ascertain separately the quantity of fatty matter left in the cake. This was also too small in quantity to materially affect the total results. In repeating the experiment with seeds from lanced capsules from the past season's crop (the previous experiments being with the seed produce of 1873), my suspicions were confirmed. I have given the results in the tabular statement D, a comparison of which with those of A shows a slight increase in favour of the former. The relative decrease in cake is due to loss in water, of which the new seeds contained more than the old seeds.

I thought it worth while also to ascertain the relative amount of water and oil in each of the cake samples. The results are shown in the following tabular statement. I may explain that, in ascertaining the amount of water, I thoroughly dried the specimen in a sand-bath at a temperature of 212° *Farenheit;* and for the oil, I treated the cake (previously reduced to a fine powder) with *ether*, poured off the latter with its fatty extract into an open glass vessel, where the ether evaporating left the oil behind:—

	Cake.	Water.	Oil.
(A) From lanced capsules	100	7·86	8·75
(B) From unlanced capsules		8·78	9·25
(C) From ditto ditto		8·65	8·95
(D) From lanced capsules		9 26	9·50

The results are thus quite in unison with all the preceding experiments under this head, all proving that the extraction of opium from the poppy capsules neither reduces the weight, nor germinative, drug-producing, and reproductive quality, nor does it either affect the seed in actual size, or even in the amount of water and fatty constituents. Variations we indeed have, but these differ neither in degree nor kind from those of the lanced capsules.

G.—Addenda to Chapter XIII, Section 4.

We have seen how largely dependent the phenomena of the circulation and exudation of the milk-sap in the poppy are dependent on the barometric condition of the atmosphere. Now, reflecting then on those physical relations of the phenomena, it naturally occurs to us to enquire as to whether they may in any tangible way be affected by the moon: whether, for example, a *clear* night with a *full* moon is more favourable to the flow of drug than a *clear* night with a new moon. I cannot, from enquiries that I have made amongst the assamees, learn that they attribute any influence whatever to the moon on vegetation. I have been surprised with this, as the ancients of nearly all countries have attributed to it considerable influence, and in sowing, planting, and harvesting their crops, had especial regard to the stages of the moon. In America the back-woodsmen are careful not to cut their timber trees during the full moon (a notion also held by the older European arboriculturists) under the impression that its tissues then contain an excess of water-sap, and that it will thus form less durable timber than if cut during the lower phases of the moon as then containing less sap . . . . . . Commenting on lunar influence, the Editor of the *Gardener's Chronicle* observes that "popular tradition has always attributed much to the *moon's influence on vegetation*, and science has almost invariably negatived the popular assertions." One of the greatest dangers that beset the grape vine and other plants was attributed in France to *la lune rousse*, from the fact that the blighted leaves or buds turn of a reddish-brown colour. The people insisted that the moon was the malignant agent, but they were not all agreed as to which moon of the year did the mischief, so that Louis XIV issued an order to men of science to determine the date of this moon, and got for answer that no such moon existed.

The effect of the moon upon vegetation has lately been brought before the Acclimatisation Society of Paris by M. Carbonnier—*un pisciculteur*—who has made some curious observations on the growth of certain algæ in his glass aquariums, which tend to confirm the old popular notions. His observations led to the conviction that the maximum intensity of growth corresponded with the time of the full moon, diminishing during its other phases until it was imperceptible. Thus, while at *full moon* the aquariums had to be cleaned every day, twice a week was sufficient during its other phases. M. DeParville confirms these deductions from experiments made by himself some years ago in the tropics. He found that the respiration of plants was very active under the influence of moonlight, and that growth was far more decided at full than at new moon . . . . There is a popular idea current that the waters of Versailles are unwholesome at the time of the autumnal equinox. The ancient philosophers probably gave rise to the popular opinion referred to: it would be curious should modern science, after so long opposing, confirm them; but before she can do so, the evidence must be much stronger and more incontrovertible than it appears to be at present.—*loc. cit., August* 1873, *p.* 1045.

With regard to its influence on animal life (and leaving aside the observed correspondence between the phenomena of lunacy and the changes of the moon as of a dubious nature or relation), we have, nevertheless, well-authenticated cases of its evil effects on our visual organs. Under *Notable Things*, Timbs gives the following illustrations of the effects of moonlight on the human subject:—In 1863, at Peckham, Surrey, a boy slept in the open air in a corn-field throughout a moonlight night, and when he awoke he was blind . . . . . . Again, in 1867, a traveller in Eastern Australia lost his way through being blinded by sleeping under the rays of the moon, and wandered for several days until his sight was partially restored. Many less or more well-authenticated cases have been recorded of temporary blindness being thus induced by exposure to the moon's rays on shipboard in the tropics. Dr. Wells, in his classical essay on dew, refers such cases of moon-blindness *to the chill produced by radiation from the eyes*, the shining of the moon being merely an accompaniment to the clearness of the atmosphere. The relation is not apparent, nor moreover is it reconcileable with observed phenomena. Thus, it is obvious, according to this view, that the same effects should be produced in all stages of the moon. And we might also, on the same grounds, expect it to be much more frequently exhibited in arctic than in tropical countries, in continents than in islands, whereas it would appear to be the reverse . . . . . . No doubt it is partly constitutional, certain individuals being optically more sensitive than others to the influence of the moon, and this again, perhaps, more largely confined to those of the so-called *sanguine* and *sangui-nervous temperaments* of the physiologist. I would thus explain the phenomena: it is highly probable, that in lying with the face thus fully exposed to the moon's rays, the *eyelids* involuntarily open and expose the *eyeballs* to their direct and continuous influence. This continued play of light on the nucleus and inner parts of the eye—especially where there is a deficiency or absence of the *pigmentum nigrum*—inducing as it must an exhaustive, though unconscious activity, is, I believe, quite sufficient to cause the phenomenon of moon-blindness.

I have dwelt on these phenomena with a view of directing attention to possible correlative influences being exercised by the moon in the circulation and exudation of the milk-sap in the opium-poppy. It is a curious and interesting subject, well worthy of careful observation and experiment. I will only add that, in so far as my observations go, the drug exudes quite as copiously in a clear and still night, during the minor phases of the moon, as in similar nights when at-full. If I recollect aright, an interesting critical dissertation on lunar influences will be found in "*Popular Astronomy*," by Dr. Dionysius Lardner. I regret that I have no copy by me of this work, which I am sure would have enabled me to illustrate more fully the above phenomena

APPENDIX.—*TABLE, A.*

Drug Returns from Experimental Plots at Deegah and Metapore for the Season 1874-75.

Deegah, Malwa varieties.			Deegah, outside lands, local varieties.			Deegah, enclosed land.			Meetapore garden.			Assamee husbandry on adjoining lands		
Area, sq. ft.	S. C.	S. C.	Area, sq ft.	S. C.	S. C.	Area, sq. ft.	S. C.	S. C.	Area, sq. ft.	S. C.	S. C.	Area, sq. ft.	S. C.	S. C.
8,148	0 13½	2 11¾	4,366	1 5	8 2¼	27,225	7 1	7 1	27,225	8 7	8 7	40,835	6 8	4 5¼
20,309	1 5	1 11½	17,142	3 14	6 2¼	12,604	3 2	6 12	13,612	2 11	5 6	13,610	3 0	4 0
11,589	0 13½	2 0½	11,319	2 6	5 11¼	27,225	11 4	11 4	13,612	2 12	5 8	34,030	4 11	3 14½
13,780	1 1	2 1	10,098	2 1	5 11¼	27,225	9 10	9 10	13,612	2 7	4 14	47,640	5 12	3 6¼
9,782	0 9	1 9	8,184	1 6	4 9¼	15,945	5 1	8 10¼	13,612	2 6	4 12	10,888	1 8	3 12
16,056	1 0½	1 11½	6,444	1 0	4 3½	16,074	6 10½	11 4½	13,612	2 0¼	4 0½	16,312	1 15	3 3½
19,309	1 0½	1 7½				27,225	9 8	9 8	20,415	3 2	4 2¾	20,415	2 3	2 14½
31,563	1 1	0 14¾				15,945	4 4	7 4	20,415	3 5	4 6¾	13,610	1 4	2 8
16,332	0 8½	0 13¾				27,225	8 12	8 12				13,610	1 3	2 6
13,780	1 4	2 7				14,480	4 0	7 9				13,610	1 2	2 4
11,319	0 11½	1 11½										20,415	1 1	1 6½
												27,225	1 4	1 4

APPENDIX.—*TABLE, B.*

Drug Return from the Experimental Gardens at Deegah and Meetapore for the Season 1875-76.

Deegah, Malwa varieties.			Deegah, inner garden, local varieties.			Deegah, inner garden, local varieties.			Meetapore gardens, local varieties.			Assamee husbandry on adjoining lands.		
Area, sq. ft.	Srs. C.	Srs. C.	Area, sq. ft.	Srs. C.	Srs. C.	Area, sq. ft.	Srs. C.	Srs. C.	Area, sq. ft.	Srs. C	Srs. C.	Area, sq. ft.	Srs. C.	Srs. C.
14,214	4 9¾	8 12¼	18,592	10 4	15 0½	15,160	8 8¼	12 1¾	6,806	3 10¼	14 9	40,837	18 0	11 13
23,385	5 10¼	6 9	13,612	6 6¼	12 12½	34,194	16 15¼	13 9½	12,000	5 5¾	12 2¼	54,450	20 0	10 0
27,225	5 0½	5 0½	21,624	9 8	11 15	1,134	0 9½	12 14	14,740	6 9	12 1	34,030	11 0	8 12
8,874	1 7¾	4 7½	25,228	10 5½	11 2½	12,784	5 8	11 11	27,225	9 5¾	9 5¾	40,837	13 0	8 10¾
8,923	1 4½	3 14½	34,246	13 4	10 13	7,320	0 8	10 5	27,225	11 1	11 1	40,837	12 8	8 5¼
14,430	1 10¾	3 2¼	18,592	7 2¾	10 8	2,350	0 11½	8 5	12,784	5 0	10 10	68,062	20 0	8 0
13,585	1 9	3 2	24,174	8 6¼	9 7	14,076	5 15¼	11 7½	27,225	10 4¾	10 4¾	81,675	22 8	7 8
12,288	1 0½	2 4½	20,496	5 11	7 8	15,301	4 11	8 4	27,225	9 14¼	9 14¼	20,620	6 4	8 5
22,650	2 8½	3 0¼	20,496	4 11	6 3	28,800	12 4	11 5	5,360	1 14¾	9 12	27,225	6 4	6 4½
						19,608	9 10¾	13 6¾	27,225	9 5¾	9 5¾	28,586	7 8	6 4
						18,348	5 1½	7 10¼	13,612	4 5¾	8 11½	47,845	10 5	5 14
						15,762	4 6¾	7 10	13,612	4 4½	8 9	13,612	2 0	4 0

APPENDIX.—*TABLE, C.*

Manurial application with the first appearance of the flower-bud.

Plot.	Area in square feet.	Manurial application to the plant.	Capsules. 1st Quality.		Capsules. 2nd Quality		Seeds. 1st Quality		Seeds. 2nd Quality.		Opium.		Opium. Average per beegha.	
			Srs.	C.	Srs.	Ch.	Srs.	C.	Srs.	C.	Srs.	C.	Srs.	C.
1	816	Shell lime 10 seers	5	0	8	0	2	14	4	8	0	6¾	14	1
2	......	Ditto 8 seers, and shorah 2 seers	4	15	8	0	3	1	4	11	0	8	16	10
3	......	Quicklime, or hydrate of lime, 10 seers.	4	8	7	0	2	12	3	13	0	7½	15	10
4	......	Shorah 10 seers, and nonimattee 20 seers.	4	10	5	8	3	0	3	4	0	7	15	7
5	......	Sujeemattee 20 seers	4	1	5	12	2	7	3	7½	0	7½	15	10
6	......	Khareenoon 5 seers, and lime 10 seers.	4	8	5	12	2	13	3	3	0	8¼	17	3¼
7	......	Shorah 10 seers, and lime 10 seers .	5	1	6	0	3	0	3	4½	0	8½	17	11½
8	......	Sujeemattee 10 seers, and lime 10 seers	3	12	6	0	2	6	3	7	0	8¼	17	3¼
9	......	Common salt 4 seers, and lime 10 seers.	4	12	6	8	2	13	3	8	0	7¼	15	10
10	......	Common salt 4 seers, shorah 4 seers, and lime 8 seers.	4	7	9	0	2	12	4	10	0	8½	17	11½
11	......	Sulphate of iron 8 oz., *water solution*, shorah 5 seers, lime 5 seers, and sujeematee 10 seers.	4	0	7	8	2	14	3	11	0	8½	17	11½
12	......	Sulphate of soda 5 seers, potash 5 seers, and lime 5 seers	4	8	7	0	2	11	3	5	0	7½	15	10
13	......	Nitrate of soda 16 oz., potash 5 seers, and lime 10 seers.	5	12	6	8	3	7	3	8	0	8¼	17	3¼
14	......	Precipitated carbonate of iron 4 oz., potash 3 seers, salt 1 seer, and lime 10 seers.	4	14	7	8	3	0	4	4	0	8½	17	11½
15	2,736	No application	16	0	22	0	8	10	11	5	1	8	14	14

APPENDIX.—*TABLE, D.*

Manurial application immediately before the expansion of the flowers.

Plot.	Area in square feet.	Manurial application to the plant.	Capsules. 1st Quality.		Capsules. 2nd Quality.		Seeds. 1st Quality.		Seeds. 2nd Quality.		Opium.		Average per beegha.	
			Srs.	C.	Srs.	C.	Srs.	C.	Srs.	C.	Srs.	C.	Srs.	C.
1	1,021	Shorah 10 seers, nonimattee 40 seers	9	0	10	0	4	15	4	14	0	12¾	21	3¾
2	......	Shell lime, 40 seers	8	0	8	0	4	9	4	0	0	12	19	25
3	......	Shorah 10 seers, shell lime 40 seers...	6	8	10	6	3	12	5	11	0	10	16	10
4	......	Lime 20 seers	8	0	8	2	4	7	4	8	0	10	16	10
5	2,042	Muriate of ammonia 10 oz., lime 10 seers, potash 5 seers, nonimattee 10 seers, sujeemattee 10 seers.	13	0	11	8	7	3	8	8	1	4	16	10
6	......	Muriate of lime 1 seer in water solution, dried up with 20 seers nonimattee, and 10 seers sujeemattee.	11	0	12	0	6	10	7	4	1	3	15	13
7	......	Sulphate of iron 16 oz. in water solution, dried up with 20 seers lime, and mixed with 5 seers of potash, and 20 seers nonimattee.	9	0	14	0	6	1	7	6	1	2¾	15	9¾
8	1,921	Sulphate of iron 10 oz., in liquor ammoniæ, 1 pint solution mixed up with 10 seers lime, and mixed with 2½ seers glauber salt, 2½ seers kharenoon, and 2 seers of potash.	5	8	6	8	3	5	3	4	0	9¾	15	13¾
9	23,984	No application	96	0	120	0	52	0	59	0	9	15¾	11	4¾

APPENDIX.—*TABLE, E.*

Manurial application to the soil with the seeds.

	Name of manurial applications.	Weight of manure.	Name of variety.	Capsules.	Seeds.	Relative weight of seed and capsule. Seed.	Relative weight of seed and capsule. Capsule.	Opium per beegha.
		Srs.		Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.
1	Castor-oil cake	200						
	Lime . ..	200						
	Shorah (crude potash nitrate).	120	Kutila	145 0	147 0	500 0	493 0	12 6¼
	Bones (superphosphate)	80						
	Charcoal dust ..	80						
2	Bones (superphosphate)	160						
	Castor-oil cake	80						
	Potash nitrate . ..	40						
	Kharee-noon (crude soda-sulphate.)	40	Ditto ..	193 0	200 0	500 0	482 0	15 2
	Charcoal dust	160						
	Lime	160						
3	Sujeemattee	120						
	Shorah (crude potash nitrate.)	80	Ditto ..	174 0	208 0	500 0	413 0	12 12½
	Kharee-noon	40						
	Charcoal dust .. .	80						
	No application	......	Ditto ...	166 0	160 0	500 0	519 0	8 9
	Green manure	...						
	Castor-oil cake	160						
	Lime	200						
	Shorah	120	Monaria .	139 0	116 0	500 0	599 0	11 15
	Bone (superphosphate)	80						
	Charcoal dust	120						
	No application	...	Ditto ..	65 0	86 0	500 0	380 0	3 7

APPENDIX.—*TABLE, F.*

Manurial application to the soil with the seeds.

	Manurial top-dressing.	Weight of manure.	Name of variety.	Capsules.	Seeds.	Relative weight of seed and capsule. Seed.	Relative weight of seed and capsule. Capsule.	Opium per beegha.
		Srs.		Srs. C.	Srs C.	Srs. C.	Srs. C	Srs. C.
1	Shorah	265	Kaladanti ...	238 0	265 0	500 0	453 0	21 3¾
	Nonimattee	1 040						
2	Shorah	265	Ditto ...	209 0	251 0	500 0	416 0	16 10
	Bicarbonate of lime ...	1,040						
3	Lime-slaked	533	Ditto ...	117 0	247 0	500 0	358 0	16 10
4	Bicarbonate of lime (shell).	1,060	Ditto ...	204 0	220 0	500 0	464 0	19 15
5	Muriate of ammonia .	4¼						
	Lime—slaked	132	Ditto ...	119 0	212 0	500 0	281 0	16 10
	Potash	66						
	Sujeemattee	132						
6	Muriate of lime	13¼						
	Sujeemattee	132	Ditto ...	119 0	186 0	500 0	320 0	15 13
	Nonimattee	264						
7	Iron sulphate	6¼						
	Lime—slaked	264	Ditto ...	121 0	174 0	500 0	348 0	15 9¾
	Potash	66						
	Nonimattee	264						
	Ammoniac sulphate of iron.	39						
	Lime—slaked	265	Ditto ...	113 0	114 0	500 0	496 0	15 13¼
	Glauber's salt	56						
	Potash	52						
9	No application	......	Ditto ...	120 0	120 0	500 0	500 0	11 4¾

APPENDIX.—*TABLE, G.*

Analyses of the opium poppy, the air-dry plant, its ash, the soil it grew on, and the water used in its irrigation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
771.—Analyses of the poppy, and the soils and waters of its cultivation.	Air-dry plants in 100 parts.				Ashes in 100 parts.					Water in 1,000 parts, Deegah wells.				Soils in 100 parts, Deegah.				Soils, in 100 parts Hajeepore district.					
Chemical constituents.	Straw.	Seeds.	Cake.	Average.	Straw.	Seeds.	Cake.	Average.	Average of Deegah plants' ash.	B.	C.	D.	Average.	B.	C.	D.	Average.	*a.*	*c.*	*d.*	*e.*	Average.	*b*
Alumina	...	.	...	...	...	...	..	...	Trace.	·0066	·0003	·0015	·0040	7·206	8·100	5·553	6·953	6·260	2·678	3·101	3·128	3·791	2·384
Iron oxide	...	...	...	..	.	..	.	..	.....		Trace.			4·028	4·431	3·983	4·147	3·659	3·250	2·927	3·151	3·246	2·256
Magnesia	4·3	5·0	4·1	4·4	6·5	9·5	4·3	6·7	5·55	·0499	·0683	·0708	·0630	1·173	0·391	1·366	0·976	0·385	1·196	1·210	1·387	1·044	0·360
Lime or calcium oxide	19·9	18·5	26·8	21·7	30·2	35·4	28·1	31·2	25·43	·1663	·1810	·1312	·1595	1·721	0·897	1·526	1·381	1·016	1·354	1·295	1·279	1·236	0·149
Potasium oxide ...	15·1	7·1	19·8	14·0	38·0	13·6	20·8	24·1	29·37	·1870	·2038	·2137	·2015	0·623	0·560	0·821	0·668	0·757	0·568	0·567	0·780	0·668	0·505
Sodium oxide... ...	0·9	0·5	4·3	1·9	1·3	1·0	4·5	2·2	......	·0060	·0094	·0268	·0146	.....	......	.....	.....	......		... .	......	0·—	0·102
Ammonia	..	...	...	6·6	.	..	...	...	None.	·0008	None.	·0004	·0006	0·017	·0036	0·090	·0047	0·0032	0·031	0·0036	0·0082	0·0045	0·002
Silica	7·5	7·7	4·6	6·6	11·9	3·2	4·8	6·4	10·42	·0421	·0513	·0774	·0569	79·893	79·231	78·080	79·334	83·744	86·318	86·752	86·873	85·921	90·620
Sulphuric acid ...	3·4	1·0	1·9	2·1	5·1	1·9	2·0	3·0	7·88	·0347	·0417	·0453	·0405			Trace.				0·005	Trace.	0·005	Trace.
Phosphoric acid ...	2·3	16·4	36·1	18·2	3·5	31·4	37·8	24·2	6·13		Trace.			0·058	0·066	0·088	0·70	0·024	0·489	0·088	0·215	0·204	0·245
Nitric acid	..	..	...	..	.	.		..	None.	·0081	·0162	·0162	·0135	0·012	0·031	0·069	0·37	0·020	0·020	0·0166	0·0205	0·0104	0·013
Chlorine	1·7	2·3	...	2·0	2·5	4·4	.	3·4	5·70	·0398	·0325	·0348	·0457	Trace.	0·015	0·141	0·78	0·025	0·019	0·022	0·041	0·026	0·010
Carbonic acid ...	..	.	...	.	.	...	..	..	7·92		.	..	.. .	0·432	0·752	0·581	0·225	0·284	0·474	0·570	0·564	0·473	0·339
	Analyses by Professor Wolff.									Analyses by Mr. Pedlar, Presidency College, Calcutta.													

APPENDIX.—*TABLE, H.*

Samples of Poppy Capsules from the Deegah Experimental Garden.

	Number of drug-producing incisions on the capsules.	Total weight of 12 capsules in grains.	Capacity of 2 capsules measured by small shot, in grains.	Total weight of good seed, the produce of column 2.	Weight of 7 cubic centimetres of seed air-dried, in grains.	Weight dried at a temperature of 212° Farenheit in grains.	Loss in water, grains.
Degenerate poppy, with small green reddish-streaked flowers (four capsules).	2-3	304·50	1,113	160·05	56·75	53·02	3·73
Degenerate poppy, with small green reddish-streaked flowers (four capsules).	Unlanced.	300	1,232	157	57·12	54 04	3·08
Patna poppy capsules, oblong, ovate, glaucous	Ditto	1,431	5,724	749	56·53	53·80	2·73
Ditto ditto, globose, ovate, glaucous	Ditto	1,272	3 578	700	55·02	51·65	3·37
Ditto ditto, ovate, oblong, glaucous	Ditto	1,113	4,134	560	55·57	51·48	4·09
Benares ditto, roundish, oblate, glaucous.	Ditto	1,431	4,770	850	56 50	52·06	4·44
Gungajull ditto, oblong, ovate, glaucous	Ditto	1,213	5,724	756	56·04	53·50	2·54
Benares ditto, globose, ovate, glaucous.	Ditto	1,630	6,480	850	56·12	53·10	3·02
Patna ditto. globose, ovate, glaucous	Ditto	1,650	5,410	890	55·03	51·33	3·70
Uggyria ditto, ovate, oblong, glaucous	Ditto	1,213	5,724	686	56·02	52·08	3·94
Ditto ditto, ovate, oblong, glaucous	Ditto	1,173	5,288	688	56·85	53·12	3·73
Benares ditto, roundish, oblate, glaucous.	Ditto	1,510	6,928	802	56·50	53 08	3·42
Patna ditto, roundish, oblate, glaucous.	Ditto	1,312	4,124	826	56·80	54·10	2·70
Ditto ditto, roundish, oblong.	8-12	1,810	8,580	951	59·35	56·25	3·10
Benares ditto, oblong, ovate.	8-10	1,685	7,724	875	58·70	55·65	3·05
Patna ditto, oblong, ovate (variety Kolodantie).	6-8	1,260	2,340	576	57·25	54·50	2·75
Chota Nagpore capsule, oblate, glaucous (one capsule).	16	138	4,897	20	......	......	......

APPENDIX.—*TABLE, I.*

Samples of Poppy Capsules from the Benares Agency.

Ghazeepore capsules, globose, oblate, glaucous (variety Majhee).	6-8	1,908	8,228	835	57·75	53·25	4·50
Ghazeepore capsules, roundish to oblong, ovate (variety Gilguloa).	2-7	1,590	8,626	636	58·15	55·35	2·80
Ghazeepore capsules, ovate, oblong (variety Kolodantic).	2-3	1,113	2,862	636	58·35	55·20	3·10
Ghazeepore, from the factory garden, capsules, roundish, oblong, and ovate.	5-6	1,431	3,120	656	58·85	54·75	4 10
Azimgurh capsules, oblong, ovate, glaucous	4-8	1,528	6,360	784	59·85	56·10	3·84
Goruckpore capsules, oblong, ovate, of a dull green color.	5-8	1,074	4,134	477	57·90	56·30	1·60
Bustee capsules, roundish, oblong, glaucous	6-10	1,669	5,367	825	58·25	56·15	2·10
Futtehgurh capsules, roundish, oblong, glaucous.	7-9	1,470	4,889	586	59·85	56·10	3·75
Futtehgurh capsules, roundish, oblate, glaucous.	6-7	4,032	9,858	843	59·75	55·12	4·63
Futtehgurh capsules, ovate, oblong, glaucous (variety Kutylea).	4-9	1,188	3,100	700	58·60	55·25	3·35
Fyzabad capsules, ovate, oblong, of a dull green colour.	3-7	1,392	5,406	675	58·15	55·35	2·80
Fyzabad capsules, oblong, ovate, glaucous ..	3-7	1,490	5,724	675	59·12	56·07	3·05
Lucknow capsules, roundish, ovate, and oblate.	6-8	1,590	9,022	742	59·85	56·20	3·15
Futtehpore capsules, roundish, oblong, glaucous.	7-9	1,749	10,494	457	57·75	55·35	2·40
Futtehpore capsules, oblate and oblong, glaucous.	4-5	1,272	5,844	626	57·12	54·15	3·07
Futtehpore capsules, ovate, oblong, glaucous	5-6	1,054	4,124	466	58·20	55·06	3·14
Bareilly capsules, roundish, oblong, glaucous	7-9	1,660	9,470	636	59·15	56·30	2·85
Bareilly capsules, roundish, oblong, glaucous	5-9	1,752	7,622	802	59·25	56·25	3·00

APPENDIX.—*TABLE, J.*

Samples of Poppy Capsules from the Behar Agency.

	Number of drug-producing incisions on the capsules.	Total weight of 12 capsules in grains.	Capacity of 2 capsules measured by small shot, in grains.	Total weight of good seed, the produce of column 2.	Weight of 7 cubic centimetres of seed air-dried, in grains.	Weight dried at a temperature of 212° Farenheit in grains.	Loss in water, grains.
Tirhoot (irrigated land) capsules, oblong, ovate (variety Kolodautic).	6-10	954	2,784	530	59·12	55·08	4·04
Tirhoot (unirrigated land) capsules, oblong, ovate.	3-7	1,010	2,498	460	58·25	55·15	3·10
Tirhoot (unirrigated land) capsules, oblong, ovate, of a dull green colour.	3-5	1,014	3,418	527	58·60	55·35	3·25
Hajeepore (irrigated land) capsules, roundish, ovate, glaucous	6-8	1,233	4,770	546	60·25	57·85	2·40
Hajeepore (unirrigated land) capsule, oblong, ovate, glaucous.	4-10	1,233	5,088	665	59·40	54·85	4·55
Hajeepore (unirrigated land) capsules, ovate, oblong, of a dull green colour.	3-8	1,014	2,300	546	58·95	55·65	3·30
Chupra capsules, roundish, oblate to oblong	7-11	1,232	4,581	636	59·30	55·75	3·55
Alleegunge (unirrigated land) capsules, ovate, oblong.	3-8	1,074	5,924	624	59·75	55·85	3·90
Alleegunge (irrigated land) capsules, roundish, oblong.	4-7	1,500	5,824	708	58·25	56·10	2·15
Motiharee (unirrigated land) capsules, ovate, oblong, glaucous.	4-6	1,193	3,8[illegible]	670	58·75	55·24	3·51
Motiharee (irrigated land) capsules, oblong, ovate, glaucous.	4-7	1,352	5,088	664	59·20	56·35	2·85
Bettiah (unirrigated land) capsules, ovate, oblong, glaucous.	6-8	1,113	5,088	408	59·85	55·90	3·95
Bettiah (irrigated land) capsules, ovate, oblong, glaucous.	5-8	1,392	5,770	784	59·50	55·05	4·45
Gya capsules, oblong and roundish, oblate, glaucous.	5-9	1,670	7,950	795	58·50	54·75	3·70
Tehtah capsules, oblong, ovate, glaucous, and of a dull green colour.	6-8	1,331	4,810	730	56·84	53·95	2·89
Patna capsules, oblong of those texture (variety Gouria).	6-9	1,272	5,724	545	58·75	55·50	3·25
Patna capsules, oblong, ovate, glaucous (variety Kutylea).	5-8	1,232	4,093	636	58·15	56·10	2·05
Monghyr capsules, glaucous, roundish, oblong	7-11	1,550	6,519	706	58·25	55·50	2·75

Chiefly with a view of ascertaining the relative size of capsules and amount of water in the seed from lanced and unlanced capsules, I requested both Agents to send me from each division of their agencies twelve of the largest and most copious drug-producing capsules. Such samples have been forwarded to me from all the divisions, and of the sub-divisions of the Benares agency, and also from those of the Behar agency with few exceptions, one of which, Chota Nagpore, as the Sub-Deputy Opium Agent explains, was due to a severe hailstorm, which has destroyed the best of his crop, and he did not care to send me inferior samples.

I have tabulated the results, not in full, as in many cases several samples were sent me from one division. In each case I have only selected a few of the best samples. The points I had specially in view in making such observations was whether or not there were any regular marked differences between lanced or unlanced capsules, *i. e* in the actual weight of capsule, its capacity as measured by small shot, the quantity of good seed produced, or the relative loss in water when dried at a temperature of 212° Farenheit. As will be seen from the tabulated results, the variations are most indefinite and can be reduced to no rule. This has surprised me much, as I had anticipated marked differences—as, for example, that the unlanced capsules should not only be heavier but of larger capacity, contain more seed, and that this also relatively to the produce of lanced capsules, would show a greater loss in water after exposure. to a high temperature. This is far from the case however, the variations being quite as great and irregular under each head (though the capsules have now been unlanced for two successive seasons) as are those of the regularly lanced capsules. Again, in the case of the irrigated, relatively to the unirrigated lands, we find the same irregular variations, though this may be largely a result of the comparisons being made with different varieties of seeds; and this much I have generally observed, when I had an opportunity of comparing similar varieties, from irrigated and unirrigated lands, that the former produced, as a rule, heavier capsules of larger capacity, and an increased quantity of seeds, as compared with those on the unirrigated lands. I have, however, failed to detect any regular differences in the amount of water they respectively contained. The first column, however, of the two tables is of some interest, as enabling us to form a distinct estimate (from that furnished by my own experiments) of the drug-producing quality of the best plants in the several divisions of both agencies. It will be observed that the best in some districts do not afford even five incisions, and from this we find them dropping off to four, three, two, and even one. With such as the best selected samples of the several divisions, we must needs form but a poor opinion of the average drug-producers. On the other hand, many fine samples, were sent to me, both of large and medium-sized capsules, which had afforded from seven to nine, and even eleven, full incisions. The seeds of these, as well as the others, I need scarcely say, are reserved by me for next season's experiments. They are valuable as comprising, I presume, all the best varieties now cultivated in the two agencies.

APPENDIX.—*TABLE K.*

Results of experiments with unselected poppy-seeds, in which the relative proportions of poor and copious drug-producing plants, &c., are shown.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Area in square feet.	* Number of plants on an area of seven square feet.	Total weight of air-dried plants, as per column 2.	Height of plants—column 2—in inches.	Seed produce of column 2.	The total weight—air-dried—of plot produced on each plot.	Estimated weight of a full and uniform crop—*vide* column 3.	Relative deficiency of actual produce.	Weight of plants bearing capsules with a minimum of four copious drug-yielding incisions.	Weight of plants bearing capsules with a minimum of five copious drug-yielding incisions.	Weight of plants bearing capsules with four copious drug-yielding incisions.	Weight of plants bearing capsules with a maximum of three copious drug-yielding incisions.	Total seed produce of column 10.	Total seed produce of column 11.	Total seed produce of column 12.	Period over which the collection of drug extended (figures indicate the month and day).	Total weight of drug at an average consistency of 75°.	Date of seed-sowing (figures indicate day and month).
		Srs. C.	Inches.	Srs. C.	Seers.	Seers.	Seers.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	D. M. D. M.	Srs. C.	D. M.
26,200	152	1 14	30—46	6 1	501	7,018	6,517	195 8	20 8	28 12	120 8	10 0	16 7	74 0	12 2—28 3	6 13	8 11
13,824	135	0 14	20—32	3 0	263	1,791	1,528	40 8	10 0	14 0	36 0	6 0	7 8	24 8	11 3—31 3	1 9	18 11
13,824	140	1 12	30—48	7 2	336	3,456	3,119	54 8	13 0	22 8	88 0	7 8	14 8	45 0	22 2—23 3	5 3	10 11
13,824	111	1 4	30—40	5 0	284	2,946	2,211	23 8	6 0	18 0	42 0	3 0	10 8	30 0	6 3—31 3	1 13	12 11
13,824	196	1 12	18—36	6 1	300	3,456	3,156	32 0	6 4	12 8	52 0	3 4	7 10	33 8	3 3—26 3	[illegible] 15	12 11
7,096	72	2 0	30—48	4 1	57	2,073	2,001	9 8	2 4	2 8	12 8	1 3	1 10	6 4	6 3—26 3	0 14	14 11
7,696	120	1 8	24—40	5 0	103	1,648	1,545	12 8	4 8	4 0	29 0	2 8	2 4	13 8	27 2—27 3	0 10	14 11
3,072	120	0 15	20—36	3 0	16	411	394	2 4	0 12	1 0	2 8	0 [illegible]	0 8	1 8	27 2—1[illegible] 3	0 4	14 11
7,636	110	1 4	38—50	4 1	179	1,364	1,184	29 4	5 12	5 4	46 12	3 4	3 0	15 4	18 2—24 3	3 1	12 11
7,636	145	2 4	34—50	7 2	132	2,454	2,321	14 0	3 4	3 4	24 0	2 0	1 11	13 4	25 2—21 3	1 3	13 11
18,316	133	2 6	24—42	6 0	491	6,213	5,721	99 4	16 12	24 0	90 0	8 14	13 8	44 8	9 2—28 3	5 5	3 11
18,316	188	2 0	24—42	4 0	375	5,294	4,978	38 8	12 0	18 8	80 8	5 8	9 0	35 0	16 2—17 3	3 1	2 11
3,312	191	1 8	27—40	4 0	229	709	479	41 0	10 4	12 0	4	5 11	6 12	24 0	16 2—17 3	1 14	5 11
2,760	171	1 5	24—42	4 2	190	517	327	23 12	6 8	4 0	2 3	3 9	2 1	13 8	9 2—31 3	1 2	5 11
1,472	174	1 2	23—39	3 2	80	236	155	8 8	0 12	1 0	8 0	0 6	0 8	3 8	18 2—17 3	0 5	1 11
9,520	150	1 12	24—40	6 2	148	2,380	2,231	15 0	3 4	0 12	18	1 12	0 4	7 4	19 2—26 3	1 3	23 11
9,960	123	1 8	24—40	5 3	91	1,920	1,828	9 8	2 4	1 8	10	1 4	0 12	5 4	27 2—26 3	1 1	25 11
8,960	182	0 14	18—36	2 3	130	1,220	989	13 8	3 0	1 4	16 0	1 8	0 14	8 0	2 3—26 3	1 1	28 11

* I have to explain that in column 2 I have given the produce in each instance of a single compartment, uniformly filled with plants, so as to enable us to form, by comparison with columns 1 and 6, a correct estimate of the general state of the crop on the respective plots.

APPENDIX.—*TABLE L.*

Average drug returns per beegha of 27,225 square feet, of the several divisions in the Behar Agency, from the season 1851-52 *to* 1874-75.

Season.	Tirhoot.	Hajeepore.	Chupra.	Allegunge.	Motiharee.	Bettiah.	Shahabad.	Gya.	Tehtah.	Patna.	Monghyr.	Chota Nagpore.	General average.	Average on irrigenous lands.	North Gangetic districts—irrigated lands average.	South Gangetic districts—irrigated lands average.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	North Gangetic Divisions.						South Gangetic Divisions.									
	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.	Srs. C.
1851-52 ...	4 8¼	......	8 3	5 5	2 14	5 0¾	7 10½	8 0	8 4	7 8	5 15	......	6 5¼	4 2	6 12	7 7½
1852-53 ...	4 12	......	8 0¼	6 8	5 12	5 15	8 3¼	8 0	7 9½	7 1[illegible]	5 4½	......	6 11¼	5 7¾	7 4	7 9¼
1853-54 ...	4 13	......	8 5¾	6 11½	6 ½	6 6¾	7 5½	7 0	6 6	6 10[illegible]	5 12½	......	6 8¾	5 12¼	8 8½	6 10
1854-55 ...	4 6¼	......	6 7¾	5 4½	4 10½	5 0½	7 3¾	6 9	7 3	6 14¾	[illegible]	......	5 11¾	4 11	5 14	6 7¾
1855-56 ...	3 12½	......	6 10¾	5 4¾	4 5	3 13½	7 6½	6 13	6 10	6 15¾	5 8	......	5 11¾	3 15½	5 15½	6 10½
1856-57 ...	2 15	......	5 9¾	3 15¾	3 14½	3 2½	5 12½	5 4	5 11¼	5 6¼	4 5	......	4 9¾	3 5¼	4 12¾	5 4½
1857-58 ...	2 14¼	......	6 10¾	5 9	5 1¾	4 12½	7 4	5 12	6 11¾	6 13	5 4	......	5 0¾	4 4	6 1¾	6 5¾
1858-59 ...	1 12½	2 7¾	3 9	3 7½	2 15½	2 5½	4 3¾	4 12	5 0	4 5½	4 3¾	......	3 13½	2 0½	3 2¼	4 4½
1859-60 ...	1 11¾	2 12	4 3¼	3 5½	2 10½	2 7¾	5 4	5 8¾	5 0	4 11	4 3¾	......	3 12¼	2 4½	3 6¾	4 15
1860-61 ...	1 14	3 1	5 9¼	5 2¼	2 10	3 10½	7 1¼	5 11	5 15	6 6¾	4 2¾	......	4 10½	2 11½	4 9½	5 13¾
1861-62 ...	2 15¾	3 15½	5 5½	4 12¼	3 11¼	4 1	5 12¾	5 0	6 0	[illegible]	4 1¼	......	4 9¼	3 9¼	4 11	5 4
1862-63 ...	3 0¼	4 8½	6 0¾	5 7¼	3 7¾	4 13¼	7 4¼	5 11¾	6 11¾	6 [illegible]	4 7¼	......	5 2¼	3 12¼	5 5½	6 1¾
1863-64 ...	4 6	5 11¼	7 4½	7 1¼	4 5¾	5 3½	7 13¼	6 13½	6 1[illegible]	6 12¼	5 10¾	......	6 0½	4 10½	6 11	6 12¼
1864-65 ...	2 9¼	4 0½	5 4	3 11½	3 3¾	4 1	6 9½	5 7¾	5 8¼	5 5¼	4 5½	......	4 8	3 4½	4 5½	5 7
1865-66 ...	3 5	5 3	6 11½	3 14¾	3 0	4 4½	6 15	5 5½	5 12½	6 6½	4 3¼	......	4 14½	3 8½	5 4½	5 11¾
1866-67 ...	4 2¾	5 1¾	6 5¼	5 15	3 8	4 8½	6 7½	5 15	5 9¼	6 1½	4 12½	......	5 3¾	4 1	5 9½	5 12¼
1867-68 ...	3 12	4 1½	4 9¼	5 3¼	3 6¾	4 0¾	5 6¾	5 3½	5 0¾	4 5¾	3 11¾	......	4 6¾	3 3½	4 10	4 12
1868-69 ...	3 0¾	4 6¾	4 13	4 12	2 13½	3 6¾	6 6	6 1¼	6 4½	5 11¼	4 2½	......	4 11¾	3 1½	4 10½	5 11½
1869-70 ...	3 7½	5 4¼	6 3½	6 3	3 8	4 0¼	6 14½	6 3¾	6 5	6 5½	4 14¾	3 9½	5 5¼	3 10½	5 14¼	5 15
1870-71 ...	2 6	3 0¼	4 2	4 2¼	2 11¾	2 15	4 13¼	4 11¾	4 7¾	4 5½	3 8½	2 8¾	3 12	2 10¾	3 15	4 5¾
1871-72 ...	3 0½	4 1	4 4½	3 11	3 2	3 6¾	5 4	5 3¾	5 2¼	4 13¾	4 4¼	3 5¼	4 2¾	3 3	4 0	4 15½
1872-73 ...	2 4¼	4 3¼	4 3½	4 6¼	1 14	2 8	7 3¼	6 8½	7 0	6 6¼	5 2¾	3 2¾	4 8½	2 3½	4 4½	6 7½
1873-74 ...	4 6¼	6 14¼	5 15	5 5¼	3 7	3 10¾	8 9¾	6 6½	7 8	7 14¼	5 14½	3 8¼	5 14½	3 13½	6 11½	7 0¼
1874-75 ...	3 3¼	4 4	4 12½	5 13	3 15½	3 8¾	5 12	5 0	5 2	5 8½	4 6½	2 2¾	4 7¼	3 9	4 15	5 2½

Regr. No. 1058—200—22-1-77