PAPER READ BY F. F. HALLETT, F.L.S., OF BRIGHTON,

Before the BRITISH ASSOCIATION *for the* ADVANCEMENT *of* SCIENCE,

AT EXETER, 1869,

ON THE LAW OF THE DEVELOPMENT OF CEREALS.

THE Author commenced by explaining that a perfect plant of a cereal consists of three principal parts, viz., the roots, the stems, and the ears, which are produced as follows :—

Shortly after the first stem appears above ground, it commences to throw out new and distinct stems, upon the first appearance of each of which a corresponding root-bud is developed for its support; and while the new stems grow out flat upon the surface, their respective roots assume a corresponding development beneath it. This process, called "tillering," will continue until the season arrives for the stems to rise to an upright position; after which the vital power of the plant is concentrated upon the production of the ears. These will be the finest the original seed is capable of producing, unless the growth of its roots has been in any way impeded, as by being cramped or crowded by those of other plants, when the size of the ears will be proportionately diminished.

The Author, throughout his continued observations and experiments, extending over nearly twenty years, had found only three instances recorded in which there were two ears on a plant containing an equal number of grains; and one of these related to the Belle Vue Talavera wheat, which must be considered quite exceptional as to variation. In both the other instances there was only a low stage of development, the equally finest two ears of each plant containing but 59 grains and 49 grains respectively. In every case where the plant presented an ear containing 60 grains and upwards, the next best ear was of less contents than the finest one. In 20 such instances taken consecutively and without omission from his journal, and referring to 7 varieties of wheat, the average difference between the contents of the first and second ears was 7½ grains. The difference in 4 of these instances was only 1 grain, but in other 4 it amounted to from 17 to 19 grains. The superior productive power of a grain over that of another may consist in a greater number of ears upon the plant it produces, or in their individually containing a greater number of grains; the latter, however, is the more sure indication of great inherent productive power, as the former may be induced by external circumstances producing excessive and untimely "tillering." Tables were submitted, showing the comparative produce in number of ears of each of the grains from the best two ears of a plant, themselves not greatly differing. The superiority of the produce of the best over that of the next best ear (although nearly equal to it as an ear) would be still more manifest when compared with the ears of the smaller plant.

One ear would also possess superiority over the others in the same plant in respect of the "quality" of the grain produced. A plant of Chevalier Barley, grown in 1862 from a single grain, consisted of 50 ears, against one of which (No. VIII.) the following note was made in 1862 :—"An extraordinary ear, all of the grains of which are short, plump, thin-skinned, and handsome; while there is a general tendency in all the other ears to produce elongated grains of not so good a colour and with thicker skins." In 1863 the grains from each of the best 10 of these 50 ears were planted in a separate division, while the collected grains from all the remaining 40 ears occupied an eleventh division. The grains in each division were subdivided into two classes, thus making in all 22 subdivisions. A sample and specimen ear of the produce of each of the 22 subdivisions at harvest, 1863, were arranged side by side in the Case (produced), so that all could be seen at a glance. An eminent maltster could scarcely credit that they all came from one grain planted in the previous year, and at once fixed upon as the best sample the produce of parent ear, No. VIII., the superior ear of the preceding year. The produce from this, afterwards weighed, gave 56.32 lbs. per bushel, whilst the average of the other produce was 53.35, being a superiority of 3 lbs. weight per bushel.

The grains from the same ear also differ in other qualities, such as tillering, producing stiff straw, resisting disease, frost, &c., an illustration of which last was given. Ten grains from an ear of Belle Vue Talavera wheat, from Colonel Le Couteur, were planted by the Author on the 1st November, 1861. Nine of the ten plants from these grains were killed by the severe frost, but the other remained perfectly healthy and vigorous. From this surviving plant he had grown it for the 7 succeeding years always as a Winter wheat: even the severe frosts of Christmas, 1863, and February, 1864, never affected it. It is, in fact, now a Winter wheat, although descended from wheat which had ever since the year 1834 not once been sown otherwise than as Spring wheat.

The transmission of minute characteristics is evidenced in the variety of wheat known as "Grace's White." There is in every grain a kind of indentation across the back, as if, when still soft, a thread had been tied tightly round it; this mark is more or less distinct, but never entirely absent. It even has a practical bearing upon its market value, the grains occupying as much room in the measure as if no such indentation existed.

The accumulation of improvement obtainable on the principles set forth in the Paper was very fully illustrated by specimen successive ears of three varieties of wheat.

GRAINS IN ORIGINAL EAR.	EARS.	GRAINS IN IMPROVED EAR.
45	Red ..... 1857 to 1869 ...	123
60	Hunter's White ... 1861 to 1869 ...	124
60	Victoria White ... 1862 to 1869 ...	113
	And "fixity of type" by those of Col. Le Couteur's Belle Vue Talavera :	
44	Engraving of Ear in 1836,..... 1860 and Actual Succession Ears to 1869 ...	59*

The successive ears from the years 1860 to 1869, together with Colonel Le Couteur's engraving of the ear in 1836 of the Belle Vue Talavera wheat, were produced, which showed an unmistakeable transmission of the characteristics of the parent to its progeny, and its practical fixity of type. The Author had been unable in 8 years cultivation to obtain the slightest variation in the direction of additional spikelets, or ranks of grains, although in upwards of 70 other varieties of wheat upon which he had experimented he had never once failed to obtain such increase.

The Author here quoted from Mr. Darwin "On Animals and Plants under Domestication," under "Ceralia," chapter ix., page 314: "As wheat is an annual, we thus see how strictly many "trifling differences in character are inherited through many generations. Colonel Le Couteur insists strongly on the same fact in "his persevering and successful attempts to raise new varieties by "selection. He 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;" and said that if Mr. Darwin really meant by this that Colonel Le Couteur grew separately and in competition with each other the grains from the same ear, and similarly the progeny of each, generation after generation (as he must have done to find that each grain of the original ear transmitted its own character through many generations), it implied that, in some measure at least, he anticipated the principles upon which he had acted, and it was due to his own claim to originality to remark that throughout the whole of Colonel Le Couteur's book there is no mention whatever of his having grown in competition with each other the grains of the same ear, nor has he once alluded to the difference in their powers.

Specimens were produced showing the maximum of stems yet obtained from a plant from a single grain of

Wheat	... ...	94 Stems.
Barley	... ...	110 ,,
Oats ...	... ...	87 ,,

It had been supposed that the powers of grains differed in relation to their positions in the ear. This the Author investigated in 1858 by planting the grains of ten ears on a plan showing their several positions in the ear. The only general result, among most conflicting ones, was that the smallest corns, those most remote from the centre of growth, exhibited throughout, most unexpectedly, a vigour equal to that of the largest; and that the remarked worst grains, in one or two instances, did not by any means fall so far short of the good ones as had been expected. Frequent trials had also been made of the comparative power of large and small, plump and thin grains—and, in the case of oats, which produce a small grain attached to a large one, trials as to their respective powers—with uniformly the same result, viz., that in good grains of the same pedigree neither mere size nor situation in the ear supplies any indication of the superior grain.

Believing that the power of vegetable growth in a grain is identical with its power of supporting animal life, and dependent mainly upon the proportion of gluten which it contains, which is also proportionate to its specific gravity, he had commenced a series of experiments of first testing the grains for specific gravity by immersion in solutions of different densities, to determine after actual growth in competition with each other whether those grains which prove the best are so in proportion to their specific gravity.

From his investigations the Author had arrived at the following conclusions, that where room has been afforded to the plant for its natural development :—

1.—Every fully developed plant, whether of wheat, oats, or barley, presents an ear superior in productive power to any of the rest on that plant.

2.—Every such plant contains one grain which, upon trial, proves more productive than any other.

3.—The best grain in a given plant is found in its best ear.

4.—The superior vigour of this grain is transmissible in different degrees to its progeny.

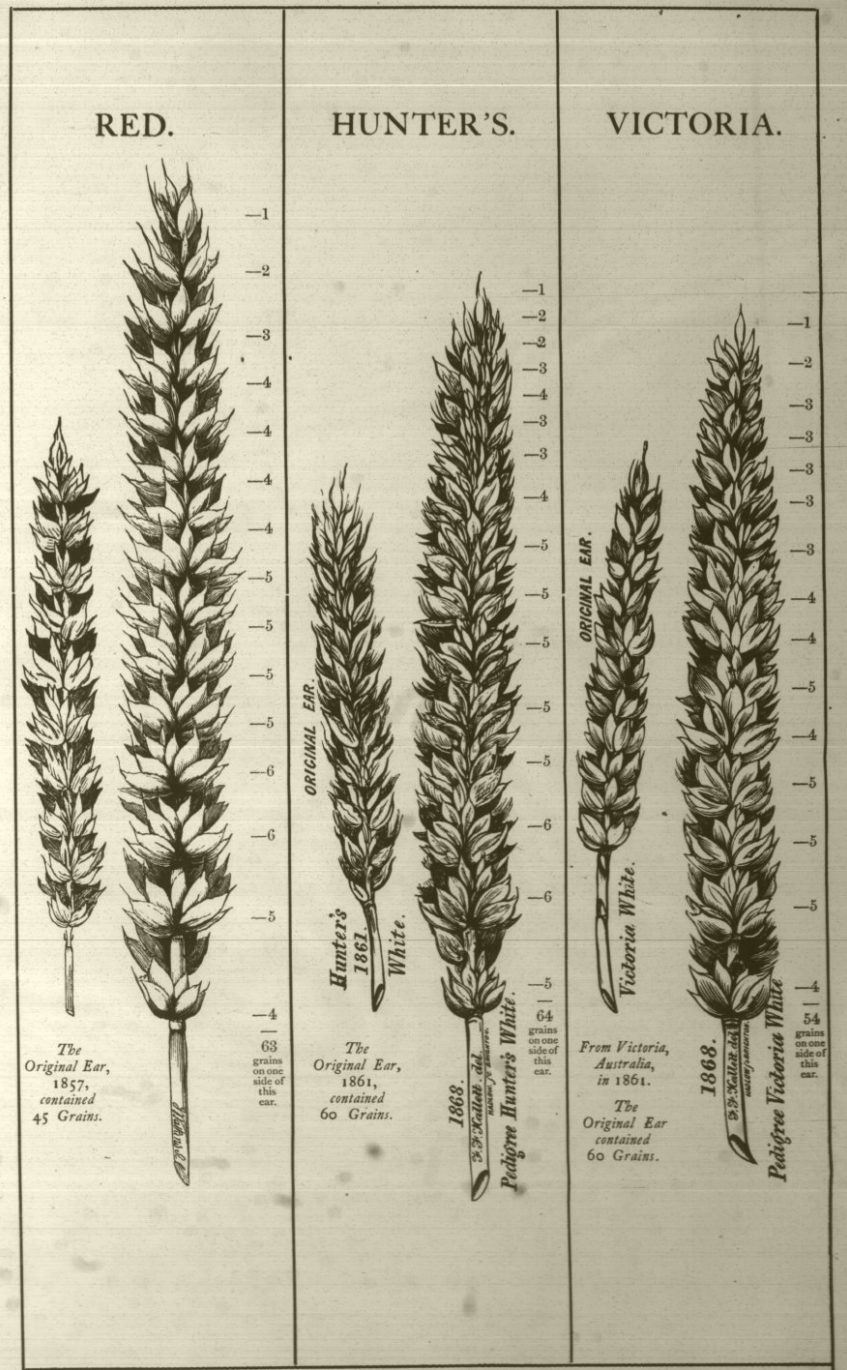
5.—By repeated careful selection the superiority is accumulated.

6.—The improvement which is at first rapid, gradually, after a long series of years, is diminished in amount, and eventually so far arrested that, practically speaking, a limit to improvement in the desired quality is reached.

7.—By still continuing to select, the improvement is maintained and *practically* a fixed type is the result.

* Even this small increase, obtained entirely in the increased *contents* of the spikelets, no addition having been obtained to their *number*.

Erratum – Last line of third paragraph, instead of "ears of the smaller plant" read "smaller ears of the plant."



Showing the increase obtained in the number of "spikelets," or ranks of grains, as well as in the number of grains in the ear.

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PAPER ON "THIN SEEDING AND THE SELECTION OF SEED," READ BEFORE THE MIDLAND FARMERS' CLUB, AT BIRMINGHAM, JUNE 4, 1874, BY MAJOR HALLETT, F.L.S., OF BRIGHTON. THE RIGHT HON. THE EARL OF YARMOUTH, M.P., PRESIDING.

MY LORD AND GENTLEMEN,

The subject upon which you have done me the honour to invite me to read a paper on the cereals is "Thin sowing and the selection of seed," and this title I will adopt for convenience sake, first treating of each of these points separately in succession, and afterwards showing what may be done by their intelligent combination.

THIN SEEDING.

If an entirely new plant were in question, and it were required to ascertain and determine the proper method of sowing its seeds, we should proceed to do so by actual experiment and observation upon their growth.

Let us then deal with wheat (and I speak of wheat alone for the sake of simplicity) as an entirely new plant, and see what its natural growth is, and what this requires.

We find then that a perfect plant of wheat consists of three principal parts, viz., the roots, the stems, and the ears. When a grain is planted in a proper manner, these are produced as follows:—shortly after the plant appears above ground it commences to throw out new and distinct stems, upon the first appearance of each of which a corresponding root-bud is developed for its support; and while the new stems grow out flat over the surface of the soil, their respective roots assume a corresponding development beneath it.

This process, called "tillering," will continue until the season arrives for the stems to assume an upright growth, when tillering ceases, and the whole vital power of the plant is concentrated upon the production of the ears. These will be the finest it is capable of producing, unless the growth of its roots has been in any way interfered with, as, for instance, by having been crowded by those of other plants, when the size of the ears will be proportionately diminished.

This tillering is the great characteristic of all the cereals, and as an instance of the extent to which it may attain, I have known a plant of wheat grown from a single grain to cover in May a circle 5ft. 6in. in diameter, measuring from the extremities of the opposite leaves as they lay tillered out flat upon the surface.

At the Exeter meeting of the British Association I exhibited three plants of wheat, barley, and oats, each from a single grain, with the following:—

Wheat	...	...	94 Stems.
Barley	...	...	110 "
Oats	...	...	87 "

The fact then at once stands out that a plant of wheat requires *space* for full development, and, therefore, *time* to fill that space. It is evident that the proper space and time to allow to each grain are those which, while sufficient for full development, leave no ground unoccupied at harvest. Such proper time must, it is plain, be much earlier than when wheat is planted so thickly that "tillering" cannot take place.

In reference to this point of time of sowing we must consider the *rate* of wheat growth during the different months, and the best measure we can have of this is the time which it takes to come up. Thus wheat sown—

	1st of Sept.	comes up in	7 days.
In a mild autumn	1st of Oct.	"	14 "
	1st of Nov.	"	21 "
	1st of Dec.	"	28 "

And assuming, as we may fairly do, this as the relative rate of wheat growth *when it is up*, then wheat which is up on the 1st September makes in the first fifteen days of that month a growth *equal to that of the whole month of October;* in the next ten days a growth *equal to that of the whole of November;* and in the last five days of September a growth *equal to that of the first twenty days of December;* or in other words, wheat up on the 1st September, compared with that up on the 1st October, has exactly a double autumn for growth before the winter sets in; and, indeed, the case is in reality much stronger than this, for it would take much more than twenty days in early

On the other hand wheat has no doubt been planted sufficiently early, as on the Cotswold Hills, where the custom was to sow in August; but then it was, as we have seen, with a seeding of nearly 2 bushels per acre. So that it may in truth be said that all previous attempts, upon any scale, at "thin seeding," have been nothing more nor less than a mere modification of existing practice.

Certainly there has been no practice grounded upon a study of the nature of the plant *carried out to its logical conclusion.*

It must be borne in mind always that it is a matter for the maturest study and judgment to correctly apportion the quantity of seed to the time of sowing *and to all the existing surrounding circumstances.*

A large quantity of seed sown early is just as much opposed to reason as the late sowing of a small quantity of seed, and, indeed, more so, for the first must become winter-proud and *cannot* succeed, while the season *may* be of such a character as to enable the last to do so.

As a *general* basis I would suggest on a large scale the drilling of wheat as follows:—End of August to 10th September, 2 to 3 gallons per acre; for each week later, to the end of September, an additional gallon per acre.

When opportunity is afforded for observing the unimpeded growth of the cereals there is seen to exist a striking variation in their mode of growth and powers of production.

The superiority of some individuals over others is so marked in various ways as to lead irresistibly to the inference that it must be hereditary, and the desire to prove this brings us to our next head.

THE SELECTION OF SEED.

In reference to the animals of the farm, whether horses, cattle, sheep, or pigs, the importance of a good pedigree is fully recognized, as also with regard to some of our agricultural *plants*; for if a farmer wants a good cabbage, mangold, turnip or carrot, he selects the seed from a good *parent*, but the moment he deals with the cereals he altogether ignores the great principle of like producing like.

Upon this great principle, running throughout all nature, I base my system of selection.

The results of selection in many agricultural plants, such as the parsnip, cabbage, turnip, potato, hop, &c., are well known; and there has recently been published, in France, a report showing how my principle of selection applied to the beet cultivated for sugar has resulted in an increase of 5 per cent. of sugar.

In the case of the vine too I may cite an instance.

Some eight years since I communicated to an Italian friend my views as to the selection of the vines. These he carried back with him to his relative in Piedmont, and two years ago he informed me that the produce in wine from his relative's estate had been trebled by adopting the principle of selection.

No one can go into a hop garden in this country without being struck with the contrast between some of the poles covered with hops, and other poles having scarcely any at all upon them, the season of course having been the same for all.

The science of Horticulture, too, presents innumerable proofs of, and indeed may be said to owe its very existence to the principle of plant selection.

Now that some, at least, of the variations of cereals are heritable is obvious from the existence of the numerous distinct varieties.

The transmission of minute characteristics is evidenced in the variety of wheat known as "Grace's White." There is in every grain a kind of indentation across the back, as if, when still soft, a thread had been tied tightly round it; this mark is more or less distinct, but never entirely absent. It even has a practical bearing upon its market value, the grains occupying as much room in the measure as if no such indentation existed.

In fact close observation shows that in the cereals, as throughout nature, no two plants or grains are precisely alike in productive power, and hence that of any two or greater number of grains or plants one is always superior to all the others, although that superiority can be discovered only by actual trial.

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(3) *General variations.*

Throughout continued observations and experiments, extending over twenty years, I have found only three instances recorded in which there were two ears on a plant containing an equal number of grains, and one of these related to the Belle Vue Talavera wheat, which must be considered quite exceptional as to variation. In both the other instances there was only a low stage of development, the equally finest two ears of each plant containing but 59 grains and 49 grains respectively. In every case where the plant presented an ear containing 60 grains and upwards the next best ear was of less contents than the finest one. In 20 such instances taken consecutively and without omission from my journal, and referring to 7 varieties of wheat, the average difference between the contents of the first and second ears was 7½ grains. The difference in 4 of these instances was only 1 grain, but in other 4 it amounted to from 17 to 19 grains. The superior productive power of a grain over that of another may consist in a greater number of ears upon the plant it produces, or in their individually containing a greater number of grains.

During these investigations no single circumstance has struck me as more forcibly illustrating the necessity for repeated selection than the fact, that *of the grains in the same ear one is found greatly to excel all the others in vital power*, as in the case of the Belle Vue Talavera already given. I will give two more instances.

The original two ears together contained 87 grains; these were all planted singly. One of them produced 10 ears containing 658 grains, and not only could the produce of no other *single* grain compare with them, but the finest 10 ears which could be collected from the produce of the whole of the other 86 grains contained only 598 grains; yet supposing that this superior grain grew in the smaller of the two original ears, and that this contained but 40 grains, there must still have been 39 of these 86 grains which grew in the same ear. So far as regards *contents* of ears.

Again, the next year the grains from the largest ear of the finest plant of the previous year were planted singly, 12 inches apart, in a continuous row; one of them produced a plant consisting of 52 ears; those next to and on either side of it of 29 and 17 ears respectively; and the finest of all the other plants consisted of only 40 ears.

The following are the *chief* points of my standard in order of their importance, but all have to be duly considered:—

1.—Hardihood of constitution.
2.—Trueness of type.
3.—Quality of sample.
4.—Productiveness.
5.—Power of tillering.
6.—Stiffness and toughness of straw.
7.—Earliness of ripening.

The plan of selection which I pursue is as follows:—A grain produces a plant, consisting of many ears. I plant the grains from these ears in such a manner that each ear occupies a row by itself, each of its grains occupying a hole in this row; the holes being 12 inches apart every way. At harvest, after the most careful study and comparison of the plants from all these grains, I select the finest *one*, which I accept as a proof that its parent grain was the best of all, under the peculiar circumstances of that season. This process is repeated annually, starting every year with the *proved* best grain, although the verification of this superiority is not obtained until the following harvest.

In illustration of these principles of selection, I now give the following results, due to their influence alone,—as the kind of seed, the land, and the system of culture employed were precisely the same for every plant for four consecutive years; neither was any manure used, nor any artificial means of fostering the plants resorted to.

Table showing the importance of each additional Generation of Selection.

Year.		Length.	Containing	Number of Ears on finest stool.
		Inches.	Grains.	
1857	Original ear	4⅝	47	..
1858	Finest ear	6¼	79	10

7.—By still continuing to select, the improvement is maintained, and *practically* a fixed type is the result.

We will now consider what may be effected by the combination of

THIN SEEDING WITH SELECTION.

In order to do this we must first glance briefly at the present usual mode of cultivating the cereals. Confining ourselves for the moment to wheat alone, we know that from 2 to 5 bushels per acre are sown.

The bushel of ordinary wheat contains 700,000 grains and upwards; and taking 2 bushels per acre as the seed sown, we have, speaking roughly, 1½ millions of grains per acre put into the ground.

I have counted at harvest the number of ears upon a quarter of an acre of wheat (drilled 20th November with 1½ bushels per acre, and which proved an exceptionally heavy crop of nearly 7 quarters per acre), and I found the number of ears per acre to be 934,120, or not so many ears as the grains sown. Here it is clear from the number of grains sown that either the natural powers of tillering could not have been exercised, or that the greater part of the seed must have been sown uselessly. Doubtless some of the grains did produce more than one ear, but this only makes the case still worse for the remainder.

Not only was the number of ears below that of the grains sown, but each ear was but the stunted survivor of a struggle for existence.

Indeed, it has been stated by Jethro Tull that if a square yard of thickly-sown wheat be counted in the spring, and the supposed number of ears then recorded, it would be found that 90 per cent. of them would be missing at harvest. Beyond all question in thickly-sown wheat a very large proportion of what appear as stems in the spring die away before harvest, and have thus grown not only uselessly, but in the struggle for existence have starved and stunted those which ultimately came to ears.

In ordinary crops the number of ears produced per acre being taken as about one million and the crop as 34 bushels, we have at 700,000 grains to the bushel, 23,800,000 grains per acre, or an *average* per ear of only 23 to 24 grains; and if more than one million ears per acre be claimed it must be at the expense of their contents.

Five pints of wheat per acre planted in September 12in. by 12in. gave 1,001,880 ears per acre, or 67,760 ears in excess of those produced on the other side of the hedge from 6 pecks, or *more than twenty-one times the seed.*

Again, 5 pints planted 12 inches by 12 inches October 17th gave 958,320 ears per acre; and planted similarly October 4th,* 966,792 per acre; while 1 bushel planted October 15th gave only 812,160.

Two plants of 24 ears each gave 1911 and 1878 grains, or 79 per ear. 20 ears per foot, at 48 grains only per ear, would produce 11 quarters per acre.

All the conditions of time and space being fulfilled, we can obtain from a *single parent grain* as many ears as are ordinarily obtained from *twenty grains*, with this most important advantage, viz.—these ears being produced from plants which have attained (or nearly so) perfect development of their growth, contain more than double the common number of grains, and their contents may be largely increased by the continued annual selection of the most vigorous parent grains.

These small quantities may in the following manner be drilled on a large scale without additional expense.

My principal object is to ensure perfect *singleness* and regularity of plant, with uniformity of depth. The two latter may be attained by the drill, as may the former also by adopting the following plan. The seed cups ordinarily used in drilling wheat are so large that they deliver *bunches* of grains, consisting of six or seven, which fall together within a very small area, from which a less produce will be obtained than if it had been occupied by a single grain. The additional grains are thus not only wasted, but are positively injurious. By using seed cups, however, which are only sufficiently large to contain one grain at a time, *a stream of single grains* is delivered, and the

resulting in a saving of *nearly one million quarters* of wheat alone.

2. *Power of withstanding frost and insects.*—The roots of wheat sown in August become by the middle of October so developed as to render it quite safe from lifting by the frost, and attacks of wireworm, &c., would be almost entirely unknown.

3. *Forwarding of the work of the farm.*—If the wheat were practically all drilled by the 10th September, the whole autumn would be at the farmer's disposal for clearing the land and getting ready for the autumn and very early spring sowing of barley and oats, beans and peas,—the root crops would not require to be hurriedly removed; and, in fact, the farmer would be always well a-head of all his work throughout the year.

4. The crop would never become "winter proud" even in the mildest seasons, or laid by heavy summer rains.

5. The harvest would be from two to three weeks earlier. Thus, notwithstanding the cold spring, I had (May 26th) August sown wheat just bursting into ear, and August sown barley, which was quite out in ear and in full bloom more than a week before. The harvest being over at least a fortnight sooner would be of immense advantage in the cleaning of the land.

6. Whereas seasons are frequently most unfavourable to late sown cereals they are scarcely ever so to early sown ones.

There is no real ground whatever for assuming our present amount of produce per acre to be final and unalterable. One hundred years ago the produce per acre probably was, and certainly might with equal reason have been, deemed so; and yet it has now been nearly doubled.

We have seen that the present *average* contents of our ears of wheat must be from 20 to 30. Were it grown as I propose the average contents of the ears would be at the very least from 40 to 60,—far more probably from 60 to 90; for under such a system so small an ear as one of 40 grains is quite the exception. And this increase of the *contents* of the ears would be obtained without any diminution of their *number*; in other words, the crop would thus at least be doubled. This is no mere speculation, as I have had 27 quarters of wheat grown upon 3 acres of land from 1 bushel of seed upon the whole 3 acres; and I have grown over a whole field 82 bushels per acre of barley, weighing 57 lbs. per bushel, from only one peck of seed per acre. And this was only an approximation to the system which I advocate before you to-day.

It may very fairly be asked me—Is your crop of wheat at present growing sown in August and the early days of September? and if not, why not? I answer at once that it is not so, I am sorry to say, although a good deal of it was got in at the end of September.

I have been foolish enough to try and combine the old practice with the new, and to hope by an approximation to August sowing *practically* to reap all its advantages. The success which has attended this earlier sowing has been most remarkable, as the crops at this moment growing upon my poor land will abundantly show; but such approximation is at the most but a half-way-house to the greatest possible improvement, as may be seen by comparing these crops with those I have which were sown in August.

I have become, by these gradual steps, convinced of the absolute necessity of abandoning entirely our ordinary practice of sowing wheat after mangolds, carrots, cabbage, rape, &c., and have arranged to have very nearly, if not quite, all my wheat drilled this year in August and the early days of September; and my crops are and will be at all times open to the inspection of every member of this Club.

There may be seen upon my farm now, wheat sown in single grains, in August, one foot apart each way; and some sown early in September, 15 inches apart each way; also about 30 acres drilled at end of September and the beginning of October with 5½ gallons per acre. Barley sown in August, single grains, 18 inches apart each way, side by side with some planted April 1st, 9 inches apart each way; also a field of barley drilled with 2 gallons per acre, and 48 acres drilled with 3¾ gallons per acre.

to each grain are those which, while sufficient for full development, leave no ground unoccupied at harvest. Such proper time must, it is plain, be much earlier than when wheat is planted so thickly that "tillering" cannot take place.

In reference to this point of time of sowing we must consider the *rate* of wheat growth during the different months, and the best measure we can have of this is the time which it takes to come up. Thus wheat sown—

	1st of Sept.	comes up in	7 days.
In a	1st of Oct.	„	14 „
mild	1st of Nov.	„	21 „
autumn	1st of Dec.	„	28 „

And assuming, as we may fairly do, this as the relative rate of wheat growth *when it is up*, then wheat which is up on the 1st September makes in the first fifteen days of that month a growth *equal to that of the whole month of October;* in the next ten days a growth *equal to that of the whole of November;* and in the last five days of September a growth *equal to that of the first twenty days of December;* or in other words, wheat up on the 1st September, compared with that up on the 1st October, has exactly a double autumn for growth before the winter sets in; and, indeed, the case is in reality much stronger than this, for if winter were to set in early, there would be for wheat sown at the end of October little or no autumn growth above ground.

The importance of every day (especially the earlier days) of September growth cannot be overrated.

To illustrate this, I produce two accurate drawings, taken by my daughter on the 30th of December last, of two plants of wheat, each from a single grain, one of which was up on the 1st September; the other was not up until the 19th September, and had thus lost the growth (after having come up) of the first nineteen days of September, the development of the earlier being double that of the later. This fact seems to point to the importance of sowing in August. Nature, too, in shedding the grain in August, seems to indicate it as the proper time, or at least a *not improper* time, or the species would not be perpetuated.

Within the present century it was the custom of many English farmers to go to wheat sowing whenever it rained during harvest.

The following extracts are from Miller's *Gardener's Dictionary*, 1807, article "*Triticum.*"—"In the downs of Hampshire, Wiltshire, and "Dorsetshire, the farmers begin sowing their "wheat in August if there happens rain; so "that when they are in their harvest, if the "weather stops them they employ their people "in sowing."

"In Mid-Lothian wheat is sown with success "from the end of August, when it is common "with several farmers to sow their fallows."

"The Cotswold hills are in a manner pro-"verbial for early sowing,—August and Septem-"ber being the principal months. The general "rule is to begin ploughing in July, and to "begin sowing the first wet weather in August. "Wheatseed time therefore generally commences "in wheat harvest. They sow in August 14 gallons and in September 19 gallons, per acre."

There can, therefore, be no possible ground for objecting that such a time of sowing is, in itself, at all unreasonable.

In determining the *space* to be assigned to each grain, I must deal with seed the result of continued selection, for the vital powers of the different grains of ordinary wheat are so *very* unequal that it would be impossible to fix upon any uniform distance. In planting grains of wheat in August, singly, and twelve inches apart each way, all the requisite conditions of time and space seem to be best fulfilled, as will be seen further on. I have known wheat planted September 9th, 9 inches by 9, to produce at the rate of 108 bushels per acre.

A paper relating to "thin seeding" should make some reference to what has been done in that direction.

The very term "thin seeding" has no definite meaning beyond thinner seeding than usual; and certainly I dare make no attempt to define what is popularly understood by the term.

So-called "thin seeding" has doubtless been practised by many, but if it has been sufficiently thin it has not been early enough.

country without being struck with the contrast between some of the poles covered with hops, and other poles having scarcely any at all upon them, the season of course having been the same for all.

The science of Horticulture, too, presents innumerable proofs of, and indeed may be said to owe its very existence to the principle of plant selection.

Now that some, at least, of the variations of cereals are heritable is obvious from the existence of the numerous distinct varieties.

The transmission of minute characteristics is evidenced in the variety of wheat known as "Grace's White." There is in every grain a kind of indentation across the back, as if, when still soft, a thread had been tied tightly round it; this mark is more or less distinct, but never entirely absent. It even has a practical bearing upon its market value, the grains occupying as much room in the measure as if no such indentation existed.

In fact close observation shows that in the cereals, as throughout nature, no two plants or grains are precisely alike in productive power, and hence that of any two or greater number of grains or plants one is always superior to all the others, although that superiority can be discovered only by actual trial.

This superiority may consist in various particular characteristics, as power to withstand frost—prolificness—size and character of ear—size, form, and quality and weight of grain—length or stiffness of straw—powers of tillering—rapidity of growth—and many others.

I beg to offer illustrations of some of these points.

(1) *Power to withstand frost.*

In 1860 Colonel Le Couteur, of Jersey, who wrote a work on wheat, which went through fourteen editions in different countries, sent me two ears of his famous Belle Vue Talavera wheat, begging me to cultivate and improve them under my pedigree system. This wheat had for years been sown as a spring wheat, and was declared to be quite incapable of withstanding the frost of winter. As an experiment, however, I picked out from one of the ears ten of its grains, and planted them on the 1st of November, 1861. Nine of the ten plants from these grains were killed by the severe frost, but the other plant, although from the same ear, remained as healthy and vigorous as any of the winter varieties of wheat by their side. From this surviving plant I have selected and grown it year after year for 12 years, as a winter wheat; the frost, even during the severe winter of 1863-4, has never affected it at all; in fact it is now as much a winter wheat as any that I have, although descended from wheat which had ever since the year 1834 not once been sown otherwise than as spring wheat.

(2) *Difference in weight of produce.*

One ear would also possess superiority over the others in the same plant in respect of the "quality" of the grain produced. A plant of Chevalier Barley, grown in 1862 from a single grain, consisted of 50 ears, against one of which (No. VIII.) the following note was made in 1862:—"An extraordinary ear, all of the grains of which are short, plump, thin-skinned, and handsome; while there is a general tendency in all the other ears to produce elongated grains of not so good a colour and with thicker skins." In 1863 the grains from each of the best 10 of these 50 ears were planted in a separate division, while the collected grains from all the remaining 40 ears occupied an eleventh division. The grains in each division were subdivided into two classes, thus making in all 22 subdivisions. A sample and specimen ear of the produce of each of the 22 subdivisions at harvest, 1863, were arranged side by side in a case so that all could be seen at a glance. An eminent maltster could scarcely credit that they all came from one grain planted in the previous year, and at once fixed upon as the best sample the produce of parent ear, No. VIII., the superior ear of the preceding year. The produce from this, afterwards weighed, gave 56·32 lbs. per bushel, whilst the average of the other produce was 53·35, being a superiority of 3 lbs. weight per bushel.

ing of many ears. I plant the grains from these ears in such a manner that each ear occupies a row by itself, each of its grains occupying a hole in this row; the holes being 12 inches apart every way. At harvest, after the most careful study and comparison of the plants from all these grains, I select the finest *one*, which I accept as a proof that its parent grain was the best of all, under the peculiar circumstances of that season. This process is repeated annually, starting every year with the *proved* best grain, although the verification of this superiority is not obtained until the following harvest.

In illustration of these principles of selection, I now give the following results, due to their influence alone,—as the kind of seed, the land, and the system of culture employed were precisely the same for every plant for four consecutive years; neither was any manure used, nor any artificial means of fostering the plants resorted to.

Table showing the importance of each additional Generation of Selection.

Year.		Length.	Containing	Number of Ears on finest stool.
		Inches.	Grains.	
1857	Original ear	4¾	47	..
1858	Finest ear	6¼	79	10
1859	Finest ear	7¾	91	22
1860	*Ears imperfect from wet season*	...	...	39
1861	Finest ear	8¾	123	52

Thus, by means of repeated selection *alone*, the length of the ears has been doubled, their *contents* nearly trebled, and the "tillering" power of the seed increased five-fold.

The following table gives similar increased *contents* of ear obtained in three other varieties of wheat.

GRAINS IN ORIGINAL EAR.		GRAINS IN IMPROVED EAR.
45	Original Red, commenced 1857	123
60	Hunter's White „ 1861	124
60	Victoria White „ 1862	114
32	Golden Drop „ 1864	96

It was supposed by the ancient writers that the powers of grains differed in relation to their positions in the ear. This I investigated in 1858 by planting the grains of ten ears on a plan showing their several positions in the ear. The only general result, among most conflicting ones, was that the smallest corns, those most remote from the centre of growth, exhibited throughout, most unexpectedly, a vigour equal to that of the largest; and that the remarked worst grains, in one or two instances, did not by any means fall so far short of the good ones as had been expected. I have also made frequent trials of the comparative power of large and small, plump and thin grains—and, in the case of oats, which produce a small grain attached to a large one, trials as to their respective powers—with uniformly the same result, viz., that in good grains of the same pedigree neither mere size nor situation in the ear supplies any indication of the superior grain.

Very close observation during many years has led me to the discovery that the variations in the cereals which nature presents to us are not only hereditary but that they proceed upon a fixed principle, and from them I have educed the following Law of Development of Cereals.

1.—Every fully developed plant, whether of wheat, oats, or barley, presents an ear superior in productive power to any of the rest on that plant.

2.—Every such plant contains one grain which, upon trial, proves more productive than any other.

3.—The best grain in a given plant is found in its best ear.

4.—The superior vigour of this grain is transmissible in different degrees to its progeny.

5.—By repeated careful selection the superiority is accumulated.

6.—The improvement, which is at first rapid, gradually, after a long series of years, is diminished in amount, and eventually so far arrested that, practically speaking, a limit to improvement in the desired quality is reached.

fourteen quarters per acre.

All the conditions of time and space being fulfilled, we can obtain from a *single parent grain* as many ears as are ordinarily obtained from *twenty grains*, with this most important advantage, viz.—these ears being produced from plants which have attained (or nearly so) perfect development of their growth, contain more than double the common number of grains, and their contents may be largely increased by the continued annual selection of the most vigorous parent grains.

These small quantities may in the following manner be drilled on a large scale without additional expense.

My principal object is to ensure perfect *singleness* and regularity of plant, with uniformity of depth. The two latter may be attained by the drill, as may the former also by adopting the following plan. The seed cups ordinarily used in drilling wheat are so large that they deliver *bunches* of grains, consisting of six or seven, which fall together within a very small area, from which a less produce will be obtained than if it had been occupied by a single grain. The additional grains are thus not only wasted, but are positively injurious. By using seed cups, however, which are only sufficiently large to contain one grain at a time, *a stream of single grains* is delivered, and the desired object, viz., the depositing of *grains singly*, at once attained. The intervals *in* the rows will not be *exactly* uniform, but *they will be sufficiently so for all practical purposes.* The width of these intervals will of course depend upon the velocity with which the seed-barrel revolves, which can be regulated at pleasure by a proper arrangement of the cog-wheels which drive it. By drilling thus we obtain the advantage of the "broad-cast" system also, *equal distribution*, as we can have the rows as close together, and the grains as thin *in* the rows, as we please.

The crop should be hoed, as soon and as frequently as practicable, with Garrett's horse-hoe. If the seed has been sown early, this should be done *in the autumn*, as it causes the plants to tiller and occupy the whole ground before the winter sets in. It is essential to the success of thin sowing to keep the land perfectly free from weeds during the growth of the crop.

We will now consider a few facts as to what may be produced under my system.

And first I would draw attention to the effect upon the crop of the mere increased size of the grain produced.

A bushel of pedigree wheat (Original Red), produced from single grains, planted 12 by 12, contains about 460,000 grains, while a bushel of ordinary wheat contains 700,000 grains and upwards. Therefore, in two crops consisting of precisely the same number of grains the crop from the thin seeding would be upwards of 70 bushels against 46 bushels, or 9 quarters against 6 quarters per acre.

Again, a bushel of pedigree barley, produced from grains planted singly 12in. by 12in., contains 390,400 grains, while a bushel of ordinary barley contains upwards of 550,000, or in two crops of equal *numbers* of grains the one would be 55 bushels, the other 39, or 7 quarters against 5 quarters per acre.

Thus in the increased size alone of the grains produced we obtain an increase of crop of from 40 to 50 per cent.

The following are some of the advantages which, apart from the increase of crop obtained, would attend the adoption of the August and early September sowing of a proper quantity of seed.

1. *The saving of seed.*—Although this is no main object of my plan, but only, as it were, a necessity arising out of it, this single one of its features is in itself of national importance,

* Rows (3 outside) Planted.	Missed.			Gave ears.	Per foot.
87	5	=	82	2184	26½
74	6	=	68	1832	27
14	0	=	14	420	30
7 inside rows.					
12	1	=	11	282	25½
17	0	=	17	395	22½
14	0	=	14	322	23
14	0	=	14	276	20
14	0	=	14	303	21½
14	2	=	12	317	26½
14	1	=	13	304	23
99			95	2199	23½

2199 (23½ including misses), or 966,792 per acre.

hope by an approximation to August sowing *practically* to reap all its advantages. The success which has attended this earlier sowing has been most remarkable, as the crops at this moment growing upon my poor land will abundantly show; but such approximation is at the most but a half-way-house to the greatest possible improvement, as may be seen by comparing these crops with those I have which were sown in August.

I have become, by these gradual steps, convinced of the absolute necessity of abandoning entirely our ordinary practice of sowing wheat after mangolds, carrots, cabbage, rape, &c., and have arranged to have very nearly, if not quite, all my wheat drilled this year in August and the early days of September; and my crops are and will be at all times open to the inspection of every member of this Club.

There may be seen upon my farm now, wheat sown in single grains, in August, one foot apart each way; and some sown early in September, 15 inches apart each way; also about 30 acres drilled at end of September and the beginning of October with 5½ gallons per acre. Barley sown in August, single grains, 18 inches apart each way, side by side with some planted April 1st, 9 inches apart each way; also a field of barley drilled with 2 gallons per acre, and 48 acres drilled with 3½ gallons per acre.

I counted (May 26th) the stems upon a plant from a single grain of wheat, of barley, and of white Canadian oats, all sown in August, as follows:—

A plant of Wheat, 84 stems.
„ Barley, 87 „
„ Oats, 36 „

I will now show how the 3½ millions of acres of wheat sown in England could be drilled in August and the early days of September.

Taking the crops of England as given in the Agricultural Returns for 1872, at the end of this paper.

First there are 585,000 acres of bare fallow. Next there are 496,000 acres of beans, and 353,000 acres of peas. And these beans and peas should be sown in the autumn and come sooner to harvest. Then there are 420,000 acres of vetches, lucerne, &c. And of clover and grasses under rotation, 2,822,000 acres. In all 4,676,000, out of which to obtain 3,337,000 acres of wheat.

To the extent of about *one-half* of the clover and grasses under rotation, whether for hay or not, it would doubtless be necessary to sacrifice all the growth at present obtained after about Midsummer or the middle of July.

In the *Standard* of Dec. 10th, 1873, in an account of the annual dinner of the Central Farmers' Club, an hon. agricultural Member is thus reported—"He was astonished, therefore, "to hear so painstaking, careful, and thought-"ful a statesman as the Earl of Derby saying "that it was his deliberate opinion that the "land of England might be made to double its "present produce, and still more that Lord "Leicester should back up that opinion."

Now, I do not hesitate to say that with regard to corn the noble lords were strictly right, and their hon. critic egregiously in the wrong.

By the adoption of my system this could be done, and the whole of the bread-stuffs which we purchase each year at the enormous sum of *forty millions sterling* might be produced upon our own land at home, enriching the proprietors and cultivators of England, and annually adding these forty millions to the wealth of the entire nation.

ENGLAND, 1872.

Bare Fallow or Uncropped Arable Land	585,417	Wheat	585,417
Clover, Sainfoin, and Grasses, under Rotation — For hay	1,734,975		2,751,471
Clover, Sainfoin, and Grasses, under Rotation — Not for hay	1,087,417		
Vetches, Lucerne, and any other green crops (except Clover or Grass)	419,689		
Beans	496,158		
Peas	352,733		
	4,676,389		3,336,888
Potatoes	329,656	Barley	1,896,403
Turnips and Swedes	1,512,496		
Mangold	321,033	Oats	1,442,075
Carrots	15,002		
Cabbage, Kohl and Rape	171,599		
	2,359,286		3,338,478
	7,035,625		6,675,366

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