THE BATTLE OF LIFE AMONG PLANTS.

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EVERY day, every hour, there is going on around us a veritable death-struggle. It excites little attention. People would be in no hurry to read the telegraphic despatches concerning it from the seat of war, even if there were any to read. Special correspondents there are, but their letters are appreciated but by a few. Nevertheless, it cannot be said that mankind in general is not interested in the result of the struggle. On the contrary, little as the affair is heeded, it is of very serious import to the human race. Our food-supplies depend on it; the well-being of our flocks and herds is essentially dependent on it; the building of our houses, the fabrication of our raiment, are to a large extent contingent on it; nay, the soil beneath our feet, and the very sky above our heads, are materially, very materially, influenced by the result of the contest of which we are about to speak. Edward Forbes was wont to say that the movement of a periwinkle over a rock might be of greater consequence to the human race than the progress of an Alexander; and the results of the wars of the plants are assuredly of no less importance, seeing that the very existence of an Alexander depends in no slight degree upon them. The campaigns we speak of are real; they are not mental figments, or allegorical illustrations. Success in the practice of horticulture, of agriculture, of forestry, depends on the action we men take towards the combatants. If we remain neutral, the weakest goes to the wall, overpowered by the stronger; if we interfere, we exert a very powerful influence for the time; but immediately we cease to exert our power, the combat begins again, and with enhanced violence. The essence of successful cultivation often consists almost entirely in the removal of the plant from the influence of that hostile "environment" to which, under natural circumstances, it would be subjected. It is this that accounts, in a great measure, though of course not wholly, for the oft-observed fact

that certain plants, flowers, and fruits, attain far greater perfection in our gardens than they ever do in their native countries.

That a war of extermination is thus going on around us may strike some with surprise. They are so accustomed to associate flowers and plants with peace and repose, that they are astonished to find that other far less amiable ideas may, with even more justice, be associated with them. And yet a moment's reflection, or a passing glance at the nearest hedgerow or pasture, will show the reality of the struggle. All that beautiful disorder, that apparently careless admixture of divers forms and colours—the sweeping curves of the brambles, the entwining coils of the honeysuckle, the creeping interlacement of the ground ivy or the pennywort—all are but indications of the fray that is constantly going on. It would seem as if the weakest must succumb, must be overpowered by the stronger-growing plants, and so they are at certain places and at certain times; but, under other conditions, the victory may be with the apparently weaker side, just as the slow-going tortoise may outrun the fleeter hare. In any case the success is often only temporary; the victor becomes in time the vanquished; the vanquished, in its turn, regains its former conquest; and so on.

It is proposed in the following notes to give a few illustrations of the nature and effects of this conflict, of the way in which it is carried on, and of the circumstances which favour it.

Agriculturists had long been practically conversant with the advantages derivable from the practice of not growing the same crop on the same soil for too long a period. The advantages consequent on this so-called rotation of crops are due to more than one cause; but it was Dureau de la Malle who, in 1825, called attention to the phenomenon of natural rotation. From long observation of what takes place in woods and pasture-lands, he established the fact that an alternation of growth, as he called it, occurs as a natural phenomenon. In pasture-lands, for instance, the grasses get the upper hand at one time, the leguminous plants at another; so that, in the course of thirty years, the author whose observations we are citing was witness of five or six such alternations.

It follows from all this that a plant, as was pointed out by the late Dean Herbert, does not necessarily grow in the situation best adapted for it, but where it can best hold its own against its hostile neighbours, and best sustain itself against unfavourable conditions generally.

The sources of success in the contest are manifold; they vary more or less in each individual case. Probably they are never exactly the same; nevertheless, there are certain circumstances which must always be operative in conducing to the

victory. A few illustrations must suffice. It is easy to understand why first comers, duly installed, should have an advantage over later visitants; why the more prolific should outnumber the less fertile; and how it is that a perennial plant has a better chance on any given spot, *cæteris paribus*, than an annual whose progeny would find the ground occupied, and their chances of survival materially interfered with by their longer-lived neighbours.

Again, there is no difficulty in understanding why such plants as quitch (*Triticum repens*) or bearbine (*Convolvulus Sepium*) hold their own so tenaciously and so much to the prejudice of their neighbours. The long creeping underground stems rooting, or capable of rooting, at every joint give them an immense advantage over plants not so favourably organised. The ends of the shoots of the convolvulus, moreover, dilate into tubers, which are thrust into the ground to form in the succeeding spring fresh centres of vegetation. A great rooting power is obviously of great benefit; not less so is an extensive leaf surface. It is not only that the copious feeding roots absorb the available nourishment from the soil, not only that the wide leaf surface avails itself of every ray of sunlight, every whiff of air that plays over it, and thus serves to build up the tissues of the plant to which the root or leaf respectively belong, but they practically oust other plants less favourably circumstanced than themselves. The roots occupy the soil, and rob the weaker plants of their share of its resources. The tree with dense foliage shuts off from its lowlier neighbour much of the light and air necessary for its existence; and hence, in a measure, the absence of vegetation in pine forests or under the shadow of dense woods.* Some plants there are specially organised to resist and overcome these hostile conditions. Among them are the climbers, the twining plants, and those with tendrils of one sort or another. The bramble or wild rose, with its slender, arching, hook-beset branches; the wild hop, with its coils of cord-like sprays; the clematis, clinging on firmly by means of its leaf-stalks to anything it can lay hold of; the ivy, grappling with the trunk of a tree—all these are, in some sense, weakly plants; they would be overweighted in the struggle with their stronger neighbours if it were not for the special adaptation of their structure just alluded to, and which enables them to bear their part bravely in the conflict.

* These struggles were not unknown to ancient naturalists, as witness the following passage from Pliny, "Nat. Hist." lib. xv. cap. 24:—"Necant invicem inter sese umbra vel densitate atque alimenti rapinâ . . . necat et edera vinciens, nec viscum prodest et cytisus necatur eo quod halimon vocant Græci."

It is easy to understand how an alteration of the conditions under which plants grow influences very materially the struggle we have been alluding to. A very slight change in climatal conditions—produced, for instance, by the growth of sheltering trees, or by the drainage of the soil—may be followed by the growth of quite a different set of plants from those that occupied the ground previously. The altered conditions have been advantageous to the one and disadvantageous to the other set of plants.

As an illustration of the complexity of the checks and relations between organic beings struggling together, Darwin mentions the case of a barren heath which fell under his observation, part of which was left intact, while another portion had been enclosed and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable. "Not only the proportional numbers of the heath plants were wholly changed, but twelve species of plants, not counting grasses and carices, flourished in the plantations which could not be found on the heath."

This sort of change was pointedly referred to by Dureau de la Malle, who relates how, after the felling of the timber in forests of a particular district of France, broom, foxglove, heaths, birch-trees, and aspens sprung up, replacing the oaks, the beech, and the ash felled by the woodman. After thirty years the birch and poplars were felled in their turn. Still very few of the original possessors of the soil, the oaks, &c., made their appearance; the ground was still occupied with young birch and poplar. It is not till after the third repetition of the coppicing—after an interval of ninety years—that the oaks and beech reconquer their original position. They retain it for a time, and then the struggle begins again.

Antiquarian researches also have proved that in the natural state of things, without any violent change in external conditions, the nature of forests becomes altered. The Hercynian forests, of which Cæsar speaks, and which then consisted of deciduous-leaved trees, are now made up principally of conifers. A forest which, in the Middle Ages, was of beech, is now stocked with oak, and *vice versâ*. Again, we have the evidence afforded by submerged forests and peat bogs, according to which certain plants, now extinct in particular localities, once flourished there. We are not alluding to plants that may have required a different climate from what they now experience, but to such cases as the silver fir, the Scotch fir, *Pinus Mughus*, &c., which are found in this partially fossilised condition in spots where there is apparently nothing to prevent them from growing now, where in fact they do grow well when planted.

Foresters in all countries are perfectly well aware of these facts, and botanists watch with interest the appearance of a different vegetation, when some accident has interfered with the previously existing conditions. When woods are cut down, when soil from a depth is laid on the surface, when extensive fires occur, when lakes are drained; in fact, when any sudden alteration takes place in external circumstances, then we may expect to find a corresponding change in the vegetation. One set of plants profits by the change, another suffers. It may be asked, "Where do the new arrivals come from?" Sometimes, no doubt, the seeds are wafted from a distance, and, finding a suitable abiding-place, germinate. This is, perhaps, more especially the case with the spores of fungi, whose extreme minuteness favours their dispersion in this way. But it often happens that the facts of the case will not admit of such an interpretation, and then we can only fall back on the supposition that the seeds or bulbs existed in the soil, but under circumstances not favourable to their development.

The ground in this way is looked on by Alphonse de Candolle and Darwin as a vast magazine of seeds, &c., capable of retaining their vitality for a more or less prolonged period, according to circumstances, and ready to avail themselves of any change that may be beneficial to them. That this is so in some places has been proved by results, but it seems equally clear that this does not hold good in all places. Allusion has already been made to the apparently capricious appearance of our British orchids. The downs or the fields that in one summer yielded abundance of bee, of fly, or of spider orchids, may, in another year, scarcely furnish a single one. The explanation of this peculiarity lies in the special organisation of the plant well described by Prillieux and other botanists, from whose observations it appears that the plants in question naturally pass through several stages, which, for our present purpose, it is not necessary to detail, and these stages may be prolonged according to circumstances. The flowering stage is thus arrived at in one season, while in another all the energies of the plant may be taken up in forming tubers and leaves. A very remarkable instance of the fact just alluded to was communicated to the writer by a competent observer, Mr. George Oxenden, of Broome Park, Kent. This gentleman had been acquainted with a particular field for some forty years, during which time it had been under the plough, but at the expiration of this period it was laid down in grass, when the very next year a profusion of bee orchids was observed in it. In this case the time was too short for seeds to have germinated and to have progressed to the flowering state. There seems no other solution than that the tubers must have been in the ground

some time previously, but that, from the ploughing and cropping of the soil, they had not had a fair chance of developing flowers.

The facts we have mentioned are, in the main, intelligible enough. We can see the why and the wherefore without much difficulty; but it is not so always. For instance, it is difficult to account for the signal defeat that native plants often incur at the hands of invading strangers.

Why does the water-cress, harmless enough in our ditches, block up the water-courses in New Zealand to such an extent as to become a costly nuisance? What can there be in English ditches and canals so propitious to the growth of the American water-weed (*Anacharis*) as to have caused it to obstruct even our navigable rivers? In America, whence it came, it is no more of an inconvenience than any other water-weed. Why in other places does the white clover (*Trifolium repens*) overcome the native grasses, and dispossess them of their territory? Why has a particular grass, the *Stipa tortilis*, invaded the South Russian steppes to such an extent as to displace almost every other plant?

There are numberless such instances—from that afforded by the island of St. Helena, in which the original vegetation is almost completely dispossessed, and its room occupied by foreign importations, to the banks of a Surrey river, yellow with the flowers of an American balsam—and the reason is not obvious. The fact is patent, and is not without analogies in the virulence with which epidemic diseases spread when introduced for the first time among a population not heretofore subjected to them.

Such cases as these recall the opinions of Humboldt and others on the antipathies of plants. According to this notion certain plants are positively injurious to others, not so much by any peculiarity of structural organisation as by the excretion of matters hurtful to other plants. It has been asserted, for instance, that the darnel (*Lolium temulentum*) is injurious to wheat; that a species of thistle (*Serratula arvensis*) is obnoxious to oats; that a spurge (*Euphorbia Peplus*) and a scabious (*Knautia arvensis*) are detrimental to flax; and spurrey (*Spergula arvensis*) similarly prejudicial to buckwheat.

In so far as this detrimental influence is due to any excrementitious product from the plant, the verdict given by modern physiologists amounts to "not proven." Some would even say "not guilty;" but we do not see clearly how those who take this view can reconcile it entirely with the existence of that natural alternation of which Dureau de la Malle speaks, and which is admitted by all subsequent observers.

Mere exhaustion of the soil will not account for the

phenomena in all cases, because a crop will fail on a particular soil after a while, and yet chemical analysis of that soil will reveal the fact that the particular elements required by a given plant are still contained in sufficient abundance in it. Land, for instance, that is "clover sick"—on which, that is, good crops of clover cannot be grown—is by no means necessarily deficient in the constituent required for the growth of the plant; and, indeed, in the Rothamsted experiments the constituents in question have been supplied as manure, but without any good result. Again, root-excretions (assuming their existence) cannot be productive of injury, as we are assured by Dr. Gilbert that clover has been grown in the same plot of garden soil at Rothamsted for eighteen years in succession, while only a few hundred yards off no condition of manuring has hitherto been successful in restoring the clover-yielding capabilities of the land.* Reverting, however, to the alleged antipathies of one plant to another, we may make passing mention of the curious circumstance recorded by M. Paul Lévy,† that the lianas or climbing plants of the forests of Central America have their likes and dislikes, and that they will not attach themselves to particular trees even when brought into juxta-position with them. It is significant that the trees which are thus slighted by the twiners are just such as are ill-adapted for the support of such plants, being such as have tall unbranched trunks with smooth bark and a dense overhanging dome-like canopy of foliage. It is not only the climbing plants that refuse to grow on such trees, but to a less extent, also, the mosses, ferns, orchids, Bromeliads, and other epiphytal plants.

It is obvious, from what has been previously said, that human interference affects these internecine conflicts of plants very materially. It is clear also that the cultivator can very often avail himself of them to his own profit. From this point of view the experiments and observations carried on at Rothamsted by Mr. Lawes and Dr. Gilbert are most important, especially those relating to the struggle among pasture plants, and the circumstances favouring certain plants more than their fellows. No detailed report of these particular experiments has hitherto been published, and only a few scattered notices in the Proceedings of the Horticultural Society (June 2, 1868) have appeared concerning them. We can, however, give some idea of their scope and nature by stating that a part of the park at Rothamsted, which has been under grass for centuries, has been divided into plots of equal size, placed side by side under conditions as nearly equal as possible. Some of these plots have

* "Journ. Hort. Soc." New Series, vol. iii. p. 91.

† Cited in "Gardeners' Chronicle," 1870, p. 383.

been left unmanured; others, some twenty in number, have, for the last ten or twelve years, been subjected to various manures, the constitution and proportions of which are accurately determined. The general herbage of the park, like that of the unmanured plots, consists of some fifty species of plants, including sundry grasses, clovers, docks, umbellifers and other plants commonly found in such situations. In the several manured plots a change is observable, sometimes slight, at other times vast, and the change does not show itself so much in the superior luxuriance of any one plant, or in the starved condition of another, as it does in the more or less complete exclusion of certain plants, and in their replacement by others. Thus, while the unmanured plots contain, say, fifty species of plants, others comprise less than half that number; from some plots the clovers and umbellifers are banished altogether, while in other cases they may be proportionately increased. Even among the grasses the competition is very severe, and the result in some cases is that all or nearly all have to give way to the cock's-foot grass (*Dactylis cæspitosa*), the growth of which is so fostered by certain manures as to cause it to overcome its fellows and remain master of the situation. To the plots to which a mixed mineral manure, consisting of salts of potash, soda, magnesia, and lime is applied, but little difference in the number of species is observable. On the other hand, manures containing ammonia salts, or nitrates, cause a great diminution in the number of species living in the plot to which they are applied. While the unmanured plots furnish by weight about 60 per cent. of grasses, the remainder, consisting of plants of other families, the plots to which admixture of mineral and nitrogenous manures is added contain as much as 95 per cent. of grasses, and these belonging to a comparatively very few species. Salts of potash and lime, which are comparatively inert as regards grasses, manifest their influence in increasing the vigour and the absolute numerical proportion of the leguminous plants.

The manner in which these results have been arrived at is worthy of a short description in this place.

Notes are taken at frequent intervals during the season of growth, the appearance of the plants noted, their relative luxuriance observed, and their comparative tendency to produce flower or stem and leaf, the abundance of flowers, &c., &c. Root-growth is studied, and also the character of the soil in the various plots, and the way in which its texture and its capacity for holding or transmitting water are modified according to the manure applied. When the crop is cut from each plot, its weight is estimated, and also the amount of dry produce. In some cases chemical analysis is pushed further, and the ashes

duly examined. In addition to these no trifling observations, three "separations" have been carried out at regular intervals. These separations consist in the picking out, from a sample of a certain weight taken from each plot, every fragment of every species contained in the sample. In this way the relative quantity and weight of each of the different plants in the several samples is accurately determined, and the proportion in the whole plot computed. The labour is enormous; but the results, when fully brought out, must be most important, both as regards the scientific aspect of the question, the history of the life-struggle between plants so circumstanced, and also as regards the practical hints to be derived by the cultivator.

Some experiments of a somewhat similar character, and bearing directly on the struggle for life among plants, have been made by Professor Hoffman of Giessen, and they are of such interest that we introduce here a very condensed account of them taken from the pages of "The Gardener's Chronicle," 1870, p. 664:—

In a previous set of experiments the Giessen Professor had ascertained that the particular plants under observation grew equally well in all the varieties of soil in which they were placed, provided due care was taken to prevent the growth of intruding weeds. Having arrived at this result, Prof. Hoffmann next left the several plants to themselves, with a view of ascertaining how they would comport themselves without assistance against the inroads of weeds. The result was, that the weeds completely gained the upper hand, as might have been expected from their known habit. The species which held out longest was *Asperula cynanchica*. This plant, after having been grown in a bed for three years, and protected from weed-invasion by the use of the hoe, was then left to take care of itself. It held out for four years, but was ultimately elbowed out by the intruders. Acting on the principle of "set a rogue to catch a rogue," Prof. Hoffmann then set himself to observe the results of the internecine struggle between the weeds themselves, thinking that the ultimate survivors would perhaps prove to have special affinities for the soil in which they grew.

Thus left to themselves the beds became so densely covered, that in a square foot the Professor counted 460 living plants, and the remnants of many others, which had succumbed in the encounter. Every year, in July, the plots were examined, and every year the number of species was found to have diminished. Melilots, at first abundant, gradually disappeared; *Artemisia vulgaris* succumbed after two or three years; and so on, till at length only a few species were left, and these not only persisted, but slowly gained ground from year to year, and

ultimately remained in possession of the plot. The plots under observation were 2 mètres 30 cents. long, 1 mètre broad, and all as nearly as possible under the same conditions, save that the soil was varied, in some cases consisting of the ordinary soil of the garden, in others of an admixture of lime, in others of sand, or of sand and lime, and so forth.

Of the 107 species under observation, all, or nearly all, found the most essential requisites of their existence equally well in all the varieties of soil; so that, other conditions being equal, the nature of the soil was indifferent. The species which remained victors, all the others being ultimately dispossessed, were *Triticum repens* (couch), *Poa pratensis*, *Potentilla reptans*, *Acer Pseudo Platanus* (sycamore), *Cornus sanguinea*, native plants; and *Aster salignus*, *A. parviflorus*, *Euphorbia virgata*, and *Prunus Padus*, derived from other portions of the garden.

It may, therefore, be inferred that the district in which these experiments were made would in process of time, if no obstacle were afforded, become covered with meadows and woods—meadows in the low ground and woods in elevated places. Again, the experiments show that the survival of certain plants has not been influenced by the nature of the soil; thus the couch-grass was ultimately spread over all the plots, whether of sand, or of loam, or of lime, whether drained or undrained. So also with *Poa pratensis* and *Potentilla reptans*. So that the chemical and physical nature of the soil, as has been so often shown in similar investigations, plays only a secondary part.

As to the action of shade, it was found by Professor Hoffman that low-growing plants, especially if annuals, disappeared rapidly, while taller-growing plants, such as couch, *Prunus Padus*, &c., survived. The survival of certain plants, then—couch, *Aster*, *Potentilla*, &c.—is due much less to external conditions than to the "habit" of the plant itself; that is to say, to the facility the plant has of adapting itself to varying external conditions, and thus of triumphing over others less favourably endowed in this wise.

The immediate source of victory lies in the powerful root-growth of the survivors, including under the general term "root" not only the root proper, but the offshoots and runners which are given off just below, or on the surface of the ground. Indeed, the latter habit of growth is more advantageous to plants in such a struggle than the development of the true root downwards would be. Among those plants where the roots were equally developed there were, nevertheless, inequalities of growth, dependent probably on the greater need for light in some species than in others, &c.

It is clear from Professor Hoffman's experiments that, but for the continual use of the hoe, and the diligent extirpation of the weeds in our fields, the stronger growing ones would not only destroy our crops, but also other weeds less vigorous than themselves. But they are not sufficient to explain all the conditions of this complicated problem; as is shown by the fact that in the district adjoining the locality where Professor Hoffman's experiments were carried on, the predominant plants are not the same as those which ultimately proved victors in the experimental beds.

We may add, that for two years a series of observations was carried on in the gardens of the Royal Horticultural Society, at Chiswick, with a view to ascertain how certain selected plants, twelve in number, and naturally growing in pastures, would be affected when growing by themselves, by the addition of manures of five different descriptions, and similar to those used at Rothamsted. In some cases the results of these experiments were unsatisfactory, from circumstances that need not be detailed here; still a large body of facts was accumulated, and, with reference to the property by which certain plants prove victorious in the struggle for life, it was clear that the natural habit or organisation of the plant was, *cæteris paribus*, the mainspring of its success over its competitors. The several manures intensified or deteriorated this peculiar organisation, as the case might be, and thus favoured or impeded its growth accordingly.