Review: Root Systems of Crop Plants

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The flora of the slight elevations, not submerged by the flood, but remaining as islets, consisted before the war of (1) cultivated plants, (2) weeds, (3) wayside species, (4) ditch and canal species. Of these (1) and (2) disappeared when the surrounding area was flooded and cultivation abandoned. (3) and (4) entered upon a competition which resulted in the incontestable victory of *Phragmites* (corresponding with the high level of the ground water). After the armistice each boss was covered with a reed thicket so dense that there was hardly room for other species. On the retreat of the waters and the corresponding fall of the ground water, *Phragmites* could no longer live on the eminences, but it sent out rhizomes which grew out in all directions on the surface of the surrounding flats to distances of 10 to 12 meters and some of the plants regained in this way lower levels and ditches where they could establish themselves, thus returning to their pre-war habitat.

Of the two bulrushes, *Typha latifolia* occupied before the war the stagnant waters of the interior of the country, while *Typha angustifolia* reigned supreme near the coast. But it is the former species which has invaded the fresh water of the innumerable holes and trenches made during the war in the coastal region, has colonised, in company with *Phragmites*, the freshwater inundations, and, around Blankaert, has ousted *Typha angustifolia* from much of its former pre-eminence. It remains to be seen if, with the return of completely normal conditions, there will be a return to the pre-war distribution of the two species.

In the coastal region, *Brassica nigra* only existed before the war as a widespread weed of the dune cultivation. At the armistice all the parapets in the triangle Pervyse-Schoorbakke-Dixmude disappeared under an ocean of this plant, which was in full flower in the summer of 1919. Since then it has decreased each year, even on the parapets which have not yet been levelled.

In the ruins of Nieuport, which was completely destroyed by bombardment, the author counted 70 species of flowering plants in the summer of 1920, neglecting the remains of garden vegetables and common garden weeds. Of these 70, 41 came from the gardens of the town itself or the immediate neighbourhood, as many as 23 from remoter regions of Belgium, and six from southern Europe, probably brought with the forage of the French army. Of the Belgian species not hitherto found in the neighbourhood of Nieuport, *Epilobium spicatum*, *Verbascum thapsus*, *Chrysanthemum vulgare* and *Artemisia vulgaris* were common in the ruins; the others, e.g. such wet soil plants as *Ulmia palustris* and *Symphytum officinale*, less so, but how and why they came is a mystery.

A. G. T.

ROOT SYSTEMS OF CROP PLANTS

Weaver, John E., Jean, Frank C., and Crist, John W. "Development and Activities of Roots of Crop Plants." Carnegie Institution of Washington Publication 316. May, 1922. Pp. vi and 117. 14 Plates and 42 Text-figures.

This is an extension of the senior author's previous investigations of the distribution of root systems, recorded especially in *The ecological relations of roots*, 1919 (of which an account was given in this JOURNAL, 8, pp. 150-154) and in *Root development in the grassland formation* (Carn. Inst. Pub. 292, 1920). It is pointed out in the Introduction that a thorough and accurate knowledge of root production by different crop plants in different types of soil and under different conditions of soil moisture, aeration, etc., forms the only direct scientific basis for the proper selection of the most suitable crops. While, of course, root development is largely reflected in that of the shoot, it is, after all, the roots themselves that directly depend upon the soil. Evidence has accumulated that the results of experiments with plants grown in containers, even very large containers, are liable to be vitiated by the check to root development involved, the roots of plants in the open soil often penetrating to astonishing depths; and similarly experiments with plants grown in close lateral contact are sometimes seriously affected by the factor of root competition.

The method of investigating the root systems of field crops was the same as that used in the previous work on native vegetation, namely, digging deep trenches beside the plants: the sides of these are then carefully excavated with a hand pick and the root systems care-

fully traced out and charted to scale on a large drawing sheet. In all cases care was taken to get well below the lowest rootlets, and the first results were always checked and corrected by further examples. It should be noted that the technique, though simple in principle, requires considerable experience and skill for its successful application.

The stations chosen were Peru, in eastern Nebraska (rainfall 33 inches), Lincoln, Nebraska (28 inches), Phillipsburg, Kansas (23 inches) and Burlington, Colorado (17 inches), forming a series with decreasing rainfall and relative humidity of the air, and corresponding respectively with "subclimax prairie" (natural wood or scrubland), true prairie, mixed prairie and shortgrass, and pure shortgrass vegetation. The correlation in all respects between the root systems of the natural vegetation and those of the crop plants was very close and striking, confirming the value of the former as crop indicators.

The first general result to be noticed is the great depths to which the crop roots penetrate. Thus, a heavy yielding strain of Kherson oats reached a depth of 6 feet or more at Peru, though the maximum development of rootlets was in the top foot of soil; barley at Phillipsburg about the same; alfalfa (*Medicago sativa*) and sweet clover (*Melilotus alba*) round about 5 feet. At Burlington, where penetration is limited by a layer of hard pan, due to a concentration of colloid clay and carbonates, the depths reached were much less, the extreme depth of wheat roots being between 2 and 3 feet, and the lateral branching much more extensive; the "working depth" of the root systems (the soil level to which the bulk of the roots penetrate) was 1.3 feet. Similar results were obtained for oats, barley, alfalfa and sweet clover, though in some of these the working depths of the root systems were greater than in wheat. The lateral spread and exploitation of the surface foot of soil were very marked. The plants of sweet clover at Burlington, growing on the side of an old filled-in investigation trench, showed a striking difference from those in undisturbed soil, several roots entering the fifth and sixth foot, and a few reaching to 6.8 feet, as contrasted with a greatest depth of 2.8 feet in untouched soil.

The authors' results as to depth of root penetration, now based on a wide range of accurate measurement in the middle western states east of the Rocky Mountains, as well as in Washington, have led to grave doubts as to the accuracy of statements current in the literature as to the depths at which roots absorb—for instance, Russell's statement that "it is well known that only the top 6 or 8 inches of the soil is suited to plant life, and that the lower part or subsoil, plays only an indirect part in plant nutrition." They point out that many of the grassland species which possess strong tap roots with little or no branching in the surface foot or two of soil cannot absorb in these layers because of the cutinised or suberised root cortex, and this is not only true of shrubs and large wild herbs, but of such crops as alfalfa and sweet clover (*Melilotus*). Even among fibrous rooted species such as the cereals the number of roots in any given layer of soil is no criterion of their activity. It seems probable that with increasing age the older roots are cutinised or suberised and, unless new branches are put out, the seat of maximum absorbing capacity is transferred to soil layers of ever increasing depth. The general conclusion is that the average working depth in Nebraska, Kansas and South Dakota is 3.7 feet for wheat and 3.9 feet for rye, while for red clover and alfalfa they are very much deeper. In fact, in nearly all cases where the roots of crop plants were excavated, the total development *below the cultivated soil-layer* was as great and usually much greater than in the surface soil. The dependence of the plant on the deeper seated portions of the root system is well illustrated in times of drought, when the vegetation remains unwithered and crops do fairly well even after the water in the surface 6 inches of soil is nearly or entirely exhausted.

It must, of course, be remembered that the depths suitable for root penetration are very much greater in the majority of the soils (such as the prairie loess) investigated by Prof. Weaver and his colleagues, than in those of much arable land elsewhere, for instance in Great Britain; but it is, nevertheless, greatly to be desired that really accurate comparative work, on the lines of the authors, should be undertaken in this country, both on wild and on crop plants.

The authors also carried out a series of experiments by growing crop plants in containers furnished with wax seals at different levels, and in which the well compacted soil

at each level occupied the same relative position as in the field, to determine the depths at which both water and nitrates (NaNO_3) were actually absorbed. Oats absorbed water at all depths to 2.5 feet: the amount of water absorbed by barley from the deeper soils (to 3.5 feet) is in direct relation to the penetration of the root system. Corn (*Zea*) absorbs large quantities from the third and fourth foot of soil and smaller amounts from the fifth foot: potatoes to 2.5 feet, the approximate limit of root penetration. Considerable quantities of nitrates were removed by the plants from corresponding levels. In every case where roots came in contact with a fertilized layer they not only developed much more abundantly and branched more profusely but the normal penetration into deeper layers was retarded. The conclusion is that fertilising the surface layer in regions where this will have very little water available in drought is detrimental to crop production.

A. G. T.

METHODOLOGY

THE NEW ZÜRICH-MONTPPELLIER SCHOOL

During the last decade or so a movement has developed in Switzerland and France which is concerned primarily with more accurate methods of analysis of plant associations regarded as social units, and with the concepts connected with these. This has sprung on the one hand from the pupils of Prof. Schröter at Zürich, and on the other from those of Prof. Flahault at Montpellier. The leading members of the new school (Rübel, Braun-Blanquet and Pavillard) are, on the whole, in fairly close agreement as to conceptions and methods of work. Many of their leading conceptions were ably summarised by Rübel in this JOURNAL two years ago ("Ueber die Entwicklung der Gesellschaftsmorphologie," *Journ. of Ecol.* 8, pp. 18-40). The school owes something to the influence of Raunkiaer in Denmark, and something to the Finnish school, but its own work has quite distinctive characters. We notice below four of its most recent publications, which will give an idea of its present position and activities. From these we in Great Britain can certainly learn a good deal, though we think the "dynamic" and also the strictly "ecological" standpoints may, with advantage, be still further adopted by our continental colleagues in their actual investigations.

Braun-Blanquet, J. "Prinzipien einer Systematik der Pflanzengesellschaften auf floristischer Grundlage." *Jahrb. d. St. Gallischen naturw. Ges.* 57, 305-351 (September, 1921).

The author points out that the accurate delimitation and characterisation of plant communities are necessary preliminaries to the study of their relationships. He lays stress on the fact (in agreement with the Upsala school) that the actually existing habitat factors are not the sole determinants of the actually existing communities, which owe their origin partly to geographical and historical causes that escape direct observation and experiment. He instances cases of aliens not only penetrating but giving a new character to pre-existing natural communities. For this reason he deplores the basing of the classification of communities on habitat, as in Warming's text-book, especially since the real nature of many of the habitats in question is either unknown or doubtful. The author rejects life-form as a practical basis for characterisation because we have no natural system of life-forms, and insists that only in the species present and their combinations can we find a satisfactory foundation. The association he takes, in agreement with practically all contemporary writers and workers, as the fundamental unit, and points out that the actual examples of an association met with often deviate widely from the abstract conception of the particular association to which they belong, just as individual plants may deviate widely from the "type" of the species. Different *facies* of an association should not be separated as distinct associations, as is often done in regions with very uniform vegetation. Many individual examples, too, which undoubtedly belong to a particular association, nevertheless give no true picture of the association, owing to want of space, biotic influences, etc. Such examples he calls *association-fragments*¹. These should be excluded in collecting statistical data to

¹ The Upsala school also uses this term.