ment is expected to pay about half the cost of the system.

There are now about 9,000 superannuated civil servants, most of them in Washington. They will go out in a body. The retired list will eventually reach about 30,000. But with the moderate annuities allowed, the maximum being $720, the government's experiment will cost little. The efficiency of the working force will be increased. More work will be done by a smaller staff.—*New York Tribune.*

THE ECOLOGICAL RELATIONS OF ROOTS[1]

PROFESSOR J. E. WEAVER has recently put out an extensive study on roots which comprises observations made in the "prairies of eastern Nebraska, chaparral of southeastern Nebraska, prairies of southeastern Washington and adjacent Idaho, plains and sandhills of Colorado, the gravel-slide, the half-gravel-slide, and forest communities of the Rocky Mountains of Colorado." The roots of about 140 species are described. The species include shrubs, grasses and other herbs. With a description of the roots is presented a characterization of the physical environment. Among other features of the latter are given the rainfall and evaporation, the temperature of the air and to a certain extent the temperature of the soil and its moisture content. The work is abundantly illustrated with root maps and reproductions of photographs.

The study by Weaver is a continuation and an extension of his well-known work along similar lines. It is wholly observational and must be considered as constituting a very noteworthy contribution to our knowledge of the habits of roots. It touches elbows with so many features associated with the habits and relations of the plants of the regions studied that it is not practicable to present a summary of the results. However, it may not be amiss to point out certain of the more interesting of the facts presented. For detailed information the reader is referred to the work itself.

[1] Carnegie Institution of Washington, Publication No. 286, 1919.

Without attempting to summarize exactly it can be said that in a general way the root systems of plants in the communities studied are fairly characteristic. Thus in the prairies and the plains also the roots usually extend widely and penetrate deeply, but more deeply in the former than in the latter community. And the tap root is the principal feature. In the sandhills the roots of several species are confined to the surface 2 feet, and practically all show a striking "profusion of long, widely spreading laterals in this surface-soil stratum." In the gravel-slide and forest communities of the Rocky Mountains, adjoining Colorado Springs, the roots are confined to the surface 18–24 inches. In the half-gravel-slide, however, the root penetration is deeper, although the root systems develop widely spreading shallow roots as well. Finally, in the case of species growing in more than one habitat it was found that in most cases the direction and extent of roots developed corresponded very well to the "community root habit."

Roots of different species may be so unlike in the extent and direction of their development, as well as in other morphological features, as to be readily identifiable. They also undoubtedly exhibit quite as distinct physiological characteristics, although such can not be told from inspection. For these reasons a knowledge of the roots of any habitat gives a very good clue to many of the striking features of that habitat, just as the nature of the shoot of a plant reveals much regarding the subaerial conditions under which it has developed. It consequently follows that through the study of roots of native plants, much can be learned in advance of culture of the possibilities of agricultural lands. Such, however, is a possible economic application of this and similar root studies and was suggested, but not developed, by the author.

The most striking root figure by Weaver is that of *Ipomœa leptophylla* of the sandhills about forty miles southeast of Colorado Springs. The soil absorbs all of the rain and there is practically no run-off. Through a

rapid drying out of the surface sand a dust mulch is formed which retards effectively further water loss from the soil. At a depth of a few inches the soil is always moist, and, from data given for another locality with similar soil, it would appear that the moisture may be fairly uniform to a depth of six feet. Exact data, however, as regards this feature are wanting. Of 19 sandhill species whose roots were studied, 8 have roots which are entirely or nearly confined to the first two feet of soil, and of the balance all save one have the greatest root development at this depth. The roots of *Ipomœa* were the most extensive of those of any species in the community, or, for that matter, apparently the most extensive of any observed during the course of the study. The block of soil included within their reach was approximately fifty feet in diameter and over ten feet in depth. The roots were fairly well distributed throughout except only in the surface foot from which they were largely wanting. Another feature of the root was the enlarged and tapering tap which was about eight inches in diameter a foot beneath the surface and the enlarged portion of which was about three feet long. The enlarged tap of *Ipomœa* constitutes an important reservoir for food and water storage.

Weaver finds in general that in the communities studied the most striking root characters, at least so far as the gross morphology is concerned, are intimately related to the moisture conditions of the soil. Where, for example, the uppermost soil layers only are moist, there is a marked development of laterals. In the event the soil carries moisture to a considerable depth, as on the prairies, deep root penetration in many species occurs. Apparently he does not find soil temperatures or soil aeration limiting factors in root penetration although that such may be the case in certain instances seems to the reviewer not unlikely. For example, the roots of *Opuntia fragilis* do not appear to attain to a depth greater than fifteen inches, and it is usually considerably less than this. The roots of *Yucca* are also for the most part shallowly placed. And, finally, in the prairies as regards penetration, there is a fairly well-marked stratification of the roots. It may be as suggested in the case of plains species that the "well developed system of shallow, widely spreading laterals is undoubtedly a response to the moisture in the surface soils resulting from frequent light summer showers." However, in the opinion of the reviewer, the possibility that the root-temperature or the root-soil aeration relation may also be of importance is by no means excluded. The various root relations are so closely interwoven that any one can only be evaluated when the rest are so far as possible controlled. And this requires exhaustive experimentation, which was not within the scope of the present study.

The extremes as regards root penetration appears to be met in the case of *Opuntia fragilis,* of the plains, on the one hand, and possibly, *Lygodesmia juncea,* of the Nebraska prairies. In *Opuntia* most of the roots lie within one to three inches of the surface of the ground, with an extreme penetration of eight to fifteen inches. While the roots of *Lygodesmia* have been found to attain a depth exceeding twenty feet seven inches. In the latter instance the soil is loess, with uniform physical properties, and is very favorably for deep root penetration. This well authenticated penetration is sufficiently deep, but it is of interest to note the observation given in Merill[2] that "Aughey has found roots of the buffalo berry (*Shepherdia argophylla*) penetrating the loess soils of Nebraska to a depth of fifty feet."

In a work so well done it seems captious to allude to a feature not by itself of fundamental importance. However that may be, it seems to the reviewer unfortunate that the English and the metric systems of measurement, especially, are both used throughout the study. Consistency in this regard would surely meet more general approval.

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[2] "Rocks and Rock Weathering," p. 181.