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LETTER TO THE EDITORS

Utilization of Soil by the Plant Root System

If the uptake of mineral nutrients by the plant is considered as a proces of extraction of part of the reserve of available substances, attention is directed to some special relationships, which might otherwise be overlooked.

One of the facts demanding closer consideration is the importance of the volume of soil available for rooting. In the field, particularly under many horticultural practices, the plant seldom has enough soil at its disposal to allow optimal development of its root system. Spread of the root system is restricted by competition or by other factors, *viz* shallow soil, pot culture *etc.*

However, often a considerable restriction of soil volume hardly impairs growth of the plant. This suggests that there must be large differences regarding the extent of soil utilization. Some of the investigators first using pot experiments already considered these implications [4]. Kraus [6] concluded that the growth of plants in pots was related to more intensive root functioning.

Attention must also be drawn to the fact that the amount of nutrients absorbed by a crop is in general only a small part of that which is available, even on poor or deficient soils, and especially with the more immobile nutrients.

The conclusion must be that generally the soil is only partly utilized, and that a large proportion of the soil is not being exploited by the roots. Bray [1] has already stressed this fact and related the utilized volumes to differences in mobility of nutrients.

Is it therefore possible to obtain some idea of the net volume of soil utilized in feeding the plant? To be able to do this data are needed on the total root surface and on the distances over which extraction of nutrients can occur.

Since the amount of labour involved in obtaining an estimate of the total root surface is prodigious, information in the literature is scarce. However, some investigators have measured total root length and root diameters and these data can be used for calculations. The objection may be raised that the total root surface is not equivalent to the active absorbing surface. But although at any fixed time this discrepancy exists, in the course of the growth of the root system all parts of it have been young and active at some time. Thus there can be no objection to taking total root surface into account.

A difficulty arises when the distance over which nutrient extraction occurs has to be estimated. Exact measurements have not been made and would be very difficult to obtain. However, a reasonable estimation seems possible. Tepe and Leidenfrost [11] have determined the distances over which several nutrients can be extracted from water-saturated soil by ion-exchange units. Their average values range from 2.5 to 20 mm, according to the mobility. Former experiments [13] suggested that, provided a mantle of soil around the root of about 2 to 3 mm – maximal root-hair length – contained a high amount of nutrient, the root was independent of nutrients supplied by diffusion over greater distances. The conclusion seems justified that at least a mantle of root-hair length thickness around the roots can be fully utilized and is the main source of supply.

In Table 1 the results of the calculations are given.

TABLE 1

Percentage of the total volume of soil occupied by the root system in direct contact with the root and functioning as source of supply of nutrients.

Author	Total soil volume dm^3	Root contact volume dm^3	Supply percentage	Crop
Weaver, Kramer, and Reed [12]	60	0.06	0,1	Winterwheat
Nutman [9]	28.3	1.5	5.3	Coffee
Pavlychenko [10]	150	50	33	Summer rye
Pavlychenko [10]	50	108	216	*Poa pratensis*, sod
Evans [3]	28.3	0.74	2.6	Sugarcane
Kullmann [7]	15	0.09	0.6	Clover
	15	0.58	3.9	*Dactylis glomerata*
	12	0.06	0.5	alfalfa
	12	0.66	5.5	*Festuca ovina*

Although the exact values obtained are debatable and will only relate to the nutrients mainly occurring in the adsorbed state the results are certainly of value. With one exception, all percentage values lie far below 100 per cent. Most values do not even attain 5 per cent. This certainly implies that the interpretation of restricted soil utilization under normal circumstances is valid. Also that restriction of the volume of soil for the growth of the plant often does not impair growth. It will be clear that here a favorable structure is of utmost importance to allow the more intensive permeation of soil by the roots.

The very high value (216 per cent) of a 5-cm layer of grass sod, suggests that here a complete utilization of this shallow layer can occur.

In the literature on uptake a few data can be found which are in accordance with the interpretation given above. Mitscherlich [8] noticed that in Neubauer tests the phosphate uptake by the seedlings was not proportional to the amount of soil used. Using 25 g of soil the phosphate uptake was 1.3 mg. When using 100 g of soil the uptake only increased to 2.5 mg, instead

of rising to 4 × 1.3 mg. Phosphate extraction is therefore better from the smaller amount of soil.

In the book Physiology of Trees, edited by Kramer and Kozlowski [5], the following reference is found. "Büsgen and Münch (1931) cite Nobbe as stating that the ability of pine to succeed where silver fir and spruce failed is the result of the pines having 24 times as many root branches and tips and 8 times the absorbing surface of the other species".

From recent research on uptake of phosphate by Fried *et al.*[3] we can quote: "According to the present experiments the rate of phosphorus release by the soil is at least 250 times as great as the rate of plant uptake. This effective soil volume would, therefore, have to be less than 0.4 per cent of the total soil mass". If the potential release rate is faster than uptake then we may conclude that the rate of diffusion between the desorption surface and the absorbing root surface is limiting. This will be the case if the soil is not in the immediate vicinity of the root. The "effective soil volume" can be interpreted as the thin mantle of soil covering the root system.

So the conclusion may be drawn that the volume of soil mainly contributing to the nutrition of the plant in the field is much smaller than the total volume occupied by the roots. An exception must be made for the highly mobile nutrients such as nitrate, which will be drawn towards the root surface along with the extracted water.

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