The Effect of Soil Depth and Soil Volume Upon Corn Yield in a Greenhouse Experiment[1]

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The growth of plants depends both upon above-ground level factors such as light, CO_2 and temperature and below-ground level factors such as water, nutrients, aeration and space for the plant roots to grow.

The rooting volume was the factor selected for study in the research presented in this paper. Much of the previous research on this factor has not separated differences which may be due to added nutrients as well as added volume in which the plant was growing.

Investigators (1,2,3) have worked with different sizes and shapes of containers in order to determine the best size to use for greenhouse experiments. In a paper concerning techniques which might help to make greenhouse experiments comparable with field plot experiments, Cook and Millar (3) state that greenhouse containers should be large so that differences between treatments are minimized. They say this is because of the limitation of root growth in some treatments and not in others when small containers are used. Cook and Millar (3) state that for many experiments 1- or 2-gallon jars are too small. Their interpretation would indicate that the volume available for root growth influences the yield.

Arminger and co-workers (1) found that for alfalfa, and quite probably for a number of other plants, greenhouse tests could be conducted just as accurately in small containers that ranged in volume from 1-gallon to 3-gallons as in large containers.

Arminger and Fried (2) used different sizes and shapes of containers in which the plant population of each was proportional to the weight of soil they contained. They also investigated the effect on plant growth that may have been caused by a varying ratio of a container's surface area relative to its depth of soil. Both yield and nutrient uptake data indicated that when plant population was proportional to weight of soil, smaller containers, 1-gallon or less, gave larger plants containing more phosphorus than did the larger containers. Further they found that the yield obtained reflected the surface area to a greater extent than the weight of soil in the pot.

The objective of this research was to determine the effect of volume available for root growth and soil depth upon crop growth. The volume available for root growth varied by using different amounts of soil and by replacing soil with sand.

Experiment I

This experiment was designed to investigate the influence of both soil depth and soil volume on plant growth using corn as the indicator crop. The soil phosphorus level was also varied to determine the effect of soil depth and volume on supplying phosphorus to the plant as well as their effect on growth itself.

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Materials and Methods

The soil used, Sidell silt loam, had a pH of 5.5, an available phosphorus level of 11 pp2m, and an available potassium level of 102 pp2m. Both of these levels were obtained by the Purdue method. The soil organic matter level was also very low. The soil was limed to pH 6.8. Three hundred pounds per acre of nitrogen and 332 pounds per acre of potassium were added to each pot. The corn was grown in #10 cans.

The treatments were arranged in a 2 x 3 x 4 factorial which consisted of with and without three inches of washed silica sand below the soil, soil depths of 3, 6 and 9 inches, and phosphorus fertilization rates of 0, 44, 87 and 131 pp2m of phosphorus. An extra treatment was added which had 12 inches of soil. All treatments were replicated twice. The moisture level was maintained fairly constant by weighing the pots regularly and bringing them back to field capacity by the addition of water.

The corn was harvested after 6½ weeks and dry weight, phosphorus content and potassium content were determined.

Results and Discussion

The weights of the tops in grams are shown in Table 1. Increased volume available for root growth by adding sand, increased soil depth,

Table 1. The effect of soil depth, phosphorus fertilization and sand on the growth of corn.

	Weight in grams							
	No sand				Sand *			
P rate pp2m	Soil depth 3″	6″	9″	Sum	Soil depth 3″	6″	9″	Sum
0	7.6	14.4	17.8	39.8	9.8	16.8	17.4	44.0
44	8.4	15.6	20.2	44.2	14.4	21.8	22.2	58.4
87	7.6	17.4	21.8	46.8	15.8	22.8	28.2	67.8
131	9.4	19.7	23.6	52.7	16.5	20.6	28.4	65.5
Sum	33.0	67.1	83.4	183.5	56.5	82.0	97.2	235.7

* 3 inches of sand below the soil

LSD 5%-2.8

LSD 1%-3.8

and increased phosphorus concentration produced highly significant increases in dry weight.

Increased volume available for root growth by adding three inches of sand beneath the soil increased the average dry weight of the tops from 15.3 grams to 19.6 grams. This appeared to be due to the increased rooting volume, because the bottoms of the cans were perforated to follow the excess moisture of drain out and inspection of the root systems at the end of the experiment showed that the roots had thoroughly penetrated the sand.

The average dry weight per pot for 3 inches of soil was 11.2 grams, for 6 inches of soil 18.6 grams, and for 9 inches of soil 22.4 grams. The effect of depth is shown in Figure 1. The top line indicates the treatments

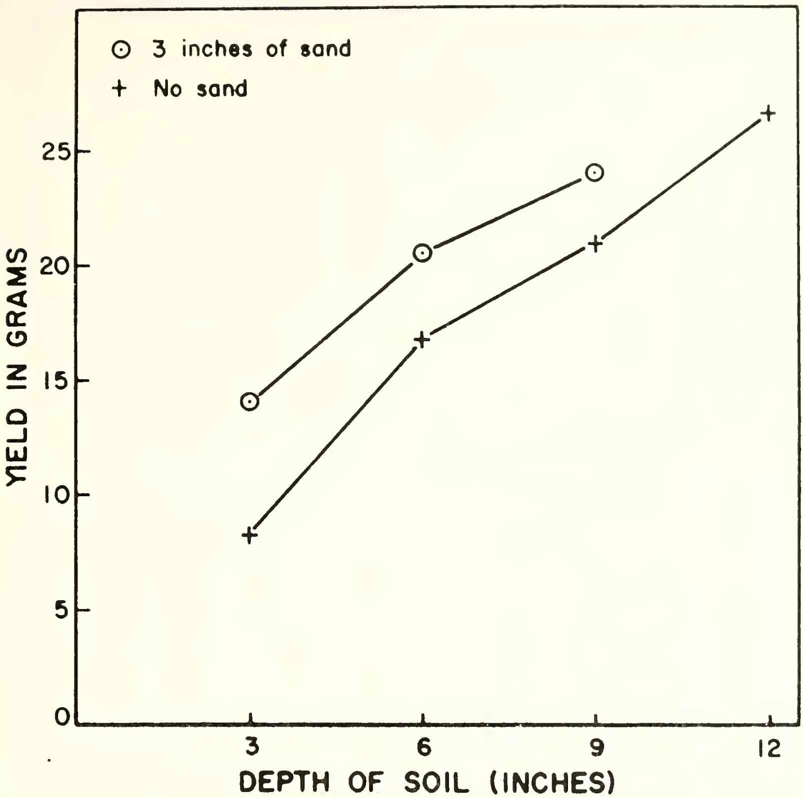

Figure 1. Effect of soil depth upon yield of corn in grams per pot.

with three inches of sand below the soil and the bottom line indicates the treatments without the sand. These lines are approximately parallel, and their displacement indicates that three inches of sand is approximately as effective as three inches of soil. The rate of increase in dry weight with increasing soil depth was approximately the same whether three inches of sand was present or not.

The increase in the amount of phosphorus applied also increased dry weight. The average dry weights for 0, 44, 87, and 131 pp2m of phosphorus were 14.0, 17.1, 18.9 and 19.2 grams respectively. The increase in yield due to phosphorus fertilization is shown in Figure 2. These values were obtained by subtracting the yield in the check pot from those of the phosphorus treated pots at each depth. The increase for the first 33 mgms. of phosphorus added was much greater when sand was present than when it was not. The increase per unit of phosphorus added after this initial rise with the sand was almost the same with and without sand. The increase per unit of phosphorus added was constant for each soil depth and was dependent on the total phosphorus added per pot rather than per unit of soil.

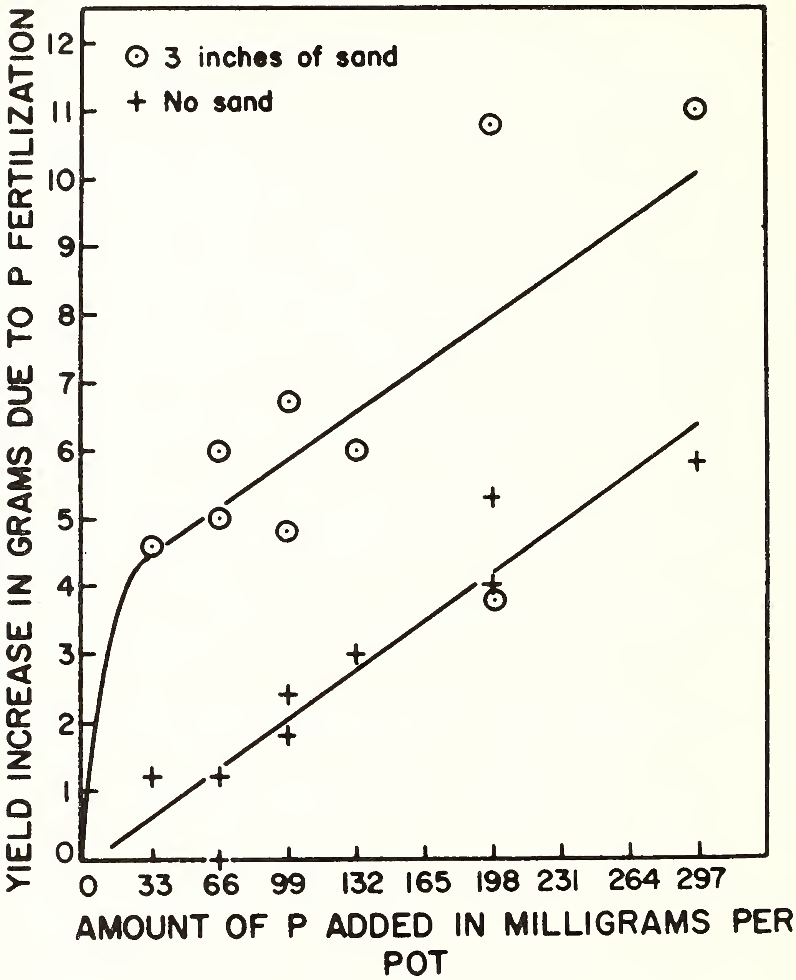

Figure 2. Effect of phosphorus fertilization on yield of corn.

The plant material was analyzed for phosphorus content and the values are given in Table 2. The percentage phosphorus at the 131 pp2m rate of phosphorus fertilization was less than at the 87 pp2m rate indicating that phosphorus was not the factor limiting yield. Phosphorus uptake in grams was the same or less at the 87 pp2m rate as that at the 131 pp2m rate in 4 of 6 cases, again indicating that phosphorus was not limiting yield at these rates.

Increased volume available for root growth, increased soil depth, and increased amount of phosphorus added decreased percentage potassium significantly as shown in Table 3.

These effects were significant at the 1% level. This indicates that potassium was not the factor limiting yield because the percentage potas-

Table 2. The effect of soil depth, phosphorus fertilization and sand on the percentage phosphorus of corn.

	Percentage Phosphorus							
	No sand				Sand *			
P rate pp2m	Soil depth 3″	6″	9″	Sum	Soil depth 3″	6″	9″	Sum
0	.124	.113	.146	.383	.079	.119	.130	.328
44	.166	.149	.142	.457	.120	.175	.160	.455
87	.192	.192	.186	.570	.140	.172	.166	.478
131	.154	.184	.174	.512	.153	.134	.158	.445
Sum	.636	.638	.648	1.922	.492	.600	.614	1.706

* Three inches of sand below the soil
LSD 5%-.028
LSD 1%-.039

Table 3. The effect of soil depth, phosphorus fertilization and sand on the percentage potassium of corn.

	Percentage Potassium							
	No sand				Sand *			
P rate pp2m	Soil depth 3″	6″	9″	Sum	Soil depth 3″	6″	9″	Sum
0	3.88	2.78	2.45	9.11	2.90	2.32	2.40	7.62
44	3.12	2.32	2.08	7.52	2.30	1.70	2.00	6.00
87	3.60	2.10	1.85	7.55	2.05	1.70	1.62	5.37
131	3.50	1.92	1.75	7.17	1.98	1.95	1.52	5.45
Sum	14.10	9.12	8.13	31.35	9.20	7.67	7.54	24.44

* Three inches of sand below the soil
LSD 5%-0.46
LSD 1%-0.64

sium was high at the low yield levels and decreased as dry weight increased. Grams of potassium taken up increased significantly with increasing soil depths. This increase was not all due to the exchangeable potassium present in the soil, because the pots with 3 inches of soil had 672 mgms. of exchangeable potassium, with 6 inches 741 mgms., and with 9 inches 810 mgms. This data also indicates that potassium was not limiting yield.

The following conclusions may be drawn from this experiment. First, increasing the volume available for root growth by adding 3 inches of sand below the soil increased dry weight and phosphorus uptake. It decreased percentage phosphorus and potassium significantly. This decrease in percentage phosphorus and potassium while dry weight increased indicates that these two elements were not limiting yield.

Second, changing the soil depth from 3 inches to 9 inches increased dry weight, percentage phosphorus, phosphorus uptake, and potassium uptake. It decreased percentage potassium. This increase in the phosphorus content of the plant samples was not due to the increased amount of available phosphorus added by the soil, since this amounted to approximately 20 mgms. per 3 inches of soil whereas the average increase in uptake was 30 mgms. per 3 inches of soil. All pots were adequately fertilized with potassium and the increased potassium uptake with depth was greater than the exchangeable potassium added with increased soil depth. Therefore this increase in potassium uptake can not be attributed to more potassium being added by the soil. Also, since percentage potassium decreased with increasing soil depth, the indication is that potassium was not limiting yield.

Third, increasing the phosphorus added to the soil increased dry weight, percentage phosphorus and phosphorus uptake, and decreased percentage potassium. Where the same amount of phosphorus was present in two different volumes, phosphorus uptake was always greater in the larger volume. This indicates that volume is a very important factor in determining yield and also in determining the availability of added phosphorus.

Experiment II

In the first experiment it was found that the increase in yield with increasing soil volume was apparently not due to increases in either available phosphorus or potassium. A second experiment was designed to determine if this increase was due to the increase in soil depth, to the increase in the soil volume, or due to other elements being supplied by the added quantities of soil.

Materials and Methods

The treatments were arranged in a 3 x 5 factorial with three soil depths of 8.8 inches, 12.0 inches, and 17.3 inches, all having the same soil volume brought about by changing the pot diameter, and five soil:sand mixtures of 1:0, 1:.20, 1:.66, 1:1.5 and 1:4. The soil used was Sidell silt loam, the same as used in the first experiment. The soil was limed to pH 6.8. Three hundred pp2m of nitrogen, 131 pp2m of phosphorus, and 124 pp2m of potassium were applied. The rate of nitrogen used was the same as used in the first experiment, while the amount of potassium was less. The amount of phosphorus was the same as used at the highest level in the first experiment. All fertilizer rates were calculated using the total volume of soil plus sand. The indicator crop used was corn. After a growing period of 5½ weeks, dry weight and potassium content were determined.

Results and Discussion

Soil depth had no significant effect on dry weight as shown in Table 4. Soil:sand ratio significantly affected dry weight with a 1:4 soil:sand ratio giving the largest yields.

There were differences in percentage potassium and potassium uptake between treatments, but there were no significant trends due to either soil depth or soil:sand ratio. The following conclusions may be drawn from this experiment. Soil depth and soil:sand ratio had no effect on yield within the limits used so long as rooting volume remained constant. Soil:sand ratio did not affect the ability of the corn plant to get adequate potassium nor did it affect the amount taken up. This would indicate that the soil did not supply any nutrient to increase yields in this case and thus the increases due to greater soil depths found in the first experiment can be attributed to volume available for root growth.

Table 4. The effect of soil depth and soil:sand ratio on corn growth.

Soil depth	1 : 0	1 :.20	1 :.66	1 : 1.5	1 : 4	Sum
8.8″	10.90	11.92	10.16	9.37	13.95	56.30
12.0″	12.41	10.64	9.82	11.74	13.53	58.14
17.3″	12.41	6.95	9.88	10.09	13.69	53.02
Sum	35.72	29.51	29.86	31.90	41.17	167.46

LSD-5%-2.93
LSD-1%-3.95

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