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Soil Aeration - Progress Report

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The solution of problems dealing with soil for floricultural crops are elusive. We have shown root damage caused by one soil inhibiting organism may overshadow any differences caused by variations in aeration and moisture content (N.Y.S.F.G. Bul. 195). So it was first necessary to exclude root rot producing pathogens before investigating soil aeration. In another article (N.Y.S.F.G. Bul. 197), we presented data on soil moisture control in greenhouse benches. This data indicated the water requirements of the plant may play a dominate role in determining moisture levels in overhead irrigated soils and showed the importance of proper selection and manipulation of a root medium before a crop is planted.

The data presented in this article are results obtained from the first crops to be grown in subirrigated plots. Data presented in Figure 1 and Table 2 were obtained in the fall of 1961. Plants were snapdragons, variety War Admiral. Not all the data obtained are reported.

Methods and Materials

Aeration control and measurement

The control of moisture levels and significance in respect to aeration were explained previously (N.Y.S.F.G. Bul. 192 and 197). Experimentally, aeration was varied by controlling the amount of water present in the soil. Various moisture levels were obtained by placing soil in plots with depths of 3, 7, 12 and 18-inches and irrigating by a constant water table. The SMT in these plots varied from 8 cm of water tension in the 3-inch depth to 700 cm of water tension for the 18-inch depth plots. The range of average SMT for these plots is shown in Table I.

Oxygen diffusion was evaluated by applying a constant D.C. voltage to a thin platinum wire (0.5 cm long) inserted 7 cm into the upper soil layer and measuring the resulting current. The platinum electrode simulates a plant root and, in operation, oxygen molecules undergo a chemical reaction at the wire's surface. The readings (microamperes) were converted to grams of oxygen delivered per square centimeter of wire surface per minute ($gO_2/cm^2/min.$). Table 1 shows the oxygen diffusion rates for the plots irrigated by a constant water table. In addition, one cubic-centimeter soil-air samples were withdrawn from selected soil plants and analyzed for O_2 and CO_2 content.

Plant measurements

All flowers cut from each plot are graded according to the SAF standard grading system which comprises the following specifications:

Special—all flowers with a weight in excess of 2½ ounces, stem length in excess of 36-inches and possessing 15 florets or more per spike,

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Table 1. Effect of aeration on growth and flowering of snapdragons irrigated by a constant water table.

Mixture	Soil Depth (Inches)	Stem Length (Inches)	Spike Length (Inches)	Florets per Spike	Oxygen Diffusion ($gO_2/cm^2/min$)	Average Soil moisture tension[a]
Peat-perlite	3	33.9	8.9	5.8	79.9×10^{-8}	8.4
	7	37.8	10.7	8.6	105.2 "	18.1
	12	41.0	9.8	9.7	48.3 "	36.0
	18	40.8	9.6	9.1	60.0 "	118.1
1-1-1	3	42.5	12.8	14.0	57.6 "	8.5
	7	45.6	14.2	16.5	102.8 "	69.6
	12	43.8	14.1	15.5	122.6 "	485.4
	18	42.3	12.8	16.0	47.0 "	637.2
Soil plus ¼th sand	3	41.8	14.4	14.6	48.9 "	8.7
	7	43.4	14.4	15.4	112.0 "	77.7
	12	42.2	12.0	14.4	116.4 "	739.1
	18	40.8	11.7	15.1	100.9 "	768.0

[a] Centimeters of water

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Fancy—all flowers weighing between 1½ and 2½ ounces, stem length greater than 30-inches and a minimum of 12 florets per spike,

Extra—all flowers weighing between 1 and 1½ ounces, minimum stem length of 24-inches and a minimum of 9 florets per spike,

First—all flowers weighing between ½ ounce and 1 ounce, minimum stem length of 18-inches and a minimum of 6 florets per spike, and

Utility—all cut flowers failing to meet the above specifications.

The numbers 6, 5, 4, 3 and 2 are assigned to each grade beginning with Special and the mean grade computed for each treatment. A mean grade of 4.00 would indicate that the majority of flowers cut were of Extra grade. In addition, random samples of 20 cut flowers were selected from each plot and stem length, spike length, number of florets per spike, fresh weight and dry weight determined.

Three soil mixtures were used in this experiment, peat moss—perlite, mixed 1-1 by volume; soil plus ¼ sand by volume; and soil, sand and peat moss, mixed 1-1-1 by volume. The soil was a local silt loam.

Results and Discussion

Effect of moisture and aeration on quality

The variations in soil depth have resulted in a wide range of soil moisture tensions (SMT) and these are shown in Table 1. In other words the range of average SMT for the peat-perlite mixture was 8 to 118 cm of water and for the soil mixes 8 to 700 cm of water.

The results of the mean grade and oxygen diffusion readings for the 3 mixtures are shown in Figure 1. The mean grade and oxygen diffusion readings for each mixture appeared to be parallel over the SMT range.

The peat-perlite mixture indicated a very narrow range of "optimum" SMT. Both the mean grade and oxygen diffusion readings were highest at about 20 cm of water, SMT, below or above the point there was a sharp drop.

What does this mean? The mean grade shows that the best quality flowers were cut from the plots with SMT's of around 20 cm of water. Observations of the plants while they were growing indicated a similar pattern. In the shallow depth plots (low SMT or high moisture) the plants were chlorotic resembling an iron or manganese deficiency. The spikes were shortened with reduced florets per spike and pale color (Table 1). There was, however, no wilting. The plants in the deeper depth plots (high SMT or low moisture) were slowed in growth and flowering was delayed as much as 3 or 4 weeks.

The oxygen diffusion readings indicate the rapidity of oxygen movement in the mixture. The higher the reading, the faster the oxygen was diffusing through the soil. Oxygen in the soil does not go directly from the soil air to the root, but it must first go into solution in the soil water. In the case of the shallow depths (low SMT or high moisture) the water films around the roots was very thick and the path of oxygen from the soil air to the root was long and slow, consequently low oxygen diffusion readings. In the case of the deep depths (high SMT or low moisture) the water film around the roots was ruptured and there wasn't enough water film to allow rapid diffusion of oxygen, consequently the low oxygen diffusion readings. This is a very important point, because the results from the air samples (i.e. an analysis of the composition of the air in the pores of the soil) showed high levels of oxygen, effectively 21%. Another explanation for the fall-off of plant quality in the drier soils may be due to a lack of nutrients to the root due to poor root to soil contact.

The oxygen diffusion rates and mean grades for the 2 soil-containing mixtures were similar to the peat-perlite mixtures except the "optimum" range of SMT was much broader. The range of "optimum" SMT (i.e. for the high mean grade and oxygen diffusion readings) for the 1-1-1 mixture was 50 to 400 cm of water. Below 50 cm of water SMT both mean grade and oxygen diffusion drop off, and above 400 cm of water SMT the oxygen diffusion drops off slowly and the mean grade begins to drop. The "optimum" range of SMT for the soil plus ¼ sand starts at 100 cm of water, but the data does not indicate a clear upper limit (undoubtedly for this mixture we did not have SMT's high enough).

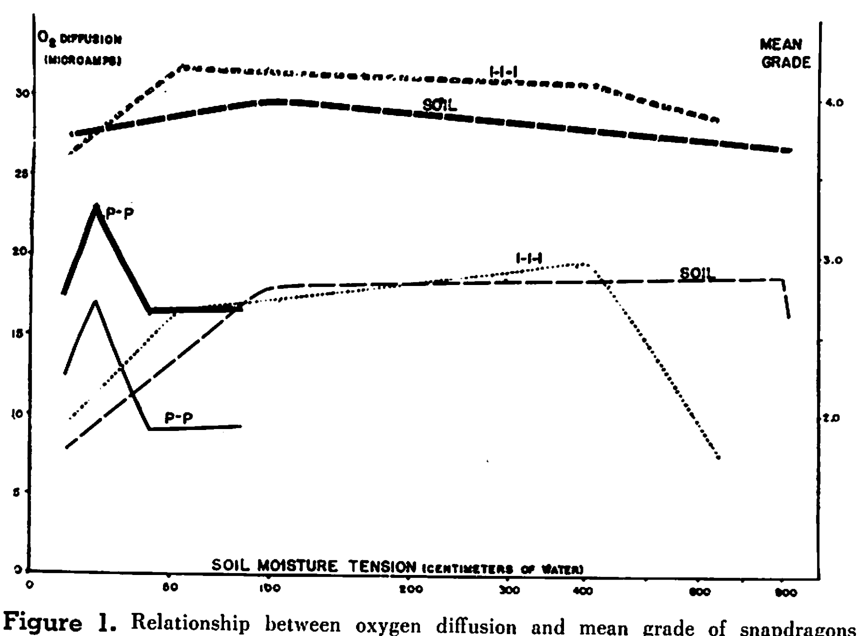

Figure 1. Relationship between oxygen diffusion and mean grade of snapdragons grown in the soil mixtures irrigated by constant water table. Narrow lines are oxygen diffusion values, upper, heavier lines are mean grade.

Letey et. al (1) indicated that snapdragons will tolerate oxygen diffusion rates as low as 20×10^{-8} $gO_2/cm^2/min$. We have not been able to obtain similar values (Table 1).

Porosity

The summation of air and moisture showed a high porosity for all 3 mixtures. Recent refinement in sampling techniques has resulted in a porosity of 80 per cent for peat-perlite, 53-58 per cent for soil plus ¼th sand and 62-69 per cent for 1-1-1 soil-sand-peat.

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Soil-air analyses

Since the start of this investigation, over 50 soil-air samples have been taken for oxygen and carbon dioxide analyses. There has been no consistent indication of reduced oxygen concentration in the soil-air in any of the plots sampled. In respect to carbon dioxide concentration, soil-containing mixtures have exhibited values ranging from 0.1 to 0.5 per cent carbon dioxide. There have been no detectable differences in the peat-perlite mixture. We feel the oxygen concentrations in the present soil mixtures for all practical purposes, may be considered as equal to that in air. The carbon dioxide concentrations do not seem to be high enough to cause damage.

Summary

In the first season of experimentation, we have not drastically damaged a snapdragon crop through deficient aeration in the soil mixtures used. The most marked decrease was in the quality of flowers cut from an artificial peat-perlite mixture, with 43 per cent free pore space at 8.4 cm of water SMT. By contrast, we have produced good quality snapdragons in soil plus ¼th sand, at the same soil moisture tension (8.7cm) but possessing 14 to 19 per cent free pore space. Apparently, the amount of free pore space, as well as porosity or the readiness with which a soil drains, are not by themselves reliable as indicators of "well aerated soil."

The trends in the soil-containing mixtures have been difficult to see, and we must await further results before making definite conclusions. In general, we think the data indicate snapdragons may be grown over a definite range of soil moisture levels. High and low moisture content at which an observable decrease in growth and quality may occur appears to be a function of soil type. This "range" may be narrow in certain artificial mixtures. Where a well-drained, well aggregated top soil (which can be economically modified) is readily available, artificial mixtures probably do not have any outstanding advantages. Also, the data, as interpreted at present, lend support to the hypothesis that each soil is an individual case and must be handled as such if maximum quality is desired.

Literature Cited

1. Letey, J. et. al. 1961. Plant growth, water use and nutritional response to rhizosphere differentials of oxygen concentration. Soil Sci. Soc. Amer. Proc. 25: 183-186.