# Soil Aeration And Moisture Controls Snapdragon Quality

Joe J. Hanan and R. W. Langhans
Department of Floriculture
Cornell University

In a series of articles, we have considered various physical aspects of greenhouse soils. It is time to see what happens when snapdragons are grown in different root media maintained at different moisture contents. We can say with assurance, that for periods of one year, it is difficult, if not almost impossible, to kill a snapdragon by deficient aeration in greenhouse benches; provided soil-borne diseases are excluded, and precautions taken to avoid hindrance to drainage from the undersurface of the soil layer. There is almost no limitation to the type of root medium that may be used if it is handled properly.

The results of this work have indicated an optimum moisture content and aeration level that produces the best quality cut flowers. The optimum moisture content for all the root media used was between 26 and 34% (expressed as % of total soil volume). The optimum aeration level, in terms of percentage of total pore space filled with air, was about 50%.

## Methods

A schematic drawing of the experiments is shown in Figure 1. Soil moisture content was controlled by depth

| MEDIA | 1-1-1PM | SOIL | P-P | SOIL | 1-1-1PM | 1-1-1PM | SOIL | P-P | SOIL | P-P | 1-1-1PM | P-P | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH | 30 | 18 | 18 | 30 | 8 | 18 | 8 | 45 | 45 | 8 | 45 | 30 | |

EXPT. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-1-1LM | 1-1-1LM | 1-1-1PM | 1-1-1LM | 1-1-1PM | 1-1-1LM | 1-1-1LM | 1-1-1PM | 1-1-1PM | 1-1-1PM | 1-1-1PM | 1-1-1PM | 1-1-1LM | 1-1-1LM |
| 18 | 30 | 60 | 45 | 18 | 13 | 23 | 8 | 13 | 45 | 23 | 30 | 8 | 60 |

EXPT. 2

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P-P | P-P | P-P | P-P | P-P | P-P | P-P | SOIL | SOIL | SOIL | SOIL | SOIL | SOIL | SOIL |
| 18 | 23 | 60 | 13 | 8 | 45 | 30 | 30 | 23 | 8 | 45 | 18 | 13 | 60 |

EXPT. 3

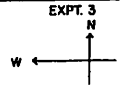


**Figure 1:** Schmatic diagram of experiments. Numbers indicate depth of soil in centimeters. (i.e. 3, 5, 7, 9, 12, 18 and 24 inches).

P-P: Equal parts peat moss and perlite.
1-1-1PM: Equal parts Eel silt loam, sand and peat moss.
1-1-1LM: Equal parts Eel silt loam, sand and leaf mold.
Soil: Eel silt loam plus ¼th sand.

and manner of irrigation (see N.Y.S.F.G. Bulletins 192), 197, and 198). Soil depths in Figure 1 are given in centimeters 1 inch=2.5 cm). In Experiment 1 (Fig. 1) constant water level irrigation was used, and these plots were never watered on the upper surface once the seedlings had been established. Experiments 2 and 3 were watered on the upper surface with Gro-hose, the frequency of irrigation being adjusted to maintain the soil moisture tension as near the theoretical value as possible (i.e. tension in cm. of water equal to soil depth).

The 4 root media were; a) equal parts by volume peat moss and perlite, b) and c) equal parts Eel silt loam, sand and peat moss or leaf mold, and d) Eel silt loam, plus ¼th by volume sand. All media were steam-pasteurized. Precautions were taken to exclude soil-borne diseases (N.Y.S.F.G. Bulletin 195). Additions of superphosphate, bone meal and 10-10-10 were made prior to planting. The peat-perlite medium also received additions of dolomitic lime and calcium carbonate. Fertilizer injection into the watering line was used when plots were irrigated overhead. At any one irrigation, water was applied until drainage equalled the application rate. Soil measurements included daily tensiometer readings, core sampling of each plot for determination of air and water content, and measurement of apparent oxygen supply rate (oxygen flux) to a root as simulated by a platinum electrode. All soil data refer to the upper 3-inches of each experimental unit. At the conclusion of this years' research (1961-62), each treatment had been sampled a total of 12 times for moisture content and 24 times for oxygen flux.

Two complete crops of the variety War Admiral were grown consecutively in each experiment, and were direct bench from the seed pan (N.Y.S.F.G. Bulletin 189) at a 4x5 inch spacing, with 99 plants per plot. The centrally located steam thermostat was set to maintain a 56° day and 56°F night temperature. All flowers removed were graded according to the S.A.F. grading system. The numbers, 6, 5, 4, 3 and 2 were assigned to each grade beginning with Special and mean grade computed. A total of 40 cut flowers from each treatment were chosen randomly and number of florets per spike, spike length, and stem length (including spike), fresh and dry weights were determined.

Records were kept on solar energy received and temperature.

## Results

Differences in moisture content and oxygen flux between root media and between extremes of depth in any one experiment were found to be significantly different.

*(continued on page 4)*

## Soil aeration

(*continued from page 3*)

In Experiment 1 (constant water level), all plant measurements were statistically significant with the exception of number of florets per spike. Mean grade and stem length were significantly different in Experiment 3. Differences in time of flowering as the result of temperature variation within the greenhouse were observed. For example, the 2 east-end plots in Experiments 2 and 3 (Fig. 1) flowered from 1 to 3 weeks ahead of all the other plots. Plots in the center of the house were usually last to be harvested. Records showed the temperature at the east end to have been 2° to 4° higher than at the middle of the house. This temperature effect was not visible on plants grown in Experiment 1. Some difficulty was experienced in maintaining proper nutrient levels in Experiment 1, but this did not appear to confuse the results.

However, aside from the effects mentioned, 2 general plant responses were observed: 1) a response caused by light intensity and temperature, and 2) a response caused by soil treatment.

*Solar radiation and mean temperature*—When mean grade for each crop was computed, regardless of soil treatment, marked differences were found. The results are presented in Figure 2, and compared with the average temperature and total solar radiation received during the period of crop growth. Times of benching are given in Figure 2's legend. Temperature appeared to be more influential than light intensity. At a mean temperature above 59°F, reduction in flower quality occurred. At a mean temperature of 57°, quality was reduced despite an increase in total solar radiation (Crop 4).

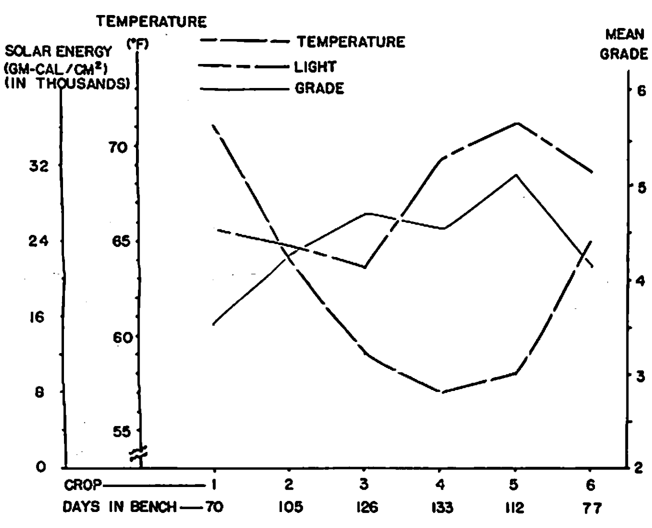


**Figure 2:** Effect of total solar energy received and mean temperature on mean grade of War Admiral snapdragons.

Planting dates:
Crop 1: (Expt. 1)—August 28, 1961
Crop 2: (Expt. 2)—September 8, 1961
Crop 3: (Expt. 3)—September 27, 1961
Crop 4: (Expt. 1)—December 20, 1961
Crop 5: (Expt. 2)—January 7, 1962
Crop 6: (Expt. 3)—March 14, 1962

*Soil moisture and aeration*—Differences in plant response as elicited in Experiment 1 indicated a possible relationship between oxygen supply, moisture content and mean grade of snapdragons. Part of these results were presented in N.Y.S.F.G. Bulletin 198. These results indicated the desirability of combining all data from the 3 experiments. Figure 3 is the outcome. Since the 1-1-1 mixtures of leaf mold and peat moss were similar, these 2 media were combined. The blackened dots represent final data from Experiment 1 (constant water level). While not strictly comparable on a point-to-point basis, a definite relationship seemed to have been present. It should be noted that the lowest value of oxygen flux occurred in soil-plus-sand, near 30 x $10^{-8}$ grams oxygen per square centimeter per minute (g $O_2/cm^2/min.$) But,

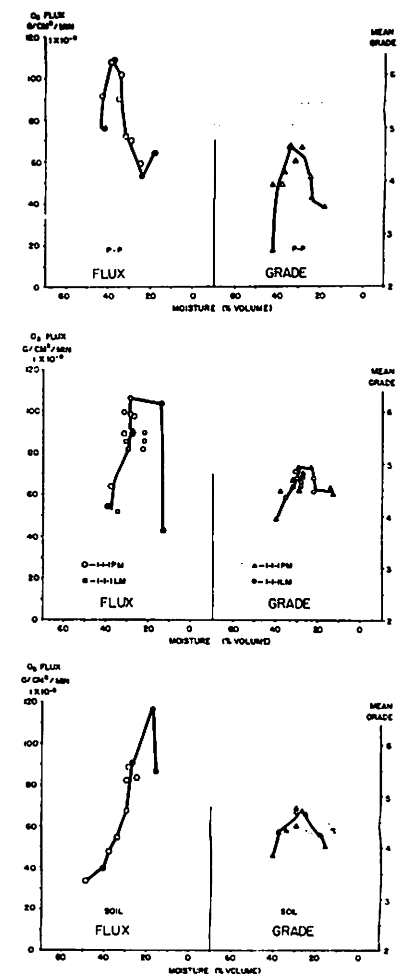


**Figure 3:** Comparisons of oxygen diffusion rate as determined with the platinum electride with mean grade of War Admiral snapdragons in 4 root media. Blackened points indicate data from Experiment 1, constant water level.

Root media:
P-P: Equal parts peat moss and perlite.
1-1-1PM: Equal parts Eel silt loam, sand and peat moss.
1-1-1LM: Equal parts Eel silt loam, sand and leaf mold.
Soil: Eel silt loam plus ¼th sand.

(*continued on page 5*)

## Soil aeration

(*continued from page 4*)

mean grade was not less than 3.5. Contrastingly, the lowest mean grade in peat-perlite was 2.7 although oxygen supply rate was more than 70 x $10^{-8}$. Plants in wet peat-perlite treatments were markedly chlorotic (similar to iron or manganese deficiency). Plants in the wet soil-containing media were only slightly chlorotic. Roots were observed growing on the surface of wet soil plots. No wilting occurred in any treatment.

Despite the relatively large number of individual determinations used to arrive at the mean of each point in Figure 3, considerable variation remained that prevented straight forward comparisons. In order to show the effect of moisture more clearly, Figure 3 was divided into sections and single mean values were derived from all points falling between 10 to 19, 20 to 29, 30 to 39 and 40 to 49% moisture content. This process was carried out for all measurements and the results are presented in Figure 4. Differences in spike length and number of florets were not great enough to warrant plotting, but followed the pattern indicated by mean grade. Several interesting relationships can be seen. First, with exception of dry weight, maximum mean grade, stem length, fresh weight,

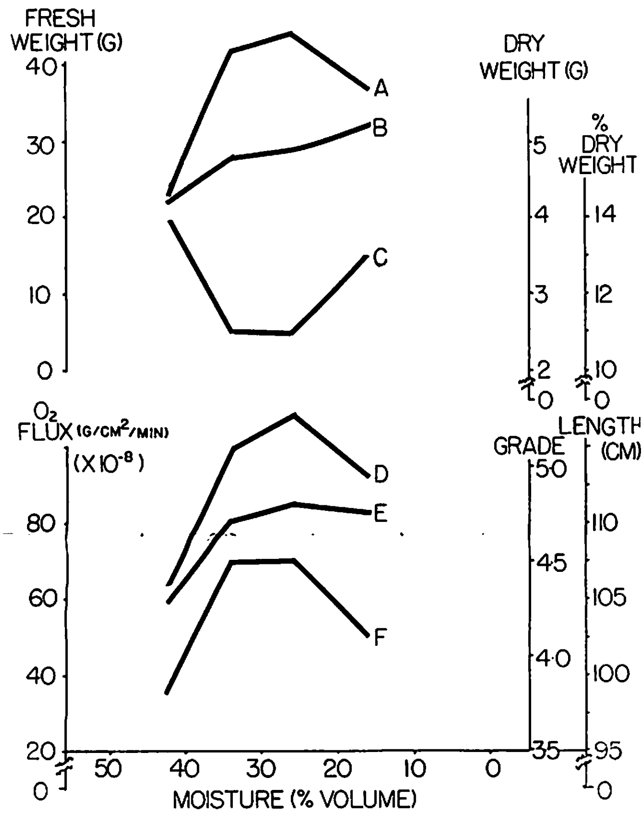


**Figure 4:** Effect of moisture content on oxygen diffusion and growth of snapdragons.

A—Fresh weight
B—Dry weight
C—Per cent dry weight
D—Stem length
E—Oxygen diffusion
F—Mean grade

florets, spike length and oxygen flux occurred between 26 and 34% moisture. Dry weight continued to increase as moisture content decreased. Per cent dry weight was reversed, the minimum between moisture contents of 26 and 34 per cent.

These results indicated the advisability of looking at response in a slightly different manner. In Figure 5, the rate of oxygen supply is plotted as a function of the amount of air present, expressed as per cent of the total pore space (air and water). This has the result of cancelling variations in total pore space (porosity), and it can be seen that maximum rate of oxygen delivery in the soils studied occurred when the amount of air-filled space was between 46 and 54%.

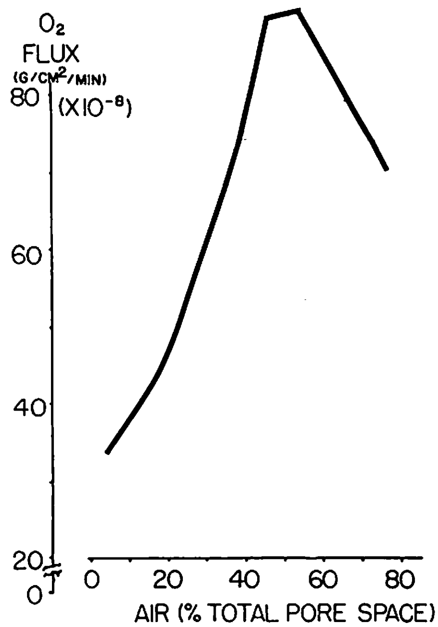


**Figure 5:** Rate of oxygen supply to a simulated root as a function of air-filled space expressed as percent of total pore space (air plus water).

## Discussion

The correspondence of the data in Figures 3 and 4 indicated the existence of a range of moisture content for maximum plant growth. It appeared that rate of oxygen diffusion as measured with the platinum electrode is a good indicator of possible plant response (provided there are a large number of determinations), and that moisture content directly influences the rate of $O_2$ supply.

The decrease of oxygen flux at low soil moisture contents was not due to a reduction in oxygen supply *per se*. This was probably a reflection of increasing electrical resistance in the soil or failure to completely wet the electrode surface. Other theories have been proposed.

The results of this research are supported by other work. Lemon and Kristensen (3) found that maximum $O_2$ supply in their study occurred near 30% while Currie (2) indicated that "minimum complexity" of the soil-water-air system occurs near this same value. Figure

(*continued on page 6*)

## Soil aeration

(*continued from page 5*)

5 has a double meaning in this respect, in that it presents the data on oxygen supply in a manner used by Currie for "complexity" factors. The correspondence between Currie's results and the "field" results are remarkable. The implications are that 30% moisture content by volume, or 50% of the total pore space filled by air, the rate of oxygen supply is at a maximum with sufficient water present to supply the needs of the plant.

Aside from the aspect of "optimum" moisture content, it can be definitely said that moisture contents in excess of 40% will reduce cut flower quality. Research in general has indicated that oxygen supply rates less than 30 x $10^{-8}$ $gO_2/cm^2/min.$ will cause death of roots (4). Other studies have indicated that rates less than 72x $10^{-8}$ may slow growth and eventually cause death (1). It can be said here that rates less than 80 x $10^{-8}$ will lower cut flower quality.

## Practical implications

The results of this research, together with preliminary observations of this years' research (1962-63), indicate to us that deficient aeration is rare in greenhouse benches. Problems formerly thought the result of deficient aeration are more likely problems caused by disease. It is our contention that we are running our soils much too dry, particularly during initial stages of growth up through flower initiation and development. We are not able to say at the present time what the implication of reduced per cent dry weight may have on cut flowers keeping and handling. But, we hope to show in future papers that manipulation of "tone" of cut flowers through the reduction of water application is limited with present practices.

It is necessary that we re-evaluate our methods of determining moisture content in greenhouse soils. What is "wet" and "dry"? Obviously, these terms as presently used, are not good and we should employ them with considerable care.

On the basis of what we have presented up to the present time, we suggest that : 1) all possible precautions should be taken to exclude soil-borne diseases. Without this, the results of this research are not applicable and can result in greater damage because many root-rot organisms grow best in moist soils, 2) soil depths in greenhouse benches should not be less than 6 inches, 3) adequate nutritional levels must be established prior to benching and they must be maintained through a fertilization program, 4) a field soil should always be modified by addition of such materials as leaf-mold or peat moss (at least ⅓ of the final volume). Sand, as the only addition is not recommended unless the amount added exceeds 70% of the final volume. 5) Hand watering should be avoided if at all possible. 6) No attempt should be made to compact soils other than through thorough watering. And 7), there should be no obstruction to the free flow of water from the undersurface of the soil layer.

## Literature Cited

1. Cline, R. A. and A. E. Erickson. 1959. The effect of oxygen diffusion rate and applied fertilizer on growth, yield and chemical composition of peas. *Soil Sci. Soc. Amer. Proc.* 23:333-335.

2. Currie, J. A. 1961. Gaseous diffusion in porous media. Part. 3. Wet granular materials. *British Jour. App. Phy.* 12:275-281.

3. Lemon, E. R. and J. Kristensen. 1960. A edaphic expression of soil structure. *Transac. 7th Intern. Cong. Soil Sci.* 1:232-240.

4. Letel, J. *et al.* 1961. Effect of temperature on oxygen-diffusion rates and subsequent shoot growth, root growth and mineral content of two plant species. *Soil Science.* 92:314-321.