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androhermaphrodite flowers at intervals throughout their entire flowering period.

Flowers collected in Iowa and Minnesota and designated as gynohermaphrodites all had sterile stamens. If this condition should prove true in other geographic areas and with other races of *Lychnis alba,* then the "hermaphrodites" of earlier writers probably were androhermaphrodites and not gynohermaphrodites since they would better fit the results obtained by selfing and crossing experiments which produced viable seeds. It is probable that androhermaphrodites of *Lychnis alba* have not been found and reported more frequently simply because they have not been searched for specifically and thus have escaped all except accidental discovery.

Literature Cited

1. Dean, H. L. 1963. Phytomorphology 13:1-13.
2. ———. 1959. Science 130:42-43.
3. Eames, A. J. 1961. Morphology of the angiosperms. McGraw-Hill Book Co. New York, N. Y.
4. Allen, C. E. 1940. Bot. Rev. 6:227-300.
5. Westergaard, M. 1958. Advances in Genetics 9:217-281.
6. Warmke, H. E. and A. F. Blakeslee. 1940. Am. Jour. Bot. 27:751-762.
7. Westergaard, M. 1940. Dansk. Botan. Ark. 10:1-131.

Influence of Aggregate Size on Soil Moisture Retention[1]

P. M. Tamboli, W. E. Larson and M. Amemiya[2]

Abstract: Soil aggregates ranging from 0.5 to 9.5 mm. in diameter from Nicollet silt loam were used to study the effect of aggregate size on soil moisture retention. It was concluded that (a) between suctions of 0.10 and 1.0 bar, the gravimetric percent moisture retained by various sized aggregates was in the following order: $0.5 < 1.0 < 2.0 \leqslant 3.0 \leqslant 5.0 \leqslant 9.5$ mm.; (b) between suctions of 1.0 and 5.0 bars, the gravimetric percent moisture retained was in the following order: $0.5 < 1.0 \leqslant 2.0 \leqslant 3.0 \leqslant 5.0 \leqslant 9.5$ mm.; and (c) at suction of 10 and 15 bars, the moisture retained by aggregates of various sizes was essentially the same.

Aggregation of particles within the soil mass imparts a characteristic structure to the soil. Both secondary and primary aggregates have been recognized within the soil (1). Secondary aggregates are generally stable when gently sieved in the dry state but usually are not stable when agitated in water. Primary

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aggregates are stable when gently agitated in water and are components of secondary aggregates. The size distribution of aggregates has been observed to affect the capacity of the soil to retain and transmit air and water and thus to influence plant growth. It was the purpose of this study to quantitatively determine the effect of secondary aggregate size on moisture retention at suctions ranging from 0.1 to 15 bars, the range in which moisture is usually considered available to plants.

Methods and Material

Bulk samples from the 0 to 9 inch depths of Nicollet silt loam were randomly collected from a field at the Agronomy Farm at Ames, Iowa.

The larger clods in the bulk sample of soil were broken by hand, and the mass of soil was air dried. The bulk sample was fractionated by sieving into the following aggregate diameter groups: <0.5, 0.5 to 1.0, 1.0 to 2.0, 2.0 to 3.0, 3.0 to 5.0, 5.0 to 9.5, and 9.5 to 12.0 mm. Hereafter, the size fractions will be referred to as <0.5, 0.5, 1.0, 2.0, 3.0, 5.0, 9.5 mm, respectively. The <0.5 fraction was discarded because it contained a mechanical composition markedly different from the other fractions.

The particle size distribution of all six aggregate size fractions was determined by the pipette method (2). Organic carbon content was determined by the wet digestion method described by Tinsley (3). Total surface area was determined by the ethylene glycol procedure of Bower and Gschwend (4) following grinding of the 0.5, 1.0 and 3.0 mm. diameter aggregates to pass a 60-mesh sieve.

The pressure plate apparatus described by Richards and Fireman (5) was used for determining the moisture retention by the aggregates at suctions between 0.10 and 1.0 bar, and the pressure membrane apparatus of Richards (6) was used at suctions between 2 and 15 bars.

The aggregates of a given diameter were gently poured into plexiglas (acrylic plastic) cylinders and placed on the pressure plates or pressure membranes. The cylinders were 50 mm. in diameter and 30 mm. in height. Very light agitation was used to adjust the packing arrangement within the cylinders so that all samples had a bulk density of about 0.95 g. per cc. The samples were then wetted overnight under a partial vacuum of about 1.0 cm. of mercury before the desired pressure was applied. Triplicate determinations were made in all cases.

The destruction of the natural aggregates during the packing and wetting treatment was determined by placing the aggregates in the cylinders and wetting under vacuum as described in the previous paragraph. The aggregates were then allowed to air dry, were resieved, and the fractional destruction determined by dividing the weight of the sample retained on the given sieve size by the original weight. The fraction of destruction was always less than 3 percent.

It was assumed that the moisture content of the aggregates was at equilibrium when moisture stopped draining from the pressure membrane or pressure plate apparatus. This required approximately 98 hours on the pressure plate and 108 hours on the pressure membrane apparatus.

A pooled error was not used in the analysis of variance for testing the significance of aggregate, because the Bartlett's test (7) indicated non-homogeneity of variance at different suction levels. Therefore, separate analysis of variance for each suction level was carried out. For testing of all comparisons among means, a procedure described by Tukey and modified by Snedecor (7) was used.

Results and Discussion

The data (Table 1) show that at all suctions, except at 10.0 and 15.0 bars, the 0.5 mm. aggregates retained less moisture

Table 1. The relationship between the gravimetric moisture retained and soil aggregate size at various soil moisture suctions

Aggregate size	Soil moisture suction (bars) 0.10	0.20	0.33	0.50	1.0	2.0	3.0	5.0	10.0	15.0
mm.	Percent									
0.5-1.0	25.0[a]	22.8	20.5	18.8	16.9	14.3	13.5	12.7	12.0	11.9
1.0-2.0	26.9	24.3	22.2	20.7	18.4	16.5	15.3	14.1	12.2	11.5
2.0-3.0	30.3	26.7	24.0	23.0	20.0	17.0	15.5	14.1	12.8	12.6
3.0-5.0	30.5	27.3	24.4	23.2	20.2	16.2	15.4	14.0	12.4	12.1
5.0-9.5	30.7	27.3	24.4	22.9	20.1	16.6	15.5	14.8	13.1	12.6
9.5-12.0	29.8	27.3		22.8	20.1	16.5			13.8	

[a] Each value is an average of three determinations.

than the larger aggregates. Between suctions of 0.10 and 1.0 bars, the gravimetric percent moisture retained by various aggregates was in the following order: $0.5<1.0<2.0\leqslant3.0\leqslant5.0\leqq9.5$ mm. Between suctions of 1.0 and 5.0 bars, the gravimetric percent moisture retained was $0.5<1.0\leqslant2.0\leqslant3.0\leqq5.0\leqslant9.5$ mm., and, at suctions of 10 and 15 bars, the moisture retained was essentially the same in all aggregate sizes. The symbols $\leqslant$ indicate that, at some suctions, the differences were statistically significant at the 5 percent level and that, at others, the differences were not significant. The differences in soil moisture retention among 20., 3.0, 5.0 and 9.5 mm. aggregates usually were not sigcant. The effect of soil moisture suction is more pronounced in the range of 0.10 to 1.0 bar than in the range of 2.0 to 15.0 bars.

Statistical analysis indicates that the relationship between the aggregate size and moisture retention is primarily quadratic up to 1.0 bar. At suction greater than 1.0 bar, this relationship becomes cubic.

The greater moisture retention by 3.0 mm. and larger aggregates as compared with 0.5 mm. is probably because the larger aggregates have greater internal porosity. These results are in agreement with those reported by Wittmus and Mazuak (8).

It has been shown by Heinonen (9) and Jamison and Kroth (10) that changes in any of the textural components of soil will tend to affect its soil moisture retentivity. The data in Table 2 show that particle size distribution was near constant over the range of aggregate sizes studied.

Table 2. Particle size distribution, organic carbon content, and total surface area of various sized soil aggregates

Aggregate size	Particle size distribution			Organic carbon	Total surface area
	clay $<2\mu$	silt $2\text{-}50\mu$	sand $>50\mu$		
mm.	%	%	%	%	$m.^2/g.$
0.5-1.0	22.6	36.1	41.5	1.6	34.8
1.0-2.0	22.4	35.9	41.7	1.6	34.3
2.0-3.0	22.2	36.0	41.9	1.4	
3.0-5.0	23.2	36.0	40.8	1.4	34.4
5.0-9.5	23.2	36.8	40.5	1.3	
9.5-12.0	23.2	36.6	40.2	1.3	

Since a considerable variation within the textural grades (sand, silt, clay) could occur between the various sized aggregates, the determination of the total surface area of the particles in the 0.5, 1.0, and 3.0 mm. aggregates was made as a measure of uniformity of particle sizes. The data (Table 2) indicate that the total surface area of the particles in the aggregates of three sizes was almost the same.

The organic carbon content decreased as the aggregate size increased from 0.5 to 9.5 mm. (Table 2). Organic matter has been reported present on the external surface of soil aggregates as a thin coating (11, 12). Since the smaller aggregates have higher external surface area per unit of volume, this may explain the negative relationship between aggregate size and organic carbon.

Miller and Mazurak (13) have shown that the growth of sunflowers was influenced by the effect of pore size upon aeration and upon area of root-solution contact. Soil moisture characteristic curves have been used in computing the pore size distribution within a soil (14) although discontinuations in the capillaries may limit the usefulness of the calculation.

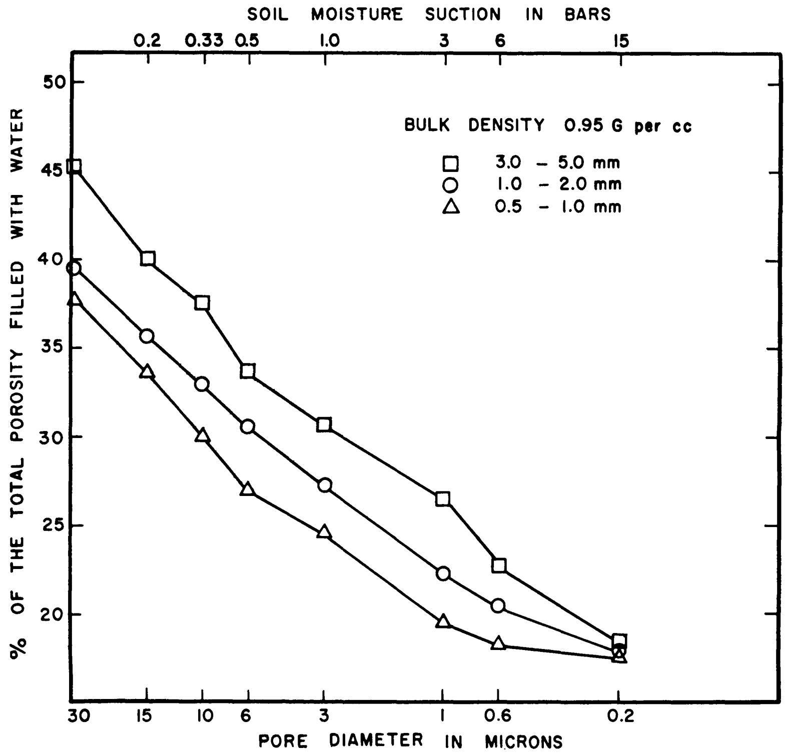

Figure 1. Pore size distribution as affected by soil aggregate size.

The data (Fig. 1) show that when the aggregate sizes are 0.5, 1.0, and 3.0 mm., the pores of 10 microns or less in diameter are 30, 33, and 37 percent of the total pore space, respectively. Theoretically, pores of 10 microns in diameter or greater will be drained at a suction of 0.33 bar (approximate field capacity), whereas those less than 0.33 bar will be filled with water. The total pore space in the beds of all aggregate sizes was 65 percent.

The moisture retention by the various sized aggregates may have a number of important consequences in plant growth. An ideal soil for air and water retention and transport probably contains a broad spectrum of pores ranging from large to small. The large pores provide avenues for movement of air and water during drainage and provide pathways for root extension. On the other hand, small pores are necessary for moisture retention against gravity and for adequate root-soil solution contact necessary for transport of water and nutrients from soil to plant.

In this study, the larger aggregates retained more moisture than the smaller aggregates at suctions above 0.1 bar. The greater moisture retention indicates that the larger aggregates had a greater volume of small pores. The beds of larger aggregates no doubt also contained larger inter-aggregate pores than the smaller aggregate beds, although the total volume of inter-aggregate pores was less. Thus, a wider range in pore sizes for both the movement and retention of water and air in the soil was provided by the beds of larger aggregates.

Literature Cited

1. Chepil, W. S. 1953. Soil Sci. Soc. Am. Proc. 17:185-190.
2. Kirkham, D. 1957. Laboratory methods for soil physics (Mimeo). Iowa State University of Science and Technology, Department of Agronomy. Ames, Iowa.
3. Tinsley, J. 1950. Trans. 4th Int. Cong. Soil Sci. 4:161-164.
4. Bower, C. A. and F. B. Gschwend. 1952. Soil Sci. Soc. Am. Proc. 16:342-345.
5. Richards, L. A. and M. Fireman. 1943. Soil Sci. 56:395-404.
6. Richards, L. A. 1947. Agr. Eng. 28:451-463.
7. Snedecor, G. W. 1959. Statistical Methods. 5th ed. The Iowa State University Press. Ames, Iowa.
8. Wittmuss, H. D. and A. P. Mazurak. 1958. Soil Sci. Soc. Am. Proc. 22:1-5.
9. Heinonen, R. 1954. Agrugeol Juk. 62:82.
10. Jamison, V. C. and E. M. Kroth. 1958. Soil Sci. Soc. Am. Proc. 22:189-192.
11. Martin, J. P. 1945. Soil Sci. 59:163-174.
12. ———. 1946. Soil Sci. 61:157-166.
13. Miller, S. A. and A. P. Mazurak. 1958. Soil Sci. Soc. Am. Proc. 22:275-278.
14. Childs, E. C. 1940. Soil Sci. 50:239-252.