THE EFFECT OF THREE METHODS OF WATERING ON THE PRODUCTION OF CARNATIONS IN SEVERAL SOILS AND SOIL MIXTURES

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THESIS

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by

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THE EFFECT OF THREE METHODS OF WATERING IN THE PRODUCTION OF CARNATIONS IN SEVERAL SOILS AND SOIL MIXTURES

For the past few years, greenhouse operators have been faced with a steadily increasing cost of labor. Accordingly, they have been searching for methods of decreasing their labor requirements, in order that they might continue to operate at a profit.

One labor consuming phase of flower production has been the prevailing method of hand watering. Several new ways of watering have been developed to eliminate some of this hand labor. Of these, sub-irrigation and constant water level sub-irrigation seemed to be the most promising.

It was the purpose of this experiment to compare the production achieved on various soils and soil mixtures, using the three above mentioned methods of watering: surface watering by hand, sub-irrigation, and constant water level sub-irrigation.

Carnations were chosen as the indicator crop, as they are widely grown commercially, and are in constant demand. They are fairly easy to grow and require about 10-11 months in the greenhouse bench, which was considered sufficient to show any differences in the soils and soil mixtures as affected by these methods of watering.

Various tests were made on the soils to determine what effect these three methods of water had on the soils and soil mixtures.

REVIEW OF LITERATURE

Carnations (*Dianthus caryophyllus*, family Caryophyllaceae) are specific in their culture requirements. According to Wildon (9), they grow best in a cool house, at a night temperature of 40°-50° F., with plenty of fresh air and sunshine. pH is best at 6.3, and nutrient levels determined as follows: Nitrogen, 10-50 ppm; Phosphorus, 5 ppm; and Potassium, 15-25 ppm. The most serious pest is red spider, which can be eliminated by spraying. Diseases of carnations are eliminated by careful selection of the cuttings, and then re-selection of the plants from cuttings, when the plants are benched from the field.

Carnations are generally benched in July, with the first blooms maturing in late December.

Ward, 1903 (8), considered sub-irrigation extremely valuable in the culture of carnations. He constructed water-tight tanks and inside these, fitted T-shaped porous clay pieces on top of which the soil rested. The bottom of the tank was constantly supplied with water, and water moved upward by capillarity through the porous clay to the soil.

Post and Seeley (2), reported that cut flower crops grown in benches or beds of soil are frequently sub-irrigated. Considerable amounts of water are injected at each watering, and the surplus is drained away. This method has been found to work satisfactorily in some soils, but poorly in others.

In water-tight benches, it was found possible to regulate sub-irrigation by injection and thus make it an outomatic method. This method uses less water, so that watering can be done less frequently. Benches that are sub-irrigated do not dry out as fast as surface watered benches.

An experiment was conducted with carnation, using a surface watered bench and an automatic watered, sub-irrigated bench. Nutrient levels were maintained and both benches were watered at a capillary tension of 8 cm of Hg. controlled through the use of tensiometers.

Early production was higher on the surface watered bench, but the total production was slightly higher on the automaticly watered bench.

Stephens and Volz (6) grew stocks and China asters on four Iowa soils in a constant-water level bench. The three soils having over 5 per cent organic matter produced significantly better crops than did the soil with only 2 per cent of organic matter.

DESCRIPTION OF SOILS AND SOIL MIXTURES

The six soils and soil mixtures used, as described by Veatch (7) are as follows:

1. Oshtemo; light brown loamy sands and light sandy loams underlain by pervious sand with a small admixture of clay and gravel. Dry, low in fertility, and low in organic matter.

Level or pitted dry sandy plains and terraces.

2. Oshtemo, two thirds by volume, and muck, one third by volume. The muck was Carlisle Muck and was well-decomposed.

3. Miami; light brownish loam and silt loam over brownish, compact, and retentive but granular gritty clay. The Clay extends to a depth of several feet.

Moist, acid surface, high fertility

gently rolling upland clay plains,

The soil used was a slightly sandier associate of the Miami.

4. Wauseon; dark gray to blackish sands and sandy loams over grayish waterlogged sand which rests upon clay at one or two feet.

Moist, neutral, medium fertility.

This soil was from a section mapped as Brookston, as it is sometimes found in association with Brookston.

5. Brookston; loams and clay loams. Dark colored plow soil underlain by wet, motted, gritty clay to depths of several feet.

Moist, slightly acid to neutral, high fertility and organic matter.

Level plains and valleys, associated with rolling land such as Miami.

6. Brookston, two-thirds by volume; Carlisle Muck, one-third by volume.

All of these soils or similar soils and soil mixtures are generally available to the greenhouse operator in Michigan.

METHODS OF PROCEDURE

Six soils and soil mixtures were placed in 25 by 36 inch plots in each of three V-bottom concrete benches. The plots were in duplicate in randomized blocks.

A single row of bench tile was placed in the "V" of each bench. Over this, one inch of gravel, and then one inch of coarse sand were placed. Next, wooden partitions were fitted into the bench at intervals of 28 inches. The soils and soil mixtures were placed in the proper compartments and filled to the surface of the bench. A small, galvanized metal tank with a poultry-watering float was placed in one end of one bench to make possible the maintenance of a constant water level in the sand just below the soil.

Lime was added to the Oshtemo sand, and to the Oshtemo sand and Muck to bring the pH to the level of 6.3. The pH of all of the other soils was deemed chose enough to the desired level.

Ammonium sulphate, superphosphate, and potassium chloride fertilizers were added to bring the nutrient levels to those decided as best for carnation; nitrogen-50 ppm, phosphorus-5 ppm, and potash-25 ppm. These levels were maintained as nearly as possible throughout the course of the experiment.

Fifteen carnation plants, variety Puritan, were planted in each section and spot-watered for approximately two weeks until established. From this time, until the conclusion of the experiment, they were watered by the following methods:

1. Surface watering. Water was applied on the surface of each plot whenever it was needed.

2. Sub-irrigation. The plots were watered when any one on them showed need, then were drained. The entire bench was watered at once.

No mechanical means were used to determine the time of watering in either of the above two benches.

3. Constant water level sub-irrigation. The water level was maintained in the sand layer just below the soil

The plants were supported by wire and string and were pinched and disbudded as is common in carnation culture.

Adequate ventilation was maintained at all times, and temperature was controlled as closely as possible with thermostatic control of the steam lines.

Red Spider was controlled by the use of Parathron, applied as a spray when needed.

Nutrient levels were maintained as nearly as possible at the desired levels throughout the course of this experiment. Tests were made frequently according to the methods devised by Spurway (5).

Pore space and volume weights of the soil were determined as follows: Core samples were taken from the various plots. The volume of each was determined by water displacement. The cores were then saturated, allowed to drain one minute, weighed, oven dried, and re-weighed. The resulting figures gave the volume of soil, weight of soil, and volume of water in the saturated soil. From these figures, the pore space by volume and the volume weight of the soil were determined.

The percent moisture of the soils, measured while the plants were growing, was determined by determining loss of weight in an oven at approximately 110^{o} Centigrade. Weights of soils were converted to a volume basis and the percent moisture by volume determined.

Aggregate analyses were made by the method suggested by Yoder(10).

Moisture equivalent was determined by the centrifuge method, and wilting coeficient by use of the following equation:

$$\text{Wilting coefficient} = \frac{\text{Hygroscopic coefficient}}{0.68}$$

Records of the number of flowers cut and the number which were split were kept during the growing season. The vegetative weights of the tops were taken at the time of harvest.

SOIL MOISTURE DETERMINATIONS AND THE EFFECT OF THE VARIOUS METHODS OF WATERING ON POROSITY AND AGGREGATION

One of the most important considerations in the production of any crop in a soil or soil mixture, is the moisture relations of the soil. Table 1. shows the percent of moisture available to the plant in the various soils and soil mixtures, determined on the basis on the difference between the moisture equivalent and the wilting coefficient. It can be seen that the heavier soils have considerable more available moisture than the lighter soils, but that the lighter soils can be greatly improved, and the heavier soils somewhat improved by the addition of organic matter (one third muck by volume in this case.)

The commercial grower who has only the lighter soils available can thus improve his crops by improving the water relationships of the soil through the addition of suitable organic matter, such as muck.

The outstancing difference in the soils and soil mixtures due to the different methods of watering, was the percent moisture in the soil during the growing period. Table 2 shows that the percent moisture was greater in the sub-irrigated plots than in the surface watered plots, and still greatest in the constant water level plots. The samples for the moisture determinations were taken from the sub-irrigated plots 45-50 hours after watering, and from the surface watered plots, 35-60 hours after watering.

The plots, at the time of tampling, contained as close to the average amount of moisture as it was possible to estimate.

This increase in percent moisture is advantageous to the point at which aeration becomes a limiting factor in plant growth. This minimum need for air is believed to be somewhere between 30 and 100 cc per liter of soil. As pore space is practically constant (see table 3) for each soil or soil mixture under all three methods of watering, the degree of aeration in the soil depends upon the percent moisture in the soil. The results of the two pore space determinations that show the greatest variation, the surface watered Oshtemo sand, and one sub-irrigated plots of Miami, are believed to be erroneous.

From the table of volume weights, table 4, it is evident that the addition of muck materially decreases the volume weights of the soils, thus increasing porosity.

In soils, where nutrient levels are maintained at a sufficiently high level, successful crop production depends largely upon the amount of moisture present, and the physical condition of the soil. Table 5 shows the moisture aeration relationships of the six soils and soil mixtures as affected by the three methods of watering.

Aeration was sufficient on all soils and soil mixtures that were surfaced watered. There is a possibility, with this method of watering, that soil moisture might become a limiting factor in plant growth. In the Oshtemo sand for instance, the amount of moisture available to plants can be only 4.27 percent (Table 1). As the soil becomes dry, the actualvolume available to the plants may become very low. The data show however, that the quanity may be greatly increased by the addition of muck to the sand. All of the other soils and soil mixtures probably contained sufficient moisture as a result of this method of watering, even though there was less moisture than where the other two methods of watering were employed. The addition of the muck to the Brookston clay loam only slightly increased the amount of available moisture, while the wilting coefficient of the soil was materially increased.

The amount of moisture varied considerably in the sub-irrigated plots. This was due to differences in soil as they were all watered at the same time. Moisture in any one of the soils or soil mixtures could have been better controlled in separate benches.

As evidenced by plant growth, aeration seemed to be sufficient in all of the sub-irrigated soils, although the volume of air per unit volume of soil was much lees than in the surface watered soils. It is believed that any soil or soil mixture can be used satisfactorily with this method of watering under properly controlled conditions, although the heavier soils with organic matter should be the best

In the constant water level bench, all of the soils received sufficient moisture at all times. Water rose so freely in the lighter (sandier) soils that air was almost entirely excluded. This was particularly true of the Oshtemo, and to a lesser extent with the Wauseon soil.

The addition of muck to the Oshtemo sand increased aeration by the increase in the amount of pore space, and probably by the effect of the organic matter in slowing up capillary rise of water.

The reason for the low amount of aeration in the sandier soils is believed to be due to the rapid capillary action in the sand which filled most of the pore spaces more rapidly than the moisture could evaporate or be used by the plants. Where capillarity was slowed down by the finer pores in the heavier soil, evaporation and plant use were fast enough to use up the water and allow sufficient air for the plant roots.

For best possible moisture-aeration relationships, heavier soils, containing considerable organic matter should be used with the constant water level method of watering.

The Oshtemo sand produced heavier growth than the Brookston clay loam and muck under surface watering, as shown in figures 1 and 2, and in the vegatative weight at the termination of the experiment. Under sub-irrigation, the growth was superior in the Brookston clay loam and muck, showed very good growth under constant water level, while those in the Oshtemo sand were severely retarded or killed as shown in figures 5 and 6.

Surface watering has a tendency to break down aggregation faster than do the methods of sub-irrigation or constant water level, as shown in table 6.

This is shown also in figures 7-10. In the Wauseon, Brookston, and Brookston and muck, the curves show that the aggregates are definitely smaller in those plots that were surface watered. In the Miami soil, the curves for surface watering and sub-irrigation cross, indicating very little difference in the effect of treatment.

The greenhouse operator that leaves his soils in the benches for several years should get better results with subsequent crops by using either the sub-irrigation or constant water level methods of watering.

The volume weights of the soils and soil mixtures were only slightly affected by the method of watering, as evidenced in table 4.

THE EFFECT OF SOILS AND METHODS OF WATERING ON FLOWER PRODUCTION AND QUALITY

High production of quality carnation flowers is subject to many variables, among which are; variety, temperature, nutrient level, climate, moisture, and soil-moisture relations.

It was attempted in this experiment to control as many of the variables as possible in order to have comparable records of production on the various soils and soil mixtures, under the various methods of watering.

Table 7 gives the production of flowers and the percentage of split calyxes in each of the plots, and the average for each soil under each of the three types of watering.

High flower production was maintained on the surface watered plots of Oshtemo sand, and there was fair production on the sub-irrigated plots. Production on the constant water level plots however was very poor, and the flowers were of the lowest quality of any of the plots, many of them being unsaleable. The plants in these plots were either killed or materially injured by the high moisture content and lack of aeration. Figure 5 shows this poor growth, and table 8, vegetative weight at the close of the experiment, shows the limited vegetation on these plots.

The Oshtemo sand with muck showed a slightly lower production on the surface watered plots, possibly due to the fact that, although the moisture content was higher at the time the samples were taken, the wilting coefficient was quite a bit higher than on the Oshtemo sand alone, and thus more water was needed. There may thus have been sometimes a shortage of available moisture.

The increase in production, caused by the muck in the Oshtemo sand, in the constant water level plots, over 250 percent, was probably due largely to better aeration. Even then, however,the yield was still lower than normal production standards.

The Miami soil, a heavy sandy loam, produced good yields under all three methods of watering. Apparently, ample moisture and sufficient soil air were present at all times on all plots. This soil, and similar soil types are very prevalent in Michigan and are easily available to many greenhouse operators. There were differences in the quality of the flowers produced under the different watering methods. Those of the surface watered plots were slightly smaller and with somewhat poorer stems. Some evidence of this is noted in table 8.

The data for the Wanseon sandy loam shows inconsistency in both the surface watered and the sub-irrigated plots. In the surface watered bench, one of the Wanseon plots was at the end of the bench nearest the door to the outside of the greenhouse. The traffic through the greenhouse seemed to have affected the production of this plot.

In the plants as received from the yield, it was later discovered that some plants of the variety Millers' Yellow, were mixed in with the variety Puritan. All of these plants appeared in the fourth and fifth plots of the sub-irrigated bench, being the Wauseon and Brookston plots, respectively, The Wauseon plot consisted of all plants of this variety, and the Brookston plot, about half and half. The number of blooms per plant of Millers' Yellow appeared to be less than the number of blooms per plant of Puritan.

The somewhat lower yield, as compared to other soils, of the constant water level Wauseon plots was probably due to the lack of proper aeration as shown in table 5.

Brookston clay loam, a heavier soil, high in organic matter, produced good yields on both the surface watered and constant water level plots. The reasons for the lower yields on the sub-irrigated plots are partially explained by the variety mix up already mentioned, and partially due to the inability to properly control the moisture content due to the fact that more than one soil was in the bench.

The addition of muck to the Brookston soil lowered the production on the surface watered plots because the wilting coefficient was increased to a much greater extent than the moisture in the soil, thus causing the possibility of occasionally too low a moisture content.

The increase in yield on the sub-irrigated plots, caused by the addition of muck to the Brookston clay loam, is believed due the fact that the moisture-aeration relations for these plots were better than for the Brookston plots.

There was no material increase in the yield obtained on the constant water level plots due to the addition of muck to the Brookston soil, because the Brookston soil was already heavy enough and sufficiently high in organic matter for good production.

It can also be seen from table 7 that there should have been some method of time control of watering on both the surface watered and sub-irrigated plots, and that only one type of soil or soil mixture should have been used in the sub-irrigated bench.

Best yield results, using the constant water level method of watering, were obtained by the use of heavier soils, high in organic matter.

Table 7 does not show that the flowers were of superior quality, both as to size of bloom and length and sturdiness of stems, in all of the sub-irrigated and constant water level plots except those of Oshtemo sand.

Table 8, showing the vegetative weights of the plants at the termination of the experiment, serves to indicate this sturdiness of the plants. The plant growth averaged 5.97 pounds per plot on all sub-irrigated plots, and 6.56 pounds on all constant water level plots, omitting the Oshtemo sand figures from this last average. As compared with an average of 4.15 pounds obtained of the surface watered plots, these figures show the superiority of the sub-irrigation methods of watering, The size and quality of the flowers varied in much the same order as did the plants at the end of the experiment. Actual size records on the flowers were not recorded.

Table 9 is another form of expressing the average production data in table 7, and is included to give the commercial grower a comparison of yields on a square foot basis, as this is the basis on which they measure their production. A quick glance shows that best production was obtained on Brookston clay loam and Brookston clay loam plus muck, but that the muck did not improve the natural Brookston soil. This might not be true with certain other crops.

SUMMARY AND CONCLUSIONS

Carnations were grown in six soils and soil mixtures. Watering was done at the surface in the conventional manner, by sub-irrigation, and by constant water level sub-irrigation. The effect of the different methods of watering was shown by porosity relationships, moisture determinations, and aggregate analyses of the soils and soil mixtures, and by recording the number of blooms per plot, and taking the vegetative weights of carnation plant from each plot at the termination of the experiment.

Judging from the effects of the soil, number and quality of blooms, and total vegetative growth of plants, sub-irrigation proved to be superior to surface watering.

It was found necessary to use a heavy soil, high in organic matter, to achieve the best results with the constant water level method of watering.

Heavier soils with organic matter were also found superior to the more sandy soils in the sub-irrigation method of watering. Best results can only be achieved by this method when only one soil is used to a bench, and the time of watering is controlled to fit the soil.

The reason the sandy soils were not satisfactory in the constant water level method was that the rapid capillary action in the sand filled up the pore spaces faster than evaporation and the plants could use the moisture, and consequently limited aeration to the extent of affecting the growth of the plants in the soil

Soils to which a large amount of organic matter has been added require more water than those low in organic matter. This is especially noticable in the surface watering method, and must be carefully watched.

Aggregate analyses showed that surface watering tended to break down aggregation faster than the other two methods of watering.

Superior size of flowers and stems in the sub-irrigation and the constant water level methods was due to the greater moisture content of the soil at all times. Perhaps sufficient moisture could be kept in the surface watered bench by using some mechanical means of controlling the time of watering, or by increasing the labor involved.

TABLE 1: SOIL MOISTURE CONSTANTS ON THE VARIOUS SOIL AND SOIL MIXTURES

Soil	Moisture Equivalent percent	Wilting Coefficient percent	Available Moisture percent
Oshtemo	5.90	1.63	4.27
Oshtemo and Muck	18.85	5.12	13.73
Miami	15.45	2.79	12.66
Wauseon	16.10	3.38	12.72
Brookston Clay Loam	26.60	5.74	20.86
Brookston Clay Loam and Muck	34.00	11.76	22.24

TABLE 2: VOLUME OF MOISTURE IN THE VARIOUS

SOILS AND SOIL MIXTURES

Soil	SURFACE WATERED		SUB-IRRIGATION		CONSTANT WATER LEVEL	
	Percent	Average Percent	Percent	Average Percent	Percent	Average Percent
Oshtemo	7.8 9.6	8.7	30.0 26.1	28.0	38.0 42.8	40.4
Oshtemo and Muck	14.9 18.7	16.8	37.0 41.9	39.5	42.8 48.4	45.6
Miami	15.1 17.7	16.4	26.8 26.3	26.6	37.6 35.8	36.7
Wauseon	19.1 21.2	20.2	28.8 30.8	29.8	42.4 42.2	42.3
Brookston Clay Loam	29.4 21.8	25.6	37.7 37.4	37.5	34.9 41.0	38.9
Brookston Clay Loam and Muck	24.1 34.1	29.1	41.7 39.1	40.4	46.9 46.5	46.7

TABLE 3: PERCENT TOTAL PORE SPACE OF THE VARIOUS SOILS AND SOIL MIXTURES ON A VOLUME BASIS

Soil	SURFACE WATERED	Average	SUB-IRRIGATION	Average	CONSTANT WATER LEVEL	Average
Oshtemo	52 50	51.0	40 46	43.0	46 41	43.5
Oshtemo and Muck	55 --	55.0	61 48	54.5	54 59	56.5
Miami	50 --	50.0	51 42	46.5	54 51	52.5
Wauseon	49 --	49.0	51 52	51.5	48 49	48.5
Brookston Clay Loam	56 --	56.0	53 61	57.0	52 58	55.0
Brookston Clay Loam and Muck	58 68	63.0	62 62	62.0	61 64	62.5

TABLE 4: VOLUME WEIGHT OF THE VARIOUS SOILS AND SOIL MIXTURES

Soil	SURFACE WATERED		SUB-IRRIGATION		CONSTANT WATER LEVEL	
		Average		Average		Average
Oshtemo	1.25 1.24	1.24	1.27 1.44	1.36	1.35 1.46	1.40
Oshtemo and Muck	.99 ----	.99	1.06 .96	1.01	1.06 1.05	1.06
Miami	1.13 ----	1.13	1.10 1.19	1.10	1.17 1.19	1.18
Wauseon	1.11 ----	1.11	1.05 1.08	1.06	1.21 1.16	1.18
Brookston Clay Loam	.98 ----	.98	1.15 .99	1.07	.95 .97	.96
Brookston Clay Loam and Muck	.83 1.03	.93	.88 .81	.84	.76 .82	.79

TABLE 5: POROSITY RELATIONSHIPS OF THE VARIOUS SOILS AND SOIL MIXTURES

Soil	TREATMENT	AVERAGE PORE SPACE	AVERAGE MOISTURE IN SOIL	AVERAGE AIR SPACE IN SOIL
		cc per liter	cc per liter	cc per liter
Oshtemo	Surface Watered	510	87	423
Oshtemo	Sub-Irrigated	430	280	150
Oshtemo	Constant Water Level	435	404	31
Oshtemo and Muck	S. W.	550	168	382
"	S. I.	545	395	150
"	C. W. L.	565	456	109
Miami	S. W.	500	164	336
"	S. I.	465	266	199
"	C. W. L.	525	367	158
Wauseon	S. W.	490	202	288
"	S. I.	515	298	217
"	C. W. L.	485	423	62
Brookston Clay Loam	S. W.	560	256	304
"	S. I.	570	375	195
"	C. W. L.	550	385	161
Brookston Clay Loam and Muck	S. W.	630	291	339
"	S. I.	620	404	216
"	C. W. L.	625	467	158

TABLE 6: THE EFFECT OF WATERING ON AGGREGATION OF THE SOILS AND SOIL MIXTURES

Soil	Treatment	AGGREGATE SIZE						
		Over 4mm per-cent	2-4mm per-cent	1-2mm per-cent	.5-1mm per-cent	.25-.5mm per-cent	.125-.25mm per-cent	Less than .125 mm per-cent
Miami	Surface watered	5.28	3.76	3.86	6.20	16.64	25.64	38.62
Miami	Sub-irrigation	2.36	4.18	4.22	6.62	18.10	27.32	37.10
Miami	Constant water level	19.52	3.42	3.22	5.30	16.70	23.66	28.18
Wauseon	S. W.	2.38	2.98	5.60	9.28	19.24	27.84	32.68
Wauseon	S. I.	9.58	3.98	4.16	8.06	20.12	28.86	25.24
Wauseon	C. W. L.	8.18	5.86	5.70	9.68	19.24	25.52	25.82
Brookston Clay Loam	S. W.	0	1.30	2.44	4.78	14.44	15.36	61.68
Brookston Clay Loam	S. I.	3.32	2.38	2.34	5.80	19.94	33.50	32.72
Brookston Clay Loam	C. W. L.	3.76	3.08	2.90	4.72	13.74	24.22	47.58
Brookston Clay Loam and Muck	S. W.	1.38	4.70	5.70	5.22	10.44	20.74	51.82
"	S. I.	19.16	3.82	4.00	4.34	10.86	16.92	40.90
"	C. W. L.	3.38	6.58	5.72	6.14	10.32	17.18	50.68

TABLE 7: NUMBER OF FLOWERS AND PERCENTAGE OF SPLIT CALYXES FROM EACH OF THE VARIOUS SOILS AND SOIL MIXTURES

Soil	SURFACE WATERED				SUB-IRRIGATION				CONSTANT WATER LEVEL			
	No. Blooms		Splits		No. Blooms		Splits		No. Blooms		Splits	
		av.	Per-Cent	av. Per-Cent		av.	Per-Cent	av. Per-Cent		av.	Per-Cent	av. Per-Cent
Oshtemo	134		15		113		8		33		33	
	119	127	26	21	100	107	17	12	30	32	37	35
Oshtemo and Muck	121		21		86		18		91		17	
	98	110	14	18	130	108	23	20	84	88	11	15
Miami	132		17		123		9		113		16	
	120	126	14	16	113	118	19	14	118	116	14	15
Wauseon	133		17		79		10		96		27	
	77	105	10	14	124	102	28	19	105	101	21	24
Brookston Clay Loam	126		14		91		8		134		10	
	120	123	22	18	115	103	19	14	124	129	18	14
Brookston Clay Loam and Muck	98		19		116		19		125		24	
	100	99	14	17	138	127	15	17	143	134	17	20

TABLE 8: VEGETATIVE WEIGHT AT THE TERMINATION OF THE EXPERIMENT FROM THE VARIOUS SOILS AND SOIL MIXTURES

Soil	SURFACE WATERED		SUB-IRRIGATION		CONSTANT WATER LEVEL	
		Average		Average		Average
Oshtemo	4.65 4.45	4.55	4.65 5.80	5.23	1.80 1.15	1.48#
Oshtemo and Muck	4.75 4.35	4.55	4.65 6.60	5.63	5.45 4.35	4.90
Miami	5.05 4.45	4.75	7.55 5.80	6.68	7.40 7.05	7.23
Wauseon	3.85 2.60	3.23	5.15 6.25	5.70	6.35 5.10	7.03
Brookston Clay Loam	4.45 3.65	4.05	5.95 6.35	6.15	6.85 7.20	7.03
Brookston Clay Loam and Muck	3.35 4.20	3.78	5.85 6.95	6.40	6.90 9.05	7.93
AVERAGE		4.15		5.97		6.56

#- Not included in method of watering average.

TABLE 9: AVERAGE FLOWER PRODUCTION PER SQUARE FOOT

ON THE VARIOUS SOILS AND SOIL MIXTURES

Soil	SURFACE WATERED	SUB-IRRIGATION	CONSTANT WATER LEVEL
Oshtemo	21	18	5
Oshtemo and Muck	18	18	15
Miami	21	20	19
Wauseon	18	17	17
Brockston Clay Loam	20	17	22
Brookston Clay Loam & Muck	16	21	22

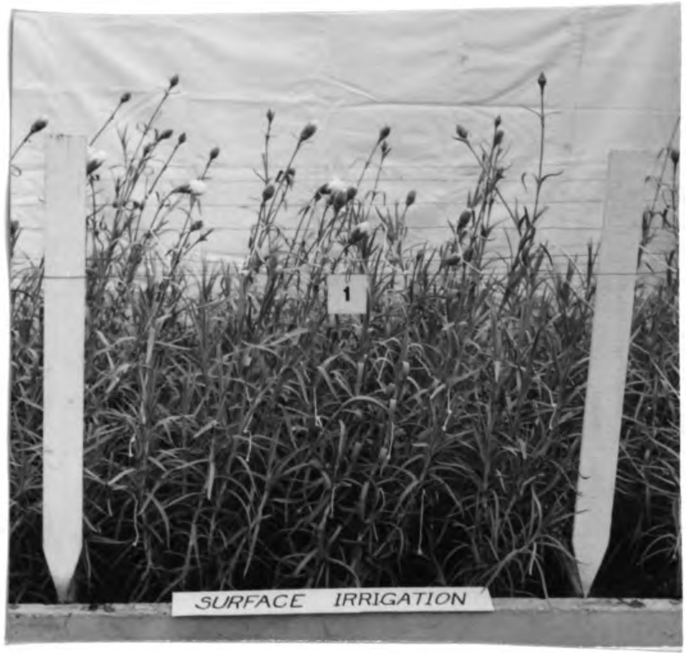


Fig. 1 GROWTH OF CARNATIONS ON OSHTEMO SAND, SURFACE WATERED.

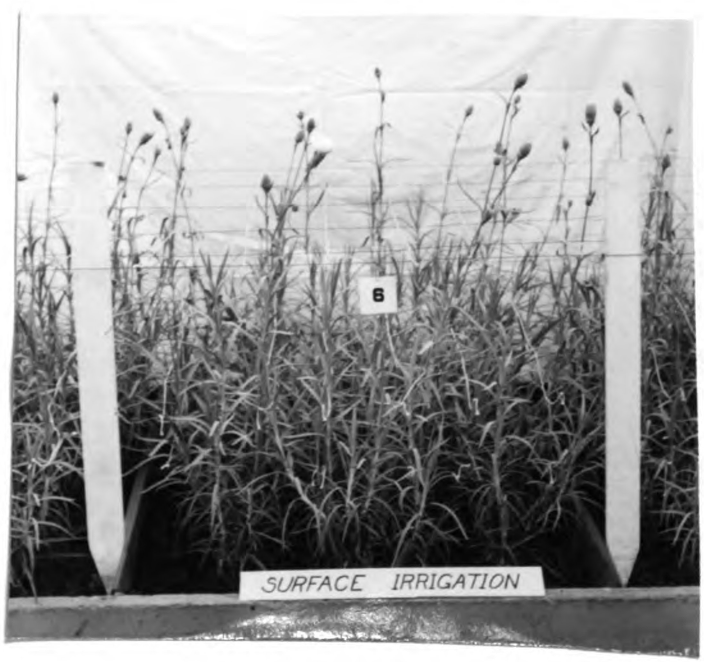


Fig. 2 GROWTH OF CARNATIONS ON BROOKSTON CLAY LOAM AND MUCK, SURFACE WATERED

Fig. 3 GROWTH OF CARNATIONS ON OSHTEMO SAND, SUB-IRRIGATED

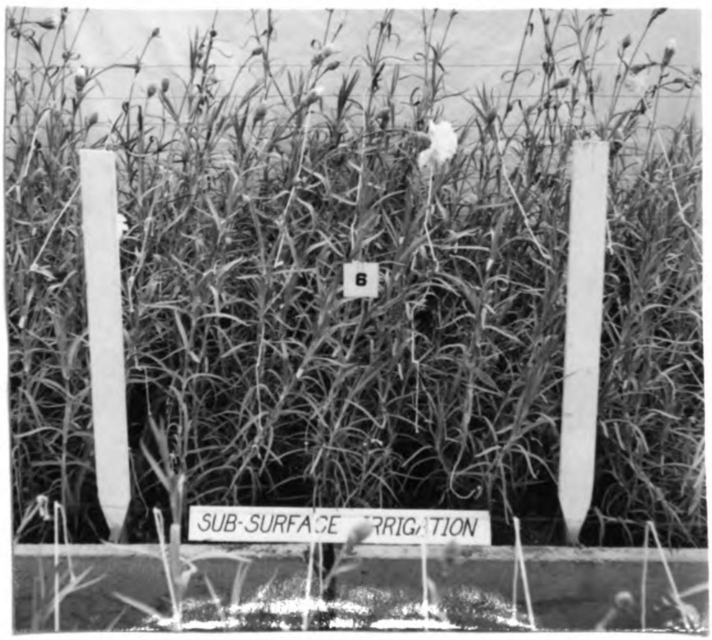


Fig. 4 GROWTH OF CARNATIONS ON BROOKSTON CLAY LOAM AND MUCK SUB-IRRIGATED

Fig. 5 GROWTH OF CARNATIONS ON OSHTEMO SAND, UNDER CONSTANT WATER LEVEL

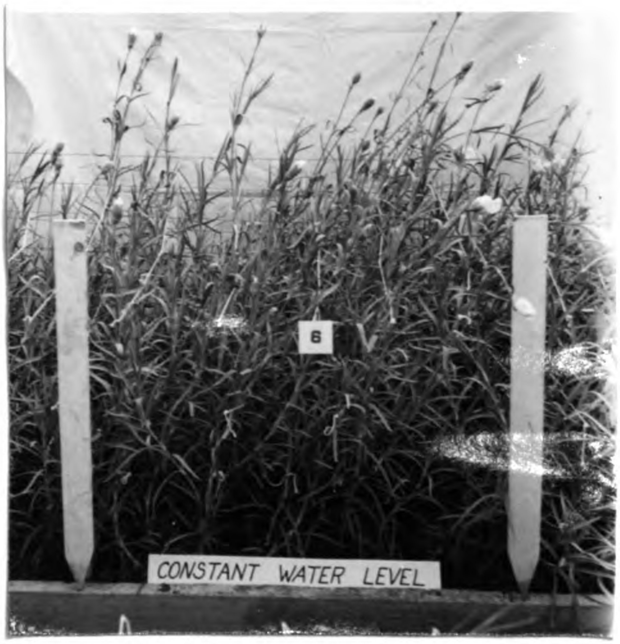


Fig. 6 GROWTH OF CARNATIONS ON BROOKSTON CLAY LOAM AND MUCK UNDER CONSTANT WATER LEVEL

Fig. 7
Accumulation of Aggregates Larger than a Given Size in Miami Soil as Affected by Three Methods of Watering

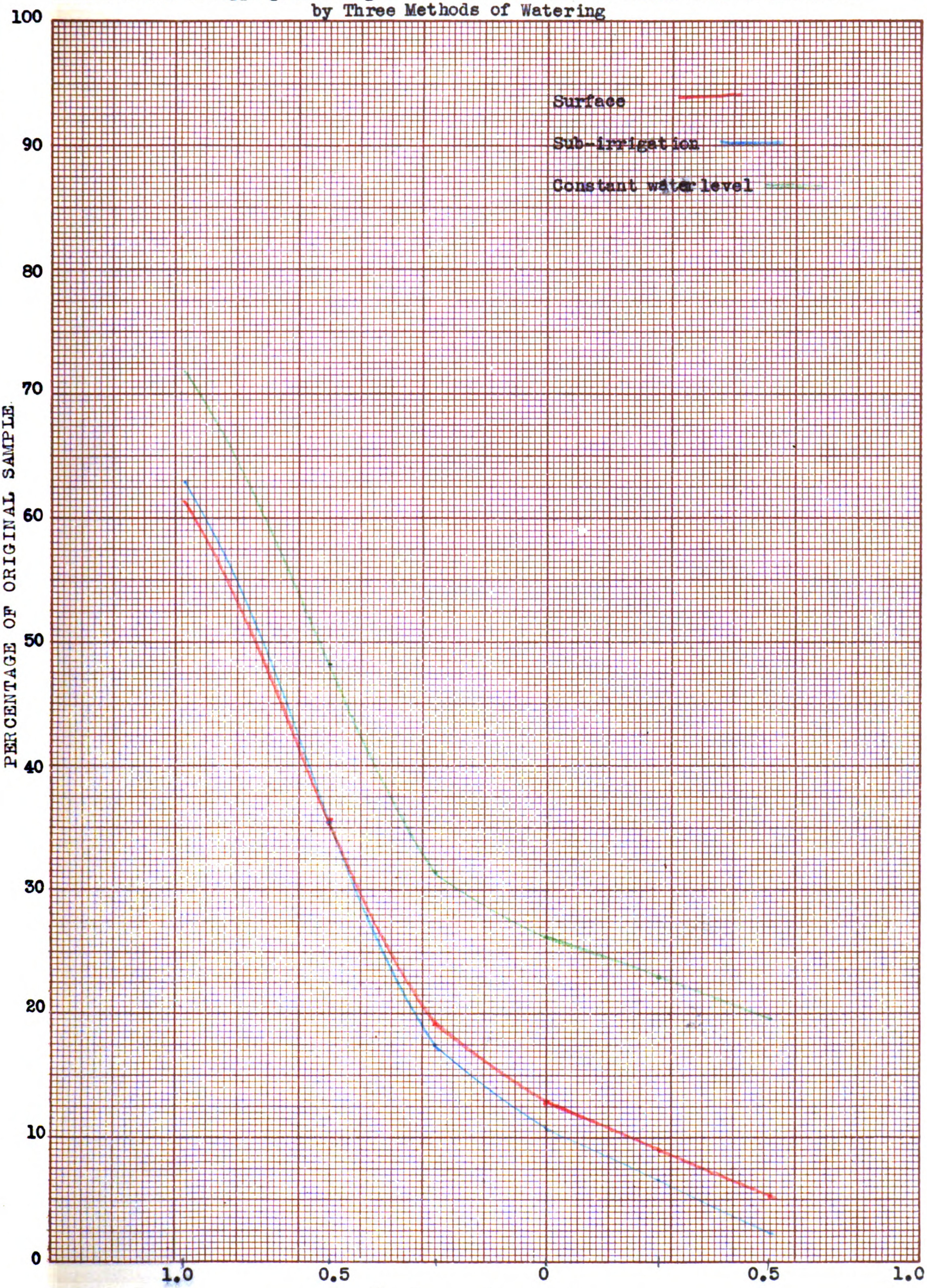


Fig. 8
Accumulation of Aggregates Larger than a Given Size in Wanseon Soil as Affected by three Methods of Watering

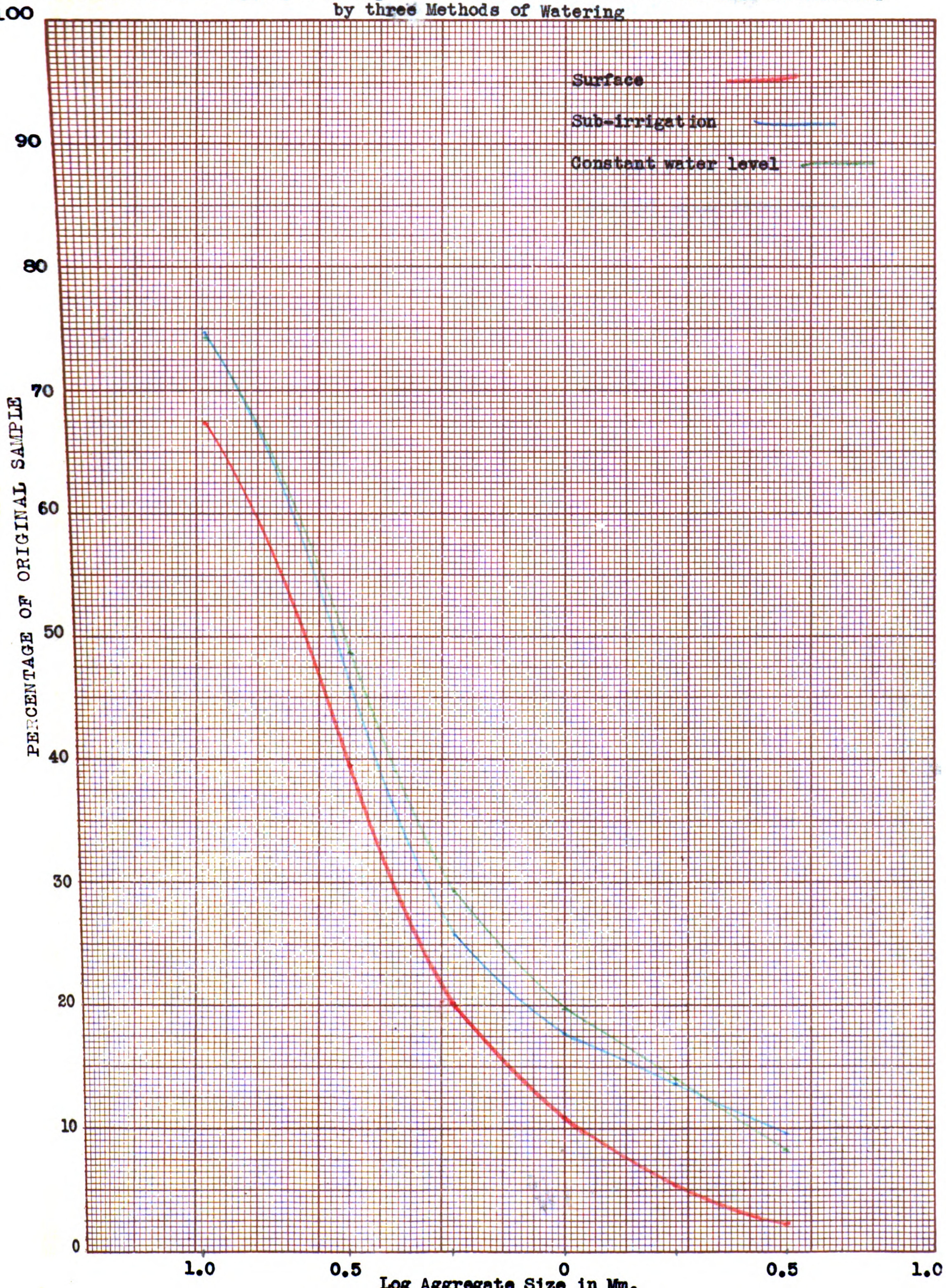


Fig. 9

Accumulation of Aggregates Larger than a Given Size in Brookston Clay Loam as Affected by Three Methods of Watering

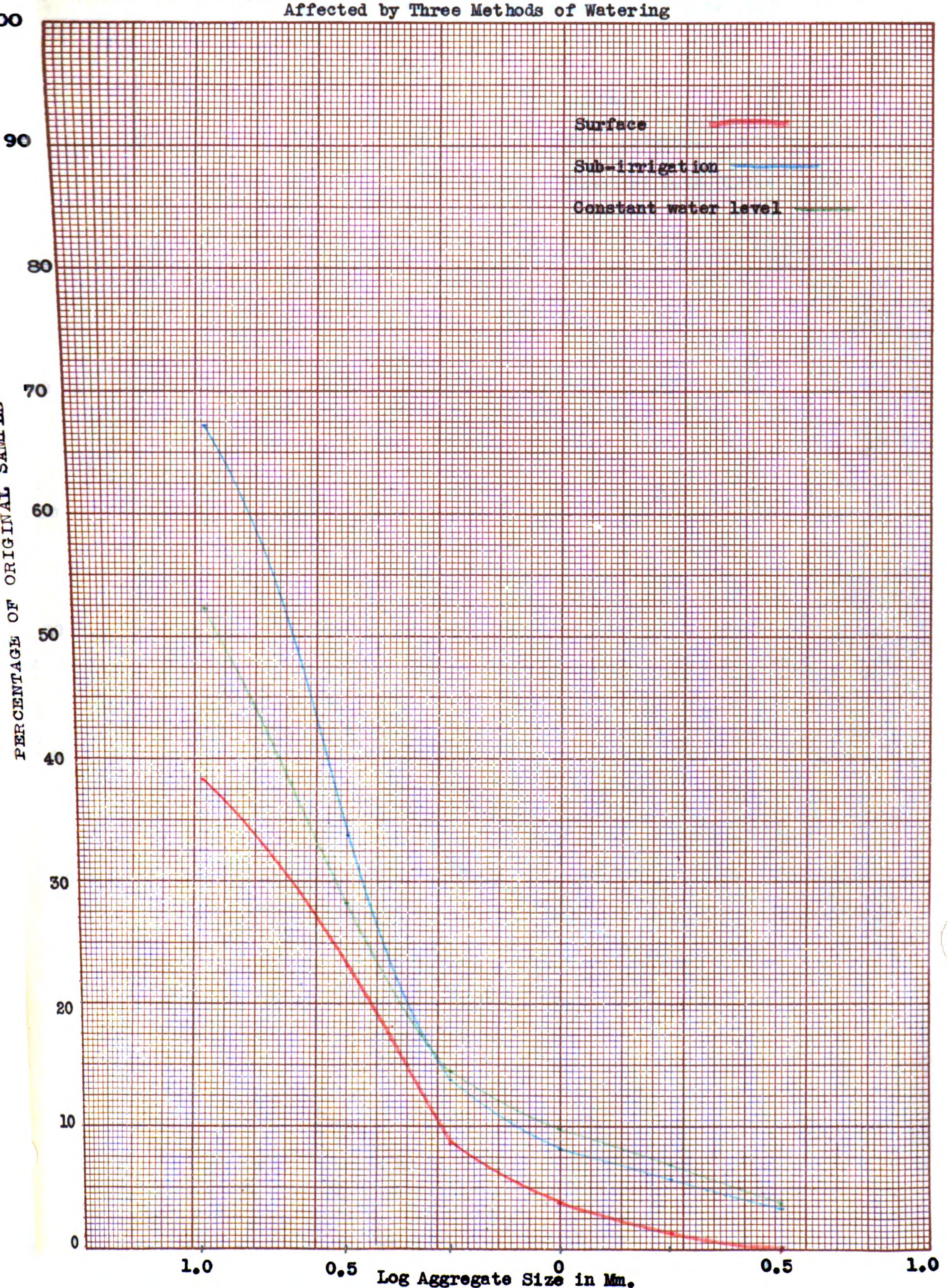
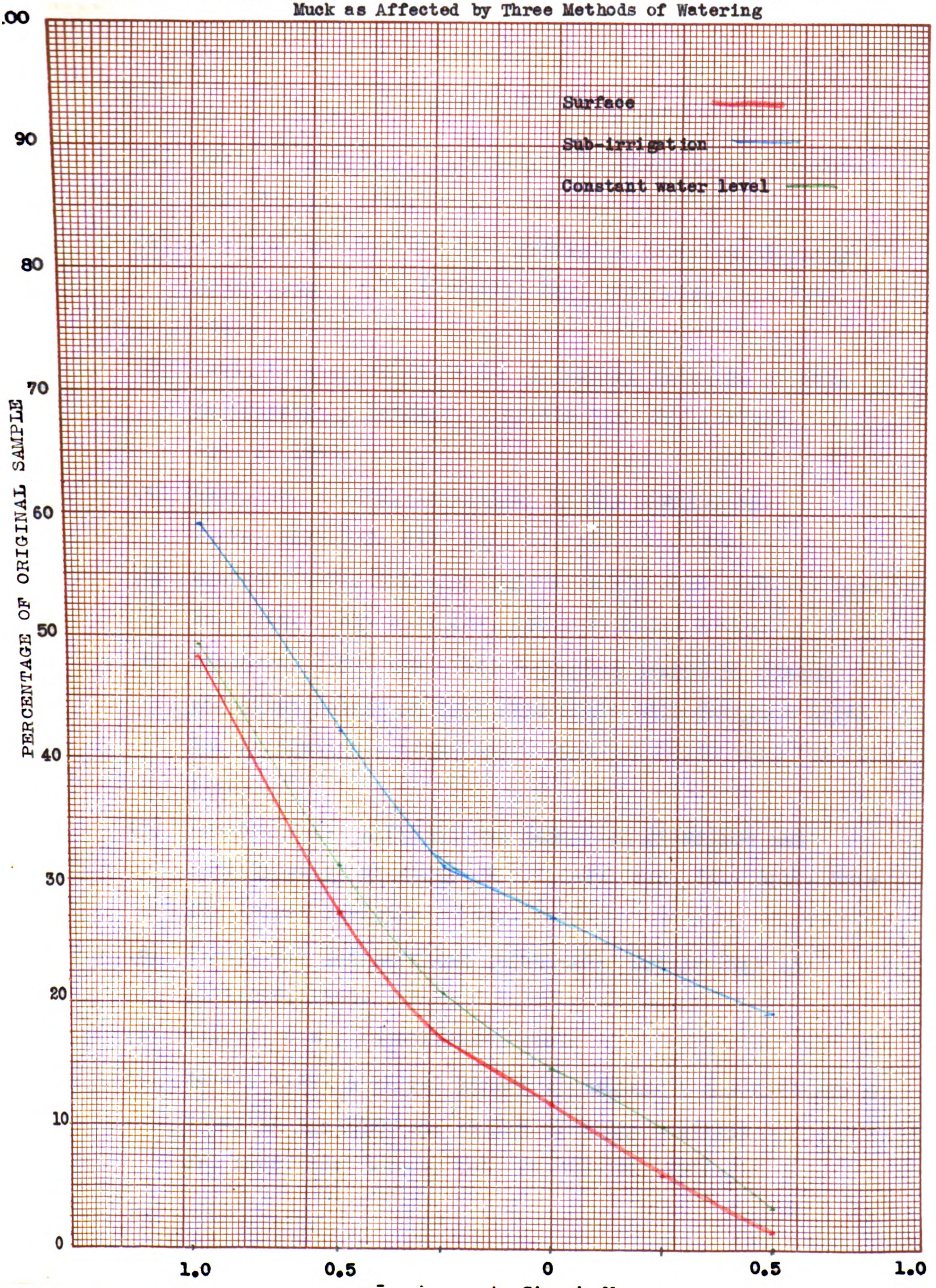


Fig. 10

Accumulation of Aggregates Larger than a Given Size in Brookston Clay Loam and Muck as Affected by Three Methods of Watering



BIBLIOGRAPHY

(1) Post, K. Automatic Watering, N.Y. State Flower Growers' Bul. 7:3-14. 1946.

(2) Post, K. and Seeley, J.G. Automatic Watering of Greenhouse Crops, N.Y. (Cornell) Agr. Exp. Sta. Bul. 793. 1943.

(3) Post, K. and Seeley, J.G., Automatic Watering of Soil in Greenhouse Benches, Florists Rev. 86, 2227:13. Aug. 1, 1940.

(4) Rane, Wm. F., Sub-irrigation in the Greenhouse, W. Va. Agr. Exp. Sta. Bul. 33, 255-270. 1893.

(5) Spurway, C.H., Soil Testing, Michigan State College Agr. Exp. Sta. Tech. Bul. 132, 2nd rev: 1-38. 1938.

(6) Stephens, J.H., and Volz, E.C., The Growth of Stocks and China Asters on four Iowa Soils with Constant Level Sub-irrigation., Proc. Amer. Soc. for Hort. Sci. Vol. 51 1948.

(7) Veatch, J.O., Agricultural Land Classification and Land Types of Michigan. M.S.C. Agr. Exp. Sta. Spec. Bul. 231 (First revision), 1941.

(8) Ward, C.W., The American Carnation. How to Grow it. p. 1-296, 1903.

(9) Wildon, C.E., Unpublished Data.

(10) Yoder, R.E., A direct Method of Aggregate Analysis and a Study of the Physical Nature of Erosion Losses. Jr. Amer. Soc. Agron. Vol. 28:337-351, 1936.