SOIL FACTORS AFFECTING THE GROWTH OF CARNATIONS

By

Jesse Melvin Rawson

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
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Department of Soil Science

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ABSTRACT

An investigation was made of the effect of several soil factors upon the production and growth of greenhouse carnations. The carnation seems to be less responsive to soil differences than other major cut flower crops and consequently has been little studied.

Northland carnations obtained from two sources were grown on three Michigan soils and under three methods of watering. All flowers were cut and graded for a six-month period. Total yields were generally similar but considerable differences were obtained between treatments when commercial or other quality grades were considered separately. Highly significant differences were obtained between plants from the two sources. This was believed to be due largely to differences in culture between time of propagation and time of benching. The clay loam soils produced more commercials and high quality flowers than did a sandy loam soil. Constant water level was the most variable method of watering but produced high quality flowers when plants from a commercial source were used.

Juno and Achilles carnations were grown in two clay loam soils in tiles cut to give five different depths of soil above a water table. Plant measurements included height increases, green weights, number, weights and lengths

of all breaks and bottom breaks and flower and bud counts. Soil measurements included oxygen diffusion studies and moisture determinations at one inch intervals throughout the columns of soil. Four inches of soil above the water table retarded growth of plants in both soils. Growth was similar in the more stably aggregated and better aerated soil when five, six, seven and eight inch soil columns were used. In the less stably aggregated and poorer aerated soil growth improved steadily as depth of soil increased.

Adequate aeration of greenhouse soils perhaps is limiting more often than previously recognized. Heavy watering and use of improper soils and soil mixtures limits soil air. In constant water level work the soil is usually not deep enough in the bench to provide proper aeration in the root zone. Evidence has been presented indicating that the depth of soil in a constant water level bench affects both shoot growth and morphological development of carnations. Improving soil aeration caused an increase in the growth and development of lateral buds with both pinched and unpinched plants. Growth substance produced in the apical tip which inhibits lateral growth may be inactivated by oxygen in the soil or its concentration may be reduced to such an extent that it becomes stimulating.

BIOGRAPHICAL SKETCH

Born, March 1, 1915 on a farm near Quincy, Michigan. Graduated from Quincy High School in 1932 as class valedictorian.

Undergraduate Studies: Freshman College, Coldwater, Michigan (F.E.R.A. sponsored under supervision of Western State Teacher's College, Kalamazoo, Michigan) 1935-36; Hillsdale College, Hillsdale, Michigan, 1936-39, bachelor of science degree in biology and botany, 1939; Michigan State College, 1940, 1946-47, bachelor of science degree in horticulture (floriculture), 1947.

Graduate Studies: Michigan State College, 1947-48, master of science degree in horticulture, 1948; Michigan State College, 1949-51, 1952-53.

Experience: Student manager, College Bookstore, Hillsdale College, 1937-39; field supervisor, nursery and bulb farm, Dowagiac, Michigan, 1940; radio operator, 32nd "Red Arrow" Division, 1941-45, two and one-half years overseas service in Australia and New Guinea; graduate assistant, Horticulture and Soil Science Departments, Michigan State College, 1947-51; extension specialist in floriculture and ornamental horticulture, North Carolina State College, Raleigh, N. C., 1951-52.

Member of Phi Kappa Phi, Pi Alpha Xi, Alpha Zeta.

Recipient of W. Atlee Burpee Award in floriculture, 1947.

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He is also deeply grateful to Dr. C. E. Wildon for his assistance and inspiration throughout his career at Michigan State College. Thanks are due to Dr. A. E. Erickson for his help in preparing and explaining the oxygen diffusion apparatus used in the problem and others who have been of assistance in one way or another.

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I. INTRODUCTION

The carnation (Dianthus caryophyllus), one of the most important greenhouse flower crops, has been a leading commercial cut flower for several centuries. Despite this, there appears to have been considerably less study of the growth and nutrition of this plant than of other leading cut flower crops. It appears to be somewhat less responsive to variations in culture than either the chrysanthemum or the rose. Perhaps the most important environmental factors in the production of carnations are light and temperature. Carnations grow best under conditions of high light intensity and low night temperatures (50 to 55 degrees Fahrenheit). Consequently, present day production centers in Colorado, New England, New York and Pennsylvania where light and temperature approach the optimum.

In southern Michigan the summer temperature is often too high for ideal carnation development and in winter the light intensity is too low. Little can be done economically to alter these two major factors. Nevertheless, because a considerable quantity of carnations are grown in southern Michigan it was decided to study some of those factors which though of secondary importance are more easily controlled. These include soil type, watering methods, soil aeration and nutrition and their effect upon carnation growth and development.

II. REVIEW OF LITERATURE

A. Methods of Watering Greenhouse Bench Crops

Because of increasing production costs and the difficulty of obtaining adequate skilled labor the emphasis in the greenhouse has been and continues to be on labor saving methods of crop production. Various methods of watering have been tried on greenhouse bench crops with the object of reducing labor costs and providing a more uniform water supply. Rane (21) in 1893 and Ward (31) in 1903 discussed subirrigation in the greenhouse. Ward considered subirrigation better than hand watering in the production of carnations as by that method he was able to increase production. Then for a period of forty years subirrigation in the greenhouse was out of favor apparently due to erratic results obtained by various operators. Post and Seeley (20) revived the method and endeavored to learn why it sometimes was not satisfactory. Their findings were published in 1943. They investigated various automatic watering methods such as the use of (1) wicks, (2) injection, (3) constant water level and (4) surface tubes. The first three of these methods are types of subirrigation. Bouyoucos (4) and others have used systems of time clocks, solenoid valves and tensiometers to make the injection and surface tube methods completely automatic.

Stephens and Volz (27) grew China asters and stocks on four Iowa soils in a constant water level bench. Significantly better flowers were produced on the three soils having over five percent organic matter compared to the fourth soil which contained only two percent organic matter. The higher organic matter was said to give better soil aeration due to increased aggregation.

Wright and Volz (34) compared constant water level subirrigation, subirrigation by injection, Ohio State nozzle, and surface watering with a hose on two varieties of roses and concluded that constant water level subirrigation produced significantly more salable blossoms and a significantly longer average stem length over a one year period than did the other three treatments.

Seeley (23) compared surface watering and constant water level on roses for three years on a sandy loam, a silty clay loam and a clay loam. There were no significant differences the first year even at the 5% level between the two methods of watering. The following two years the surface watered sandy and silty clay loams produced a significantly greater number of flowers than did the same soils under constant water level, three of the differences being significant at the 1% level.

B. The Effect of Aeration on Root and Shoot Growth

Soil moisture affects root growth not only directly, but also indirectly, because it affects soil aeration. Kramer (12) stated that larger root systems are produced in soil that contains an abundance of moisture if aeration is adequate but a limited supply of water produces a larger ratio of roots to shoots.

Cannon and Free (6) made an extensive study of the relation of soil aeration to the physiological features of roots with several plant species and concluded that there were optimum concentrations of oxygen for root growth which may vary for different species and should be related to definite temperatures. They stated at that time that little had been done on the effect of aeration upon shoot growth.

Soil aeration is largely a function of the larger non-capillary pores which are determined by the soil texture, structure and aggregate stability. The non-capillary pores act as the arteries for the flow of most of the soil water and soil air. Buckingham (5), Penman (18) and others have established the fact that diffusion is the most important process causing interchange of gases between the soil atmosphere and the air above the soil.

Gilbert and Shive (11) obtained increased growth of oats and tomato with increased oxygen concentration to the highest concentration used which was twice that of the atmosphere.

They concluded that the oxygen concentration occurring naturally even in well-aerated, fertile soil was not high enough for the best growth of some plants.

Durell (9) grew tomato plants in shallow nutrient solution tanks having varying degrees of aeration and also in a tank of sandy loam soil. He obtained greater vegetative growth and greater yield of fruit in even slightly aerated cultures than in the well-drained soil. Slight aeration yielded optimum growth of roots and greatest fruit yields but the greatest dry weight of stems and leaves were obtained at the highest rate of aeration. He concluded that for tomato the aeration requirement for optimum shoot growth was much higher than for optimum root and fruit development.

Lawton (13) working with corn and Smith and Cook (25) with sugar beets reported increased shoot growth when additional aeration was supplied to the roots of plants grown in jars of soil in the greenhouse. Arnon and Hoagland (1) found that tomato plants growing in aerated solutions absorbed greater quantities of all nutrients and produced larger yields of fruit than did plants growing in unaerated solutions. It has been established by these investigators and others that proper soil aeration increases root and shoot growth and increases both water and nutrient uptake. This, however, is specific and the optimum aeration for one species may be suboptimum for another species.

Beach (3) reported that carnations grown under very wet conditions appeared better than those under average moisture or dry conditions during growth but final yields were not significantly different. Van Laan and Cook (30), however, working with Puritan carnations obtained greatly decreased growth and yields under high moisture conditions.

If a soil is of such texture and structure that the diffusion rate of the air into and out of the soil is greatly retarded another condition occurs. In this case the oxygen concentration is reduced and the carbon dioxide concentration may be greatly increased due to the respiration of living roots and soil microorganisms, the decay of organic material and the decreased rate of movement of the soil atmosphere. There has been considerable disagreement in the past whether under these conditions root injury was due to low oxygen or high carbon dioxide concentrations. It would appear from the recent work of Leonard (16), Leonard and Pinckard (17) and Erickson (10), however, that carbon dioxide levels are seldom high enough in the soil to cause root injury but that the oxygen concentration is often too low for optimum root growth.

C. Hormone Theory and the Possible Relation of Aeration

Growth by cell extension takes place almost exclusively by the absorption of water according to Audus (2). Further, it is now widely accepted that there is no growth without growth substance.

Thimann and Skoog (29) showed that auxin produced in the apical buds mainly by young leaves was responsible for the inhibition of axillary buds. Dormant axillary buds produce almost no auxin but production begins as soon as they begin to develop. They found in Vicia faba that the amount of auxin diffusing from the terminal bud decreased with increased size of the plant. Also, that two factors were concerned in the development of axillary buds, namely, hormone control and the supply of nutritive material.

Thimann (28) found that auxin effects were dependent at least in part on concentration of the hormone, relatively low concentrations increasing growth and relatively high concentrations inhibiting growth.

Shrank (24) stated that the inactivation of indoleacetic acid, a universally occurring growth hormone, is apparently a first order reaction requiring oxygen.

Reinders (22) found that water absorption by potato slices in distilled water was very sensitive to aeration. Water absorbed under aerobic conditions was lost when the potato slices were transferred to anaerobic conditions. Addition of beta-indoleacetic acid to the medium surrounding the slices greatly increased the water absorption. Commoner and Mazia (7) confirmed the findings of Reinders and also observed that potassium chloride uptake was increased when beta-indoleacetic acid was added to the medium. It has not been proven, however, that the auxin-water-salt relationship obtained for slices of potato tuber apply in general to the growth of entire plants.

Went (33) increased the growth rate of tomato and cosmos by dividing the roots in half and placing half of them in a nutrient solution and half of them in moist peat, Haydite or sand over the rate obtained when the entire root system was placed in an aerated nutrient solution. Root growth was satisfactory in either case but maximal stem development required that a portion of the roots develop in moist air. He concluded that roots which develop in moist air supply one or more factors required for stem growth. This factor he termed caulocaline. He postulated that caulocaline produced in the aerated roots flows upward in the stem and accumulates near the place of auxin production. Removing the tip of the apical shoot or otherwise inactivating it causes lateral buds with their slight auxin production to divert caulocaline and grow.

In greenhouse practice lateral buds are forced into growth in carnation, and other plants as well, by pinching out the tip of the apical shoot. Sometimes the tips of the first laterals are also pinched out to develop several branches and therefore several flowering shoots on each plant.

III. EXPERIMENTAL

A. The Effect of Three Watering Methods and Three Soils on Carnation Yields and Quality

Experimental methods and design. A greenhouse experiment was begun in September 1949 to determine the effect of three soils and three methods of watering upon the production of greenhouse carnations. Three new V-bottom concrete benches each 48 feet long and 40 inches wide were used. Each bench was partitioned into six equal plots. In the first and third benches the partitions were of one inch wood cut to fit but were not water-tight. In the second bench the partitions were of brick sealed to make each compartment water-tight. A row of bench tile was placed over the V in the bottom of each bench to facilitate drainage in the second and third benches and to aid in the movement of water in the first and second benches. A layer of gravel was placed in the bottom of the bench to just cover the bench tile and one inch of coarse sand was placed over the gravel. The top layer consisted of five inches of soil.

Figure I shows the bench arrangement as regards watering methods and soil plots. The soils were randomized in each half of each bench giving two replicated blocks in each of three locations (benches) for a total of six blocks.

Figure I. Diagram of the arrangement of benches and soil plots

tank & float Grassed Brookston	Oshtemo sandy loam	Cropped Brookston	Grassed Brookston	Cropped Brookston	Oshtemo sandy loam

Bench I Constant Water Level

Oshtemo sandy loam	Grassed Brookston	Cropped Brookston	Oshtemo sandy loam	Cropped Brookston	Grassed Brookston

Bench II Subirrigation

Oshtemo sandy loam	Cropped Brookston	Grassed Brookston	Cropped Brookston	Oshtemo sandy loam	Grassed Brookston

Bench III Surface Watered

Bench I was provided with a small tank and a float in one end to automatically control the water level. The water level was held constant in the lower half of the sand layer. Bench II was provided with a drainage hole in each water-tight compartment. Each hole was threaded and provided with pipe and elbows so that water could be injected into the bottom of the bench. When the main arm of pipe was vertical the top of the pipe was level with the surface of the soil in the bench. By inserting the hose into the pipe each plot was watered from below until the surface soil was moist. Excess water was immediately drained away by turning the vertical pipe arm down below the horizontal. The bench was constructed so that the drainage holes in the four center plots were in the lowest part of the compartment but the drainage hole in each end plot was in the end of the bench somewhat above the lowest point. Bench III was set up for normal hand watering, called surface watering in this experiment. The drainage holes were all continuously open in this bench. At each watering, water was applied by hose until the soil was wetted and water drained freely.

Three soils were used in each bench. They were twice replicated and arranged randomly as shown in Figure I. Oshtemo sandy loam was used as representative of a light sandy soil and Brookston clay loam as a heavy type soil. Two forms of Brookston clay loam differing in past history and present organic matter content and state of physical aggregation were used and were designated as grassed Brookston and cropped Brookston. Both Brookston soils were obtained near Britton, Michigan from the Stanley Wood farm. The cropped Brookston soil was taken from a field having a history of continuous corn for several years. The grassed Brookston soil was from an adjoining pasture said to have been in sod for many years.

The percent organic matter as determined by the dry combustion method was as follows: Grassed Brookston, 6.12%; cropped Brookston, 4.73%; Oshtemo sandy loam, 1.28%.

The aggregate stability of the Brookston soils as determined by the Yoder method (35) is given in Tables 32 and 33 of the appendix. The first entry under each soil is the aggregate analysis of the original soil before it was placed in the greenhouse benches.

Lime was added to the Oshtemo sandy loam plots at the rate of five pounds per hundred square feet of bench and superphosphate (0-20-0) was applied at this same rate to all plots. After the plants were well established a program of soil testing was begun using the Simplex testing method developed by Spurway and Lawton (26). An attempt was made to maintain the following levels as recommended by Post (19): 50 parts per million of nitrate nitrogen, 5 parts per million of phosphorus and 20 parts per million of potassium (K_2O).

Soil tests were made at six to eight week intervals and ammonium nitrate and potassium chloride were added in solution whenever tests showed that nutrient levels had dropped below the minimums stated above.

After the lime and superphosphate had been worked into the soil sixty carnation plants were planted in each plot. The plants were spaced eight inches apart both lengthwise and across the benches. Two varieties were used, Northland, a standard white variety, and Victory Red. Each plot contained 45 Northland and 15 Victory Red plants. The Northland plants were obtained from two sources. The first 20 Northland plants (four rows) in each plot were obtained from Guy Munt, a commercial carnation grower of St. Clair, Michigan. The next 25 Northland plants (five rows) were field grown during the summer of 1949 on the Michigan State College horticultural farm. The 15 Victory Red plants in each plot were also grown on the college farm.

The plants were supported by wires lengthwise of each bench and by strings crosswise between the plants according to standard practice. Disbudding was done as needed in order to produce one flower per stalk.

The night temperature was kept at 50 degrees Fahrenheit during the winter by means of thermostatic controls that regulated the ridge ventilators as well as the heat inflow. In warm weather the side vents were also opened.

Red spider mites and aphis were controlled with parathion applied by means of an aerosol "bomb".

No cultivating was done. Removal of a few weeds constituted the only soil disturbance during the experiment except for possible changes due to watering.

From December 1 to June 22 all blooms were cut and graded according to the Cornell grading system suggested by Post (19). This system classifies the commercial grade flowers as follows:

GRADES	WEIGHT (OZ.)	MINIMUM STEM LENGTH (INCHES)
Special	1 and over	24
Fancy	3/4 to 1	24
Extra	1/2 to 3/4	18
No. 1	1/4 to 1/2	12
No. 2	Less than 1/4	12

All other flowers were classified as rejects of little commercial value and were subdivided into (1) "shorts", good flowers having stems less than twelve inches in length, (2) "splits" having split calyces and (3) culls of no value. Actually the shorts and splits would be used by a retail grower in his own shop but would usually not find ready sale otherwise.

On June 22 the plants in each plot were cut at the soil surface and green weights of the tops were recorded. Soil samples were also taken at that time. Moisture determinations were made at three depths in each plot of the constant water level bench. Aggregate analyses were made at two depths in each plot containing the Brookston clay loams using the Yoder method (35). The results were compared with those obtained from samples of the original soil. The Oshtemo sandy loam soil was not considered to be aggregated.

Discussion of results. From the time flowering began it was apparent that the variety Victory Red was of poor quality and badly mixed with Miller's Yellow. Accordingly, the decision was made to keep records on the variety Northland and leave Victory Red principally as a boundary marker between plots.

Total monthly yields, the number of commercial grade flowers and the number of rejects by months for the variety Northland and also the percent of each month's yield composed of commercial grade flowers and rejects are given in Table 1. Good yields were obtained throughout the season with peak production occurring in January and May. Over the entire experiment 18.5% of the total yield were of low quality.

It was decided to end the data on May 31 as this gave six full months yield and ended production after Memorial Day as is often done commercially. Therefore, Table 1 and all yield tables and figures which follow are based upon the production data for the six month period, December 1, 1949 to June 1, 1950.

TABLE 1

MONTHLY PRODUCTION OF NORTHLAND CARNATIONS

	Commercial Grade		Rejects		
Month	Number	Per Cent of Monthly Yield	Number	Per Cent of Monthly Yield	Total Monthly Yield
December	619	73.7	221	26.3	840
January	1315	81.6	297	18.4	1612
February	877	84.7	159	15.3	1036
March	666	77.5	193	22.5	859
April	752	82.2	163	17.8	915
May	1464	84.9	261	15.1	1725
Total	5693	81.5	1294	18.5	6987

Table 2 shows that in terms of all flowers cut soil type was of little importance. When watering methods are considered surface watering seems to be somewhat better than constant water level. Statistically, however, there were no significant differences either between soils or between watering methods.

The picture changes somewhat when only commercial grade flowers are considered, as in Table 3. In this case a difference is noted favoring both of the Brookston clay loam soils over the Oshtemo sandy loam. The differences in yield due to watering methods show that the constant water level bench yielded the fewest commercial flowers while the other two methods were nearly equal. These differences are significant statistically at the 5% level.

The Oshtemo sandy loam plots in the constant water level bench yielded the least flowers as shown in Tables 2 and 3. Van Laan and Cook (30) obtained an even greater depression in yield under similar conditions with the variety Puritan. They obtained only five flowers per square foot of bench but did not state the length of the cutting period nor whether this value was total yield or only commercial yield. They attributed the depression in yield to lack of soil aeration but this does not seem to be the entire explanation in view of the results obtained in this experiment between plants from two sources. This point will be developed later.

TABLE 2

INFLUENCE OF THREE SOILS AND THREE METHODS OF WATERING ON TOTAL FLOWER PRODUCTION

Watering Method	Soil: Grassed Brookston	Cropped Brookston	Oshtemo Sandy Loam	Total	Mean
Constant Water Level	739	770	709	2218	739
Subirrigation	789	752	809	2350	783
Surface Watered	828	769	822	2419	806
Total	2356	2291	2340	6987	
Mean	785	764	780		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	8	26,132		
Soils	2	765	382.5	0.08
Watering Methods	2	6,954	3,477.0	0.76
Error	4	18,413	4,603.3	

TABLE 3

INFLUENCE OF THREE SOILS AND THREE METHODS OF WATERING ON COMMERCIAL FLOWER PRODUCTION

	Soil				
Watering Method	Grassed Brookston	Cropped Brookston	Oshtemo Sandy Loam	Total	Mean
Constant Water Level	624	603	520	1747	582
Subirrigation	677	636	643	1956	652
Surface watered	702	678	610	1990	663
Total	2003	1917	1773	5693	
Mean	668	639	591		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	8	23,108		
Soils	2	9,003	4,502	7.03*
Watering Methods	2	11,543	5,772	9.01*
Error	4	2,562	640.5	

*LSD at 5% level is 30.6

Differences in quantities of flowers produced under the different treatments were nominal in most instances except for the cases cited above. However, because quality is also very important in flower production, quality differences between the various treatments were analyzed using the Cornell grading system previously described. Further, plants obtained from Munt were compared with those grown at the college and the replications were examined for possible differences. Table 4 classifies the yield data by plant source, by treatment, and by grade. Each value is the sum of two replications. Originally it had been planned to use only plants from the college farm. However, as there were too few of these it became necessary to obtain enough plants from an outside source to fill the benches. Due to the difference in number of plants from each source in each plot some adjustments were necessary in order to compare the Munt carnations with the MSC carnations.

In Table 5 the data is expressed in percent of total yield in each grade of the plants from each source. The superiority of the Munt carnations becomes at once apparent. The plants from the two sources were grown side by side in each plot and after benching were subjected to exactly the same treatments. At the time of benching the plants appeared to be of comparable size and quality. The quality differences shown in the table may have been due largely to a difference in cultural treatment from the time of propagation to the

TABLE 4

TOTAL YIELD OF NORTHLAND CARNATIONS, DEC. 1, 1949 TO JUNE 1, 1950 CLASSIFIED BY PLANT SOURCE, BY TREATMENT AND BY GRADE

MUNT NORTHLAND

Watering Method	Soil	Commercials							Rejects				Total Yield
		Spec.	Fancy	Extra	Spefex*	No. 1	No. 2	Sum	Short	Split	Cull	Sum	
I CWL	Grassed Brookston	10	47	144	201	97	3	301	5	24	1	30	331
	Cropped Brookston	12	43	110	165	95	6	266	4	32	0	36	302
	Oshtemo Sandy L.	15	51	139	205	116	9	330	10	35	2	47	377
	Sum	37	141	393	571	308	18	897	19	91	3	113	1010
II SI	Grassed Brookston	33	77	113	223	103	6	332	1	25	1	27	359
	Cropped Brookston	28	65	152	245	88	5	338	2	23	0	25	363
	Oshtemo Sandy L.	9	45	110	164	143	8	315	9	37	0	46	361
	Sum	70	187	375	632	334	19	985	12	85	1	98	1083
III SW	Grassed Brookston	30	88	126	244	115	2	361	2	18	0	20	381
	Cropped Brookston	9	82	147	238	104	6	348	2	13	0	15	363
	Oshtemo Sandy L.	6	36	85	127	159	27	313	26	34	1	61	374
	Sum	45	206	358	609	378	35	1022	30	65	1	96	1118
	Total Yield	152	534	1126	1812	1020	72	2904	61	241	5	307	3211

TABLE 4 (Cont.)

MSC NORTHLAND

		Commercials							Rejects				
Watering Method	Soil	Spec.	Fancy	Extra	Spefex*	No. 1	No. 2	Sum	Short	Split	Cull	Sum	Total Yield
I CWL	Grassed Brookston	16	47	82	145	155	23	323	22	59	4	85	408
	Cropped Brookston	9	27	71	107	199	31	337	39	88	4	131	468
	Oshtemo Sandy L.	18	15	42	75	104	11	190	87	49	6	142	332
	Sum	43	89	195	327	458	65	850	148	196	14	358	1208
II SI	Grassed Brookston	6	30	39	75	207	63	345	39	44	2	85	430
	Cropped Brookston	14	21	31	66	184	48	298	31	59	1	91	389
	Oshtemo Sandy L.	8	43	58	109	187	32	328	66	45	9	120	448
	Sum	28	94	128	250	578	143	971	136	148	12	296	1267
III SW	Grassed Brookston	17	34	40	91	206	44	341	38	66	2	106	447
	Cropped Brookston	14	49	55	118	185	27	330	40	34	2	76	406
	Oshtemo Sandy L.	3	52	54	109	150	38	297	104	41	6	151	448
	Sum	34	135	149	318	541	109	968	182	141	10	333	1301
	Total Yield	105	318	472	895	1577	317	2789	466	485	36	987	3776

*A term coined to represent the three highest grades (SPEcial, Fancy, EXtra) combined into one value

TABLE 5

PERCENT OF TOTAL FLOWER YIELD FOR EACH SOURCE ACCORDING TO GRADE

Source	Grade										
	Special	Fancy	Extra	Spefex	No. 1	No. 2	Commercial	Shorts	Splits	Culls	Rejects
Munt	4.7	16.6	35.1	56.4	31.8	2.2	90.4	1.9	7.5	0.2	9.6
MSC	2.8	8.4	12.5	23.7	41.8	8.4	73.9	12.3	12.8	1.0	26.1

time of benching although the possibility of disease in the MSC stock can not be overlooked. Unfortunately, at the time of the investigation the disease factor was not investigated.

Reduction of all data to "yield per square foot of bench" provides the most satisfactory way of comparing the data and is used in the tables which follow. In addition, yield per square foot of bench is a measure commonly used and understood by commercial growers. As the spacing between plants was 8 x 8 inches there were 2.25 plants per square foot of bench.

Data for each grade and statistical analyses are given in Tables 20 through 30 of the appendix. Differences are summarized in Tables 6, 7, 8 and 9. Table 6 shows the sources of variance that are statistically significant for each grade. The most consistent differences were between the Munt and MSC plants. Soils and watering methods were more important for some grades than for others. Interactions were also significant in some cases. The highly significant difference between replications in total flowers was due almost entirely to low yields of the MSC plants in Bench III, replication 1, on all three soils.

Flower yields for each grade on each soil are summarized in Table 7. Soil differences did not affect the total yield but did have a significant effect on five grades or combinations of grades. The grassed Brookston clay loam produced

TABLE 6

SUMMARY OF ANALYSES OF VARIANCE

	SOURCES OF VARIANCE							
Grade	Soils	Replications	Benches	Soils x Benches	Sources	Soils x Sources	Benches x Sources	Soils x Benches x Sources
Total		**	**					
Commercial	*		**		**			
Special					*			
Fancy	*		**		**	*		**
Extra					**			*
Spefex	**			**	**	*		**
No. 1			*		*	*		
No. 2					**	**	*	
Rejects	**			*	**			
Splits			*	*	**	*		
Shorts	**	*			**			

*Significant at 5% level
**Significant at 1% level

TABLE 7

THE INFLUENCE OF SOIL TYPE ON FLOWER YIELD PER SQUARE FOOT OF BENCH FOR EACH GRADE

Soil	Grade											
	Special	Fancy	Extra	Spefex	No. 1	No. 2	Commercial	Shorts	Splits	Culls	Rejects	Total Yield
Grassed Brookston	0.98	** 2.82	4.80	** 8.60	7.21	1.08	** 16.89	0.82	1.90	-	2.79	19.68
Cropped Brookston	0.81	2.51	5.01	** 8.26	6.95	0.96	16.16	0.90	2.00	-	2.95	19.12
Oshtemo Sandy Loam	0.50	2.06	4.29	6.85	7.23	1.02	15.10	** 2.35	2.01	-	** 4.54	19.64

significantly more commercial, fancy and spefex grade flowers than did the Oshtemo sandy loam. The Oshtemo sandy loam produced more shorts and rejects than did either Brookston soil. Yields from the cropped Brookston clay loam were intermediate so that in only one grade (spefex) were yields significantly greater than from the Oshtemo sandy loam. Conversely, they were not significantly lower than from the grassed Brookston clay loam in any grade. This summary combines both sources of plants so differences between sources on the three soils can not be distinguished. By referring to the tables in the appendix it will be noted that the Munt and MSC plants did not always respond to soil differences in the same manner. This was especially noticeable in the constant water level bench. The Munt plants in this bench yielded well on the Oshtemo sandy loam soil including highest total yield, most commercials, specials, fancys, spefexes, No. 1's, No. 2's, and also most rejects and splits. The MSC strain on Oshtemo sandy loam soil in the same bench produced the lowest total yield, least commercials, fancys, extras, spefexes, No. 1's, No. 2's and most rejects.

Table 8 summarizes flower yield for each watering method for each grade. Here again the Munt and MSC plants are combined. Among watering methods, subirrigation by injection and surface watering were both significantly better than constant water level at the 1% level. The constant water level

TABLE 8

THE INFLUENCE OF WATERING METHODS ON FLOWER YIELD PER SQUARE FOOT OF BENCH FOR EACH GRADE

Watering Method	Grade											
	Special	Fancy	Extra	Spefex	No. 1	No. 2	Commercial	Shorts	Splits	Culls	Re-jects	Total Yield
Constant Water Level	0.75	1.99	5.15	7.81	6.32	0.66	14.79	-	2.33*	-	3.75*	18.53
Subirrigation	0.87	2.46	4.48	7.80	7.47*	1.25*	16.52**	-	1.91	-	3.14	19.66**
Surface Watered	0.68	2.94**	4.47	8.10	7.60*	1.15	16.84**	-	1.67	-	3.40	20.24**

bench was least productive yet the yield of the Munt plants on the Oshtemo sandy loam and the MSC plants on the cropped Brookston clay loam in this bench ranked very high (second and third over the entire experiment). Lowest yields over the entire experiment were also found in the constant water level bench. For the Munt plants lowest production occurred on the cropped Brookston clay loam, and for the MSC plants lowest production occurred on the Oshtemo sandy loam. Thus greatest variation in yields occurred under the constant water level method of watering. The constant water level bench yielded the most rejects and splits and the Oshtemo sandy loam produced the greatest number of rejects and splits in this bench with both Munt and MSC plants. Differences between subirrigation by injection and surface watering were generally not significant although surface watering gave slightly higher yields in several grades than did subirrigation by injection. Based on these data subirrigation by injection appears to be the most practical method of watering carnations because it resulted in good yields, less variability and would require less labor than surface watering.

Theoretically, the constant water level method of watering a greenhouse bench should be the most economical to operate after the benches are once installed. In practice, however, this system is often unsatisfactory and has been tried and abandoned by many operators. The reasons for failure are not always evident but often appear to be related to unfavorable air-water relationships in the soils used. Figure II shows that with constant water level the Oshtemo sandy loam was very wet even in the top inch while the Brookston soils varied considerably in moisture content from top to bottom of the soil layer. If aeration is a limiting factor for carnation production in this type of bench, a sandy soil such as Oshtemo sandy loam would presumably depress yields. In order to graph these data, soil samples were assumed to have been taken from the midpoint of the depth class although this was not actually the case. As shown in Table 9 the greatest variation between replications occurred at the one to two inch depth and may have been due to errors in sampling.

Table 10 presents the commercial yields by months for each source on each soil. If each month's production is added to the previous yields cumulative yields can be expressed by a graph as in Figure III. This emphasizes the fact that the MSC plants were more strongly influenced quantity-wise by the soil than were the Munt plants.

Table 11 shows commercial yields by months for Munt and MSC plants in each bench. Cumulative yields are graphed in Figure IV. It is noted that the method of watering had little effect upon the Munt plants until May when cumulative yields from subirrigation by injection and surface watering both surpassed the cumulative yield obtained in the constant water level

Figure II. Moisture percentages of three soils taken at three depths in the constant water level bench

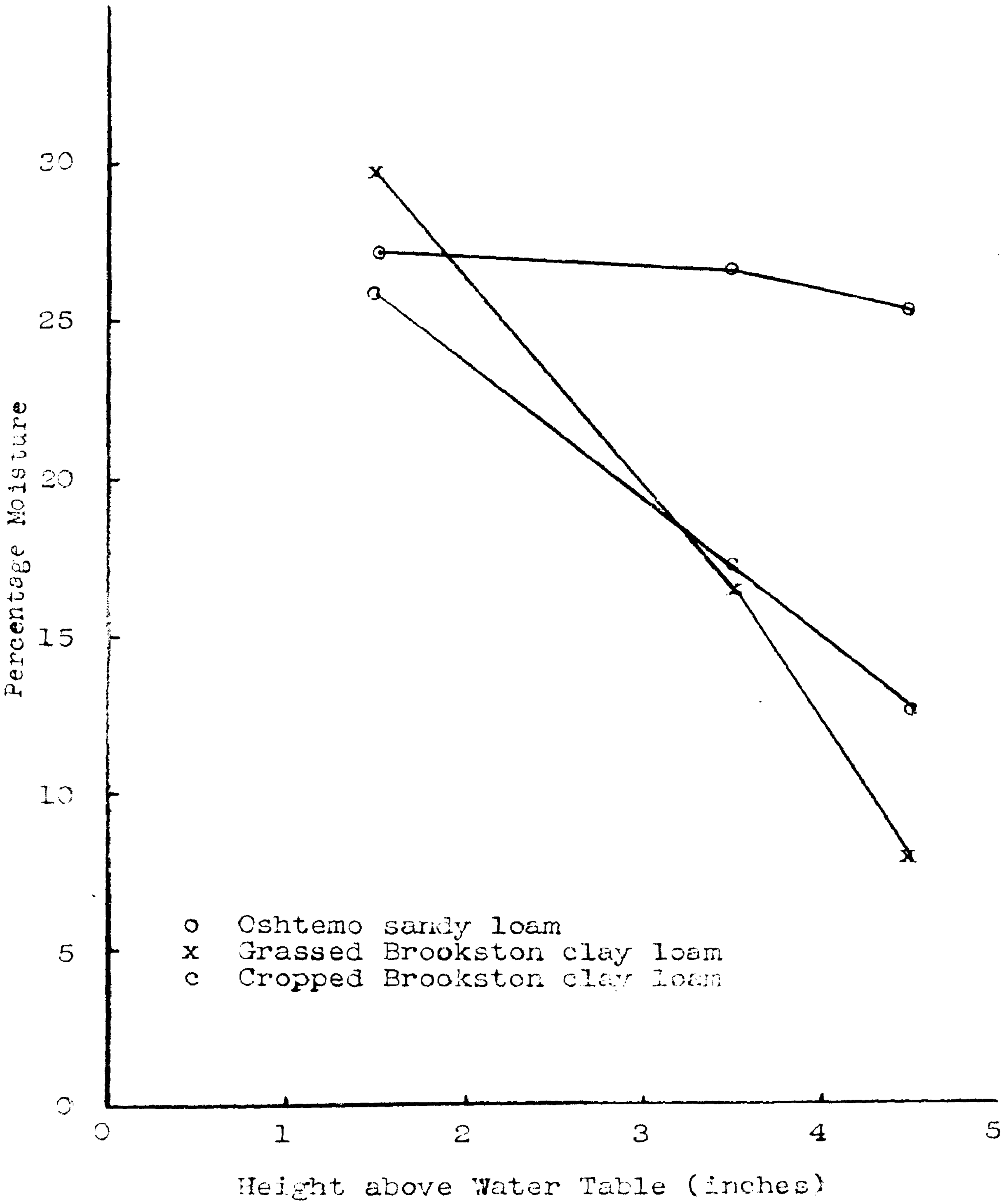

Percentage Moisture
30
25
20
15
10
5
0
0
1
2
3
4
5
o Oshtemo sandy loam
x Grassed Brookston clay loam
c Cropped Brookston clay loam
Height above Water Table (inches)

TABLE 9

MOISTURE PERCENTAGES OF THREE SOILS AT THREE DEPTHS IN THE CONSTANT WATER LEVEL BENCH

Soil	Replication	Depth in Bench *		
		0-1	1-2	2-5
Grassed Brookston	1	7.61	19.28	31.57
	2	8.32	14.06	28.00
	Average	7.97	16.67	29.79
Cropped Brookston	1	12.35	15.49	25.13
	2	13.52	19.03	26.99
	Average	12.94	17.26	26.06
Oshtemo Sandy Loam	1	24.37	24.91	26.41
	2	26.77	28.95	27.98
	Average	25.57	26.93	27.20

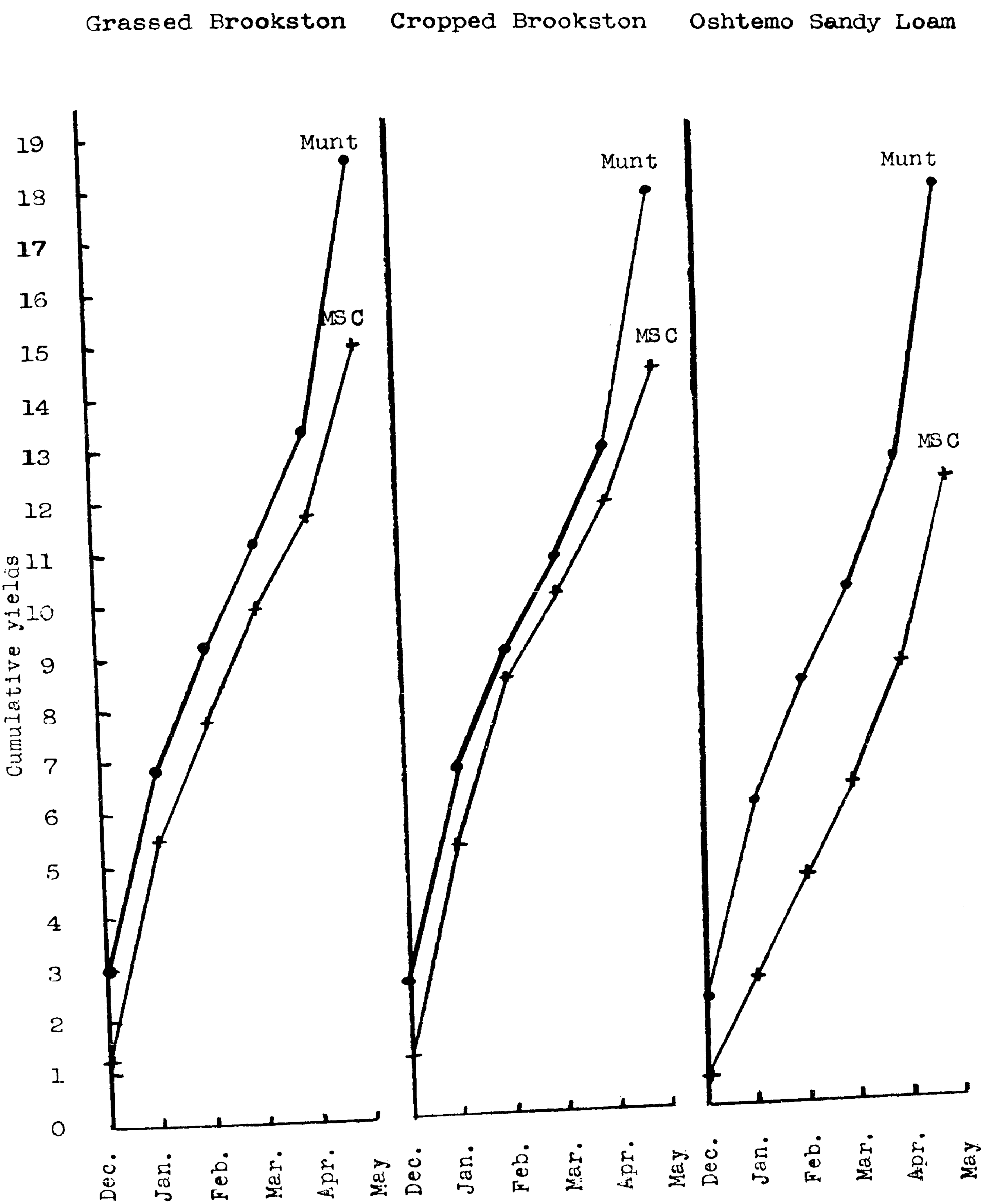
*Inches from the surface

TABLE 10

COMMERCIAL YIELDS PER SQUARE FOOT OF BENCH BY MONTHS AND PLANT SOURCES FOR EACH SOIL

Month	Soil					
	Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam	
	Munt	MSC	Munt	MSC	Munt	MSC
December	3.04	1.28	2.66	1.99	2.12	0.56
January	3.89	4.25	4.12	4.07	3.85	1.91
February	2.41	2.32	2.23	3.26	2.36	2.00
March	1.94	2.16	1.82	1.60	1.80	1.80
April	2.18	1.82	2.09	1.73	2.48	2.34
May	5.20	3.31	4.95	2.63	5.36	3.60
Total	18.66	15.14	17.87	14.48	17.97	12.21

Figure III. Cumulative monthly yields of commercial grade flowers, Munt plants versus MSC plants on each soil



Grassed Brookston
Cropped Brookston
Oshtemo Sandy Loam
Cumulative yields
Munt
MSC
Munt
MSC
Munt
MSC
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Dec.
Jan.
Feb.
Mar.
Apr.
May

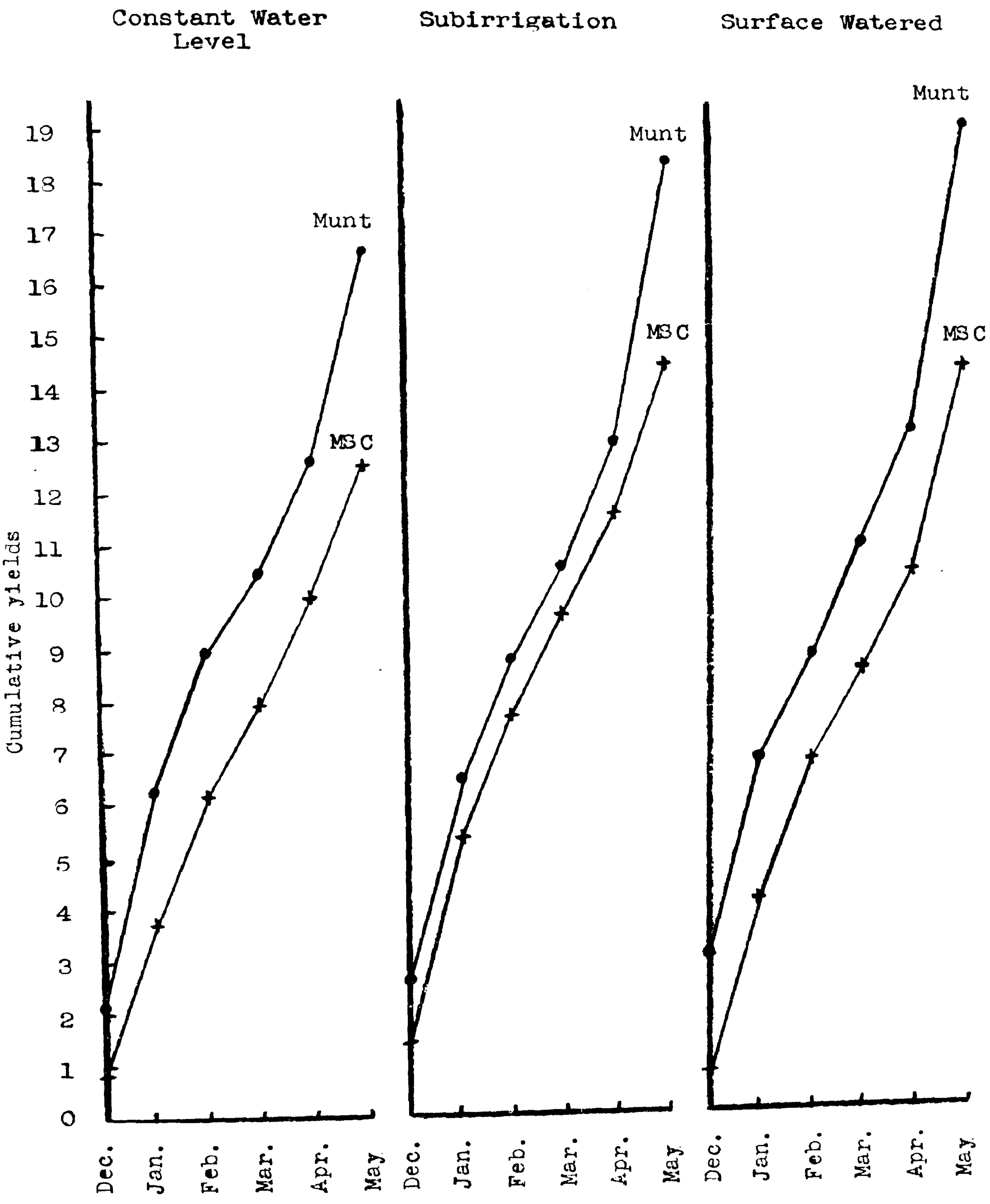
TABLE 11

COMMERCIAL YIELDS PER SQUARE FOOT OF BENCH BY MONTHS AND PLANT SOURCES FOR EACH WATERING METHOD

Month	Constant Water Level		Subirrigation		Surface Watered	
	Munt	MSC	Munt	MSC	Munt	MSC
December	2.18	0.92	2.61	1.37	3.02	0.74
January	4.19	2.90	3.83	3.96	3.87	3.38
February	2.66	2.45	2.34	2.39	2.00	2.72
March	1.53	1.76	1.87	2.00	2.14	1.78
April	2.16	2.07	2.41	1.94	2.18	1.89
May	4.12	2.63	5.42	2.90	5.96	4.01
Total	16.84	12.73	18.48	14.56	19.17	14.52

Watering Method spans all columns except Month.

Figure IV. Cumulative monthly yields of commercial grade flowers, Munt plants versus MSC plants for each method of watering



Constant Water Level
Subirrigation
Surface Watered
Cumulative yields
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Munt
MSC
Dec.
Jan.
Feb.
Mar.
Apr.
May

bench. When the MSC plants are considered, subirrigation by injection proved superior to either constant water level subirrigation or surface watering.

When only the three highest grades (spefex) are considered as in Table 12 and Figure V not only is a much greater difference noted between the Munt and MSC plants but it also becomes evident that soil type affected the quality of flowers produced from the Munt plants much more than it did the quantity.

Table 13 and Figure VI show the effect of the watering method on quality. The wide divergence between the Munt and MSC plants is noteworthy. Until May the Munt plants yielded as well in the constant water level bench as in the subirrigation by injection bench and both the constant water level bench and the subirrigation by injection bench produced slightly more than did the surface watered bench. In May, however, the yield from the constant water level bench did not increase to the same degree that yields did under the other two methods of watering. When the MSC plants are considered the constant water level bench produced more high quality flowers each month than did either the subirrigation by injection bench or the surface watered bench. In May, however, production from the surface watered bench was great enough to bring the cumulative yield from this bench up to the cumulative yield from the constant water level bench.

Table 14 summarizes the differences found between the

TABLE 12

SPEFEX YIELDS PER SQUARE FOOT OF BENCH BY MONTHS AND PLANT SOURCES FOR EACH SOIL

Month	Soil					
	Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam	
	Munt	MSC	Munt	MSC	Munt	MSC
December	0.73	0.06	0.51	0.02	0.21	0.02
January	1.74	0.33	1.97	0.20	0.86	0.02
February	1.63	0.25	1.56	0.45	0.92	0.15
March	1.44	0.45	1.42	0.27	0.92	0.24
April	1.89	0.81	1.86	1.02	1.93	0.95
May	5.08	2.76	4.84	2.41	4.46	3.03
Total	12.51	4.66	12.16	4.37	9.30	4.41

Figure V. Cumulative monthly yields of spefex grade flowers, Munt plants versus MSC plants on each soil

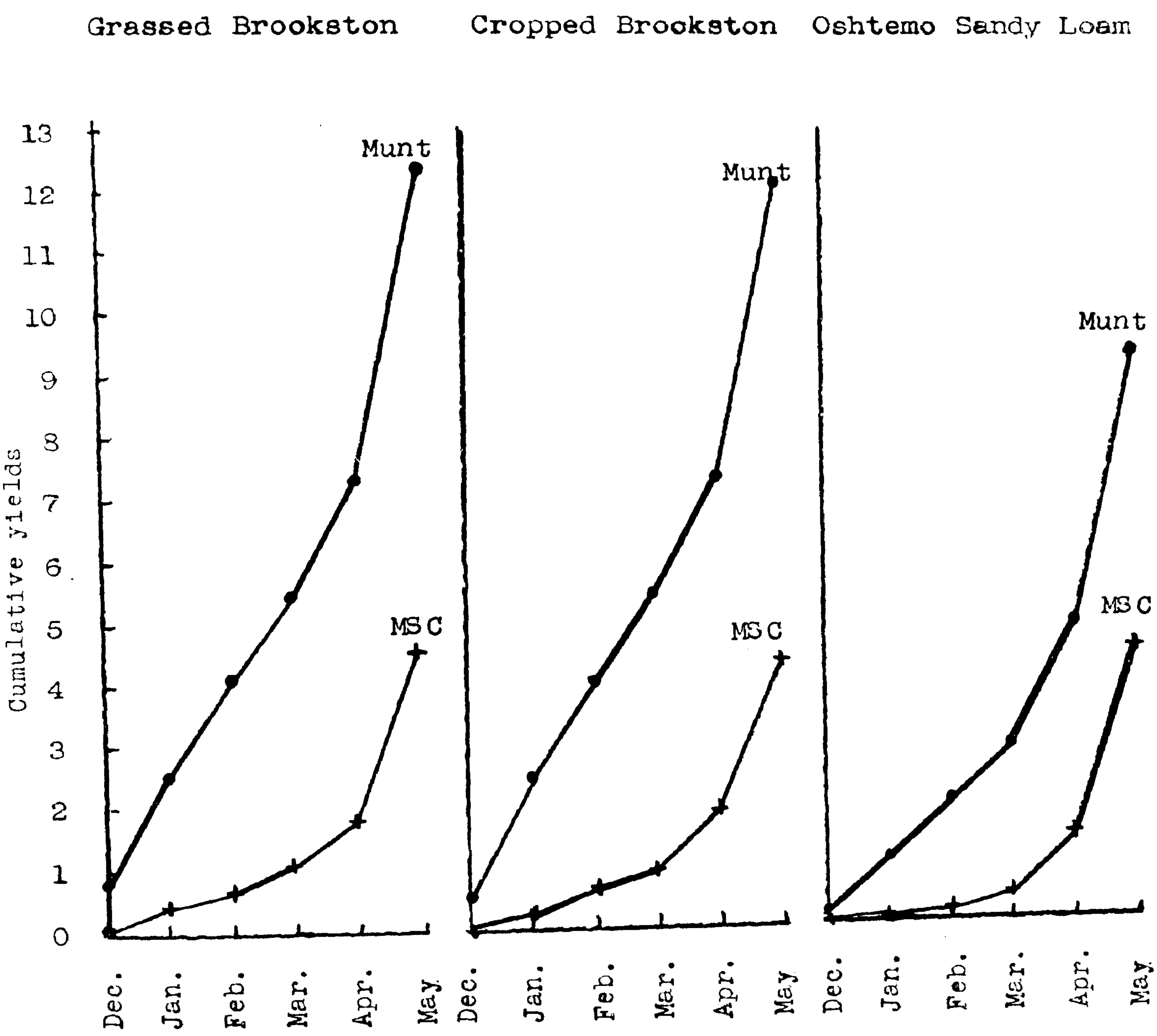
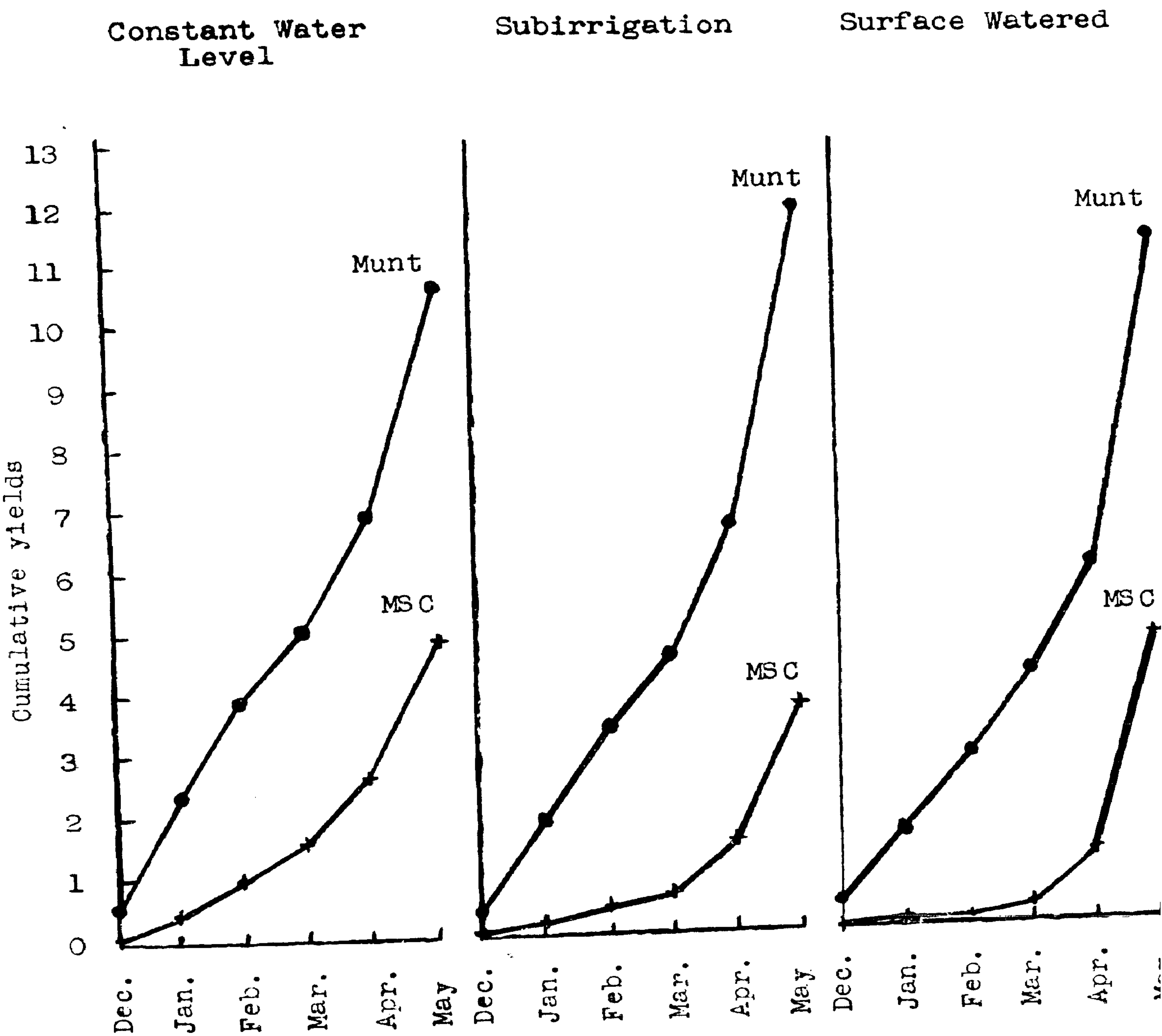

Grassed Brookston
Cropped Brookston
Oshtemo Sandy Loam
Cumulative yields
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Munt
MSC
Munt
MSC
Munt
MSC
Dec.
Jan.
Feb.
Mar.
Apr.
May
Dec.
Jan.
Feb.
Mar.
Apr.
May
Dec.
Jan.
Feb.
Mar.
Apr.
May

TABLE 13

SPEFEX YIELDS PER SQUARE FOOT OF BENCH BY MONTHS AND PLANT SOURCES FOR EACH WATERING METHOD

Month	Watering Method					
	Constant Water Level		Subirrigation		Surface Watered	
	Munt	MSC	Munt	MSC	Munt	MSC
December	0.54	0.06	0.38	0.03	0.52	-
January	1.82	0.33	1.54	0.15	1.22	0.06
February	1.52	0.57	1.44	0.20	1.14	0.09
March	1.14	0.54	1.20	0.23	1.44	0.20
April	1.84	1.08	2.12	0.84	1.73	0.86
May	3.84	2.32	5.18	2.31	5.36	3.57
Total	10.70	4.90	11.86	3.75	11.41	4.78

Figure VI. Cumulative monthly yields of spefex grade flowers, Munt plants versus MSC plants for each method of watering



Constant Water Level
Subirrigation
Surface Watered
Cumulative yields
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Munt
MS C
Munt
MS C
Munt
MS C
Dec.
Jan.
Feb.
Mar.
Apr.
May
Dec.
Jan.
Feb.
Mar.
Apr.
May
Dec.
Jan.
Feb.
Mar.
Apr.

TABLE 14

COMPARISON OF THE FLOWER YIELDS PER SQUARE FOOT OF BENCH FOR THE MUNT AND MSC PLANTS, ACCORDING TO GRADE

Source	Grade										
	Special	Fancy	Extra	Spefex	No. 1	No. 2	Commercial	Shorts	Splits	Culls	Rejects	Total Yield
Munt	1.00*	3.34**	7.04**	11.38**	6.38	0.45	18.15**	0.38	1.51	-	1.92	20.07
MSC	0.53	1.59	2.36	4.48	7.89*	1.59**	13.95	2.33**	2.43**	-	4.94**	18.88

*Significant at the 5% level
**Significant at the 1% level

Munt and MSC plants when the various grades were analyzed separately. While the total number of flowers produced per square foot of bench was not significantly different between the Munt and MSC plants all except two of the grades or combinations of grades showed differences significant at the 1% level. The Munt plants yielded significantly more commercials and more special, fancy and extra grade flowers while the MSC plants yielded a significantly greater number of No. 1's, No. 2's, rejects, shorts and splits.

It appears from the data obtained that the constant water level method of bench watering can be used successfully to produce high quality carnations provided vigorous, well-grown plants are used. A highly organic clay loam soil having a stable, well-aggregated structure may contribute to the improvement of quality but this was not definitely proven in all cases under the conditions of this experiment. It was apparent, however, that constant water level is a method requiring greater skill to use successfully than either surface watering or subirrigation by injection.

It is often stated that the structure of the soil in a greenhouse bench is broken down because of the heavy watering to which the soil is subjected. If soil aggregates are degraded by watering then the aeration status will be changed. This in turn may affect plants growing in the soil. With this thought in mind the aggregate stability of the two Brookston soils in the different benches was compared with the aggregate stability of the same soils prior to their use in the greenhouse. The Oshtemo sandy loam soil was not analyzed as its structure was considered to be practically single-grained and thus would contain few stable aggregates. These data are presented in Tables 32 and 33 of the appendix. Two samples were taken at two depths in each plot which contained the Brookston clay loam soils. A marked difference was found between the two Brookston soils, the grassed Brookston containing a much larger percentage of stable aggregates. In terms of aggregates four millimeters or more in diameter which remained on the top screen after "dunking" aggregation was improved in all benches and at both depths over the original soils except in three cases. These three were all surface samples of the grassed Brookston and were in benches I and II. In general, the surface aggregation was not improved as much as was the sub-surface aggregation. This was believed to be due to greater root growth at the lower depth. In the constant water level bench the roots may have been nearer the surface thus accounting for the better aggregation of the surface soil in this bench, particularly with the cropped Brookston. Unfortunately, the roots were not examined during this experiment.

Surface watering improved the structural stability of the grassed Brookston soil and caused structural disintegration of the cropped soil. The greatest increase in aggregation in the cropped soil occurred in bench I where the water level was held constant. The method of watering had little degrading effect upon the soil provided the soil contained consider-organic matter and clay and initially was stably aggregated.

A number of observations were made as a result of the soil testing program. Nutrient levels fluctuated most in the Oshtemo sandy loam and least in the grassed Brookston clay loam. This was expected because of the low clay and organic matter content of the Oshtemo soil and the high clay and organic matter content of the grassed Brookston soil.

Another property of the sandy loam soil was its high moisture content at all depths in the constant water level bench. Figure II shows that the Oshtemo sandy loam soil was very wet even at the surface of the bench. This caused poor aeration and produced anaerobic conditions as indicated by positive tests for ammonia. Apparently carnations are able to utilize ammonia nitrogen, however, because some very good yields were obtained with the Munt plants on the Oshtemo soil in the constant water level bench as previously shown. The soil in the west plot of bench II also showed a positive test for ammonia. This plot contained Oshtemo sandy loam soil. Drainage, however, was not complete due to the fact that the drainage hole in the end plots was in the end of the bench rather than in the bottom. The Brookston soils showed blank tests for ammonia in all benches. As shown by Figure II the moisture content and, therefore, the aeration varied considerably from top to bottom of the Brookston soil layers.

In the constant water level bench phosphorus and potassium tended to remain highest with phosphorus decreasing most rapidly in the subirrigation bench and potassium decreasing most rapidly in the surface watered bench. Nitrate nitrogen was removed most rapidly from the soil by surface watering and least rapidly by the injection method of subirrigation.

Summary of results. 1. Northland carnations from two sources were grown on three soils and in three benches in which different methods of watering were used. Production records were kept for a sox month period and all flowers cut were graded for quality. Almost 7,000 flowers were cut, of which 81.5% were of commercial quality.

2. In terms of total yield over the entire experiment there were no significant differences either between the soils or between the watering methods used. However, in terms of commercial yield both of the Brookston clay loam soils yielded sognificantly more flowers than did the Oshtemo sandy loam. Also, both subirrigation by injection and surface watering resulted in significantly more commercial grade flowers than did constant water level subirrigation.

3. The most consistent quality differences throughout the experiment occurred between plants from the two sources. The Munt plants yielded more flowers in all high quality

grades and the MSC plants yielded more flowers in the lower grades and in rejects. In terms of commercial yields the MSC plants were affected more by differences in soils and watering methods than were the Munt plants. In the case of the Munt plants soil differences affected quality more than numbers of flowers. As treatments after benching were identical for both Munt and MSC plants the differences in quality observed between Munt and MSC plants may have been due primarily to differences in culture from time of propagation to time of benching.

4. The grassed Brookston clay loam soil produced significantly more commercial, fancy and spefex grade flowers than did the Oshtemo sandy loam. Conversely, the Oshtemo soil produced more rejects than did either of the Brookston soils. Yields from the cropped Brookston clay loam soil were intermediate. In only one case (spefex) were yields significantly better than those from the Oshtemo sandy loam. On the other hand, they were in no case significantly poorer than those from the grassed Brookston.

5. The greatest variation between plots occurred on the constant water level bench as the lowest yielding plot and the second and third highest occurred on this bench. For both MSC and Munt plants more top quality flowers were produced on this bench during the first five months than on either of the other benches. Constant water level also produced most rejects and

splits. It appears that constant water level can be used successfully to produce high quality carnations but requires greater management skill than either surface watering or sub-irrigation by injection.

6. The grassed Brookston soil was more stably aggregated than was the cropped Brookston. Surface watering tended to degrade the surface layer of the latter more than did other methods of watering but did not affect the grassed Brookston. The structure of the cropped Brookston soil was most improved in the constant water level bench. Both Brookston soils contained more stable aggregates after nine months use in the greenhouse than did the original soils.

B. The Influence of Depth of Soil Above a Water Table upon Growth and Development of Carnations

The importance of aeration in greenhouse soils. The differences in commercial yields and quality obtained in the first experiment as well as the experiences of many growers indicate that some soil property other than the chemical nutrient supplying power is often limiting in greenhouse soils. A deficiency of water seldom occurs in a well managed greenhouse. In fact, as has been indicated previously in this report, unsatisfactory production has often been obtained on constant water level benches where water is always present in abundance. In recent years a greater emphasis has been placed upon the importance of proper aeration in field soils. In the greenhouse where watering is much more intense than in the field there is every reason to believe that aeration is limiting much more often than has been recognized in the past.

Chemical soil testing has impressed upon many greenhouse people the importance of proper nutrition for their crops. Unfortunately, there has been no good method of measuring soil air and as a consequence the importance of soil aeration has been largely disregarded. However, soil physicists have been searching for methods of measuring the oxygen supplying power of soils and of correlating the data obtained with the growth and yield of plants. A survey of the modern concepts and methods of characterizing soil aeration has recently been made by Lemon (14). Much remains to be done on soil aeration and its evaluation before a testing method for soil air will be as generally accepted by greenhouse operators as chemical soil testing has been. However, it is believed that measuring oxygen diffusion by the method developed by Lemon and Erickson (15) offers to date the most satisfactory way of evaluating oxygen supplying ability of a soil in a greenhouse bench or pot. For this reason a second greenhouse experiment was designed in an effort to correlate carnation growth with varying conditions of soil water and soil air.

Experimental methods and design. Eight-inch glazed drainage tiles were cut into 8, 9, 10, 11 and 12 inch lengths.

One end of each section was covered with several layers of cheesecloth. The sections were then set into galvanized pans three inches deep with the covered end down. The tiles were filled with soil leaving a one inch space at the top of each. When the pans were filled with water the effect was similar to a constant water level bench. Depth of soil above the water level in each tile was four inches less than the height of the tile. Thus the actual soil columns above the water table were four, five, six, seven and eight inches. The grassed Brookston clay loam and the cropped Brookston clay loam soils from the Stanley Wood farm as described in the previous experiment were used. There were four replications at each depth with each soil and three sets of carnation plants were used.

Fertilizer was applied on an area basis so it was the same in all tiles regardless of the depth of the soil layer. Initially ten grams of an 0-10-10 fertilizer was stirred into the soil in each tile prior to the addition of the top inch of soil. Soil tests were made at eight week intervals and equal amounts of K_2HPO_4 in solution were added to all tiles when testing showed the need. According to the test results nitrate nitrogen was never limiting.

Two varieties of carnations were planted, Juno and Achilles, both of which are white flowered. The plants were obtained from Yoder Brothers of Barberton, Ohio.

The first set of plants was planted on December 3, 1952. One plant of the variety Juno was planted in each tile. Care was taken to set the plants at a uniform depth and the soil was firmed gently around the roots in order to damage the structural aggregates of the soil as little as possible. In the deeper tiles it was necessary to water from above for several days. This watering was carefully done in order to prevent particle erosion.

Plants were chosen randomly from those available, the main requisites being that each be single stemmed and have no visible axillary buds. In later trials plants were also chosen for uniformity.

In the first trial, growth was measured by increase in height at harvest over the initial height, green weight, total number of "breaks"[1] and the number and green weight of "bottom breaks"[2].

The plants were cut on January 20, 1953 after heights had been recorded and counts made. Some flower buds were

---

[1]Axillary buds that have begun growth. One-half inch was used here as the lower limit of length because shorter breaks were few and not readily measured.

[2]Axillary shoots developed on the lower portion of the stem in the region of short internodes. Of importance because they flower only after considerable increase in stem length thus yielding good blooms for later cutting. This is in contrast to "top breaks" which flower on very short stems.

present but were not counted. More were observed, however, on the grassed Brookston soil than on the cropped Brookston.

All height measurements were made one inch from the soil surface and recorded to the nearest quarter inch. A notched guide stick which rested on the rim of the tile was used to insure uniform measurements from plant to plant and from one time of measurement to the next.

The second and third sets of plants were planted on January 25, 1953. Two plants were placed in each tile at that time. As before, the variety Juno was unpinched and was allowed to develop into a single stemmed plant. The variety Achilles was pinched so that four nodes and four good sets of leaves were left on each plant. The same standards as before were used but because of the variability noted in the first set of plants initial uniformity within the limits of the plants available was also striven for.

The variety Achilles was harvested on April 19th. Increase in height, green weight of plants and number and total length of breaks were recorded.

The variety Juno was harvested on May 27th. Height measurements were made at planting time and at intervals ranging from eight to fifteen days until harvest to enable growth curves to be drawn. Green weights of plants, of total breaks, and of bottom breaks, counts of total breaks and bottom breaks, total length of breaks and bottom breaks, and the flower and bud count were recorded at time of harvest.

Later, when the equipment became available, oxygen diffusion studies were made of the soils using the platinum electrode method developed by Lemon and Erickson (15). Five electrodes were used in each tile and readings were made at one inch intervals from one inch below the soil surface down to the water table. Moisture determinations of the various layers were also made on the soil in several of the tiles.

Discussion of results. In the first trial perhaps the most important effect was in the development of breaks, especially bottom breaks. On the grassed Brookston soil the total number of breaks developed was least in the tiles having only four inches of soil above the water table. The number then increased up to seven inches of soil and dropped off again at eight inches. When the number and weight of bottom breaks alone were considered there was a consistent increase on the cropped Brookston soil as the height above the water table increased from four to eight inches. Yield data for the first set of plants which were harvested January 19th are presented in Table 15.

Carnations grow slowly in Michigan during the winter because of low light intensity which prevails at that time. Perhaps for this reason other differences in growth were not consistent. On this account and because of the initial

TABLE 15

GROWTH OF UNPINCHED JUNO CARNATIONS ON TWO SOILS USING FIVE DEPTHS OF SOIL ABOVE THE WATER TABLE. FIRST TRIAL, HARVESTED JANUARY 19, 1953

GRASSED BROOKSTON

	Entire Plant		Total Breaks	Bottom Breaks	
Depth of Soil (in.)	Increase in Height (in.)	Green Weight (grams)	Number**	Number**	Green Weight (grams)
4	8.31*	22.70	10.75	4.50	2.45
5	8.63	22.80	11.50	3.50	1.58
6	8.19	22.78	13.25	4.50	1.25
7	8.50	25.25	13.75	4.25	1.60
8	8.56	22.48	13.00	4.50	2.28
Average	8.44	23.20	12.45	4.25	1.83

CROPPED BROOKSTON

4	7.69	15.98	5.50	1.50	0.28
5	8.50	18.93	9.75	2.25	0.45
6	6.88	15.93	6.00	2.75	0.60
7	7.50	17.70	7.75	3.50	0.73
8	7.63	18.10	7.00	4.25	1.18
Average	7.64	17.33	7.20	2.85	0.65

*All values are mean of four replications
**Over one-half inch in length

variability, the first set of plants was harvested early and the second and third sets were planted in late January. These plants were selected for uniformity within the group of plants available. The variety Juno was grown unpinched as before and the variety Achilles was pinched to four nodes. Because of differences in morphological development caused by pinching, the two varieties must be considered separately.

The Achilles plants were harvested on April 19th and the yield data are given in Table 16. Because the apical bud was removed by pinching, lateral buds began to develop immediately. The carnation has opposite leaves but the tendency is for only one bud to develop per node. Therefore, the number of breaks was limited by the number of nodes remaining. It is interesting to note, however, that two buds per node occurred frequently enough give an average of somewhat more than four breaks per plant in all but one case---the cropped Brookston soil in the four inch depth.

Height increases of the tallest branch over the original heights, green weights of the top growth and total lengths of breaks vary in a similar fashion. With each soil eight inches of soil above the water table gave the greatest increase in length of breaks and four inches of soil gave the least. The grassed Brookston clay loam soil which was well aggregated and had satisfactory soil water and soil relations produced the best growth from the pinched plants when the soil column was

TABLE 16

GROWTH OF PINCHED ACHILLES CARNATIONS ON TWO SOILS USING FIVE DEPTHS OF SOIL ABOVE THE WATER TABLE. SECOND TRIAL, HARVESTED APRIL 19, 1953

Depth of Soil (in.)	Increase in Height (in.)	Green Weight (grams)	Number of Breaks	Length of Breaks (in.)
GRASSED BROOKSTON				
4	2.31*	16.25	5.00	33.19 **
5	4.06	28.45	4.75	42.19
6	3.38	23.13	5.25	41.25
7	3.38	22.73	5.00	40.75
8	3.56	25.70	5.75	46.75
Average	3.34	23.25	5.15	40.83
CROPPED BROOKSTON				
4	0.19	7.10	3.50	19.06
5	0.38	8.00	4.75	23.06
6	1.31	12.65	5.25	30.38
7	1.69	12.55	4.25	27.81
8	3.25	19.80	4.50	34.94
Average	1.36	12.02	4.45	27.05

*All values are mean of four replications
**Over one-half inch in length

over four inches in thickness. The growth pattern varied little as the soil column increased in height from five to eight inches. Thus it appeared that optimum conditions were attained within this range. Five or six inches of this soil in a constant water level bench would produce satisfactory carnations. In the case of the cropped Brookston clay loam soil there was no indication that optimum growth was reached even at eight inches as the growth continued to improve. If a soil such as this were to be used in a constant water level bench the layer of soil above the water table should be at least eight inches thick. Cook, Erickson and Krone (8) concluded that for proper snapdragon growth a constant water level bench should have nine inches of Brookston clay loam soil or twenty-one inches of Oshtemo sandy loam soil above the water table.

When the two soils are compared the grassed Brookston is observed to have promoted greater growth than did the cropped Brookston. However, a yield overlap occurred as the eight inch depth of the cropped Brookston yielded somewhat better than did the four inch depth of the grassed Brookston.

The variety Juno was harvested on May 27th and measurements made at that time are presented in Table 17. Each figure is the mean of four replications. Some flowers and a considerable number of buds were present at that time. The commercial practice of removing all but one bud per stem

TABLE 17

GROWTH OF UNPINCHED JUNO CARNATIONS ON TWO SOILS USING FIVE DEPTHS OF SOIL ABOVE THE WATER TABLE. THIRD TRIAL, HARVESTED MAY 27, 1953

	Entire Plant		Total Breaks			Bottom Breaks				
Depth of Soil(in.)	Increase in Height(in.)	Green Weight (grams)	Number	Green Weight (grams)	** Length (in.)	Number	Green Weight (grams)	** Length (in.)	Flowers and Buds	Open Flowers
				GRASSED BROOKSTON						
4	21.58 *	57.43	4.25	5.35	17.50	3.25	3.83	12.13	7.50	1.50
5	23.64	79.20	5.75	13.13	28.75	4.00	11.75	22.13	9.50	4.50
6	23.59	88.75	6.00	15.90	34.94	4.50	13.53	26.38	8.75	5.25
7	22.34	82.70	8.50	17.53	40.63	6.00	15.08	31.56	9.00	8.00
8	21.18	96.85	10.25	21.65	49.88	6.25	17.95	34.44	10.00	6.50
Average	22.47	80.99	6.95	14.71	34.34	4.80	12.43	25.33	8.95	5.15
				CROPPED BROOKSTON						
4	19.95	33.45	0.75	0.35	1.81	0.50	0.28	1.19	5.50	0.25
5	17.58	38.18	3.25	2.00	7.69	1.75	1.88	5.75	4.25	0.25
6	19.84	46.70	3.25	4.18	11.25	1.50	3.55	7.44	5.25	2.50
7	20.75	60.23	4.25	6.08	16.25	3.75	5.40	14.06	6.75	4.75
8	21.28	70.60	7.50	11.20	30.44	4.50	8.58	19.75	7.50	6.00
Average	19.88	49.83	3.80	4.76	13.49	2.40	3.94	9.64	5.85	2.75

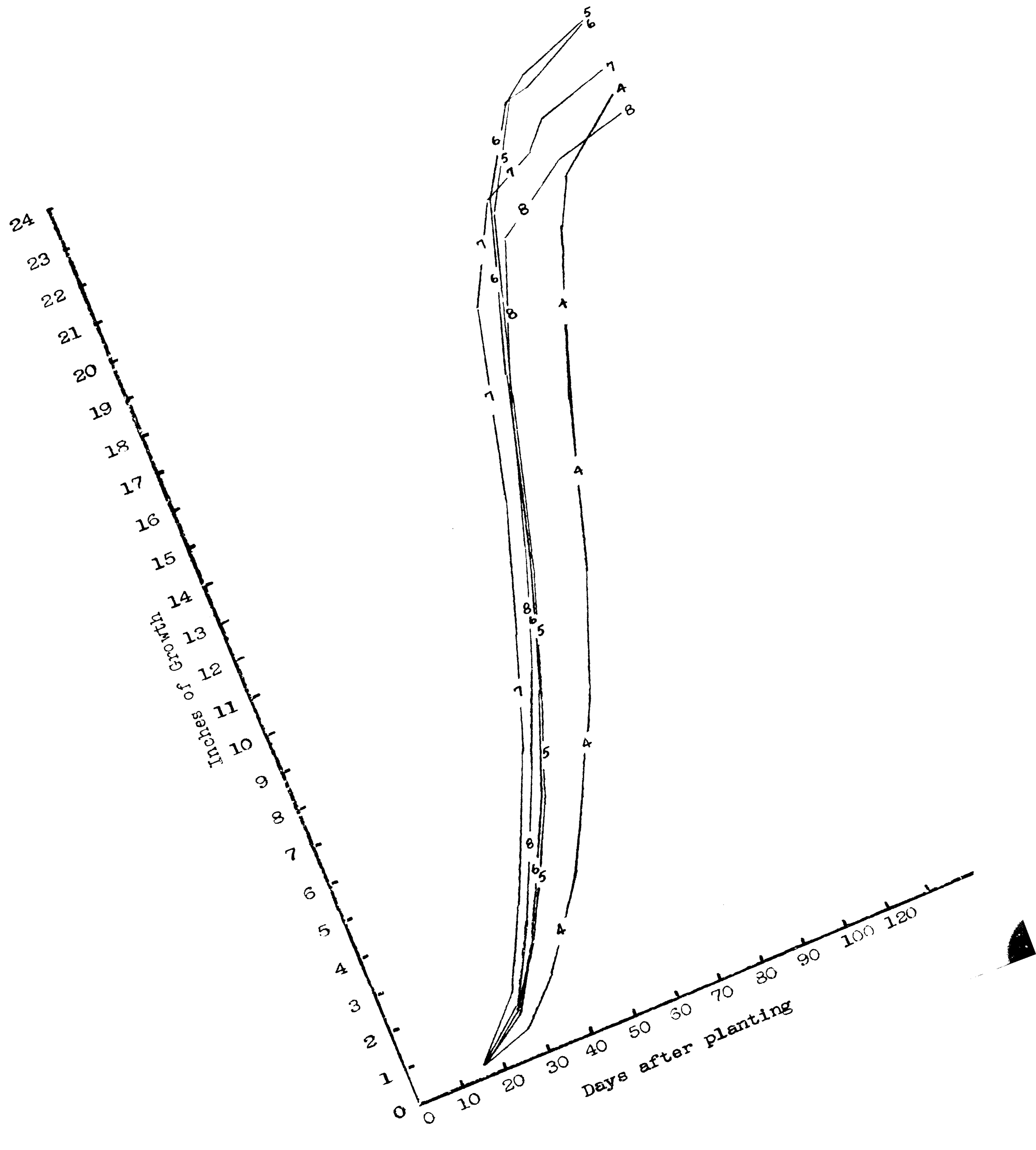
*All values are mean of four replications
**Over one-half inch in length

was not used in this experiment. Instead, all buds were allowed to develop naturally. The total number of flowers and well-developed buds did not vary greatly with depth of soil but the earliest flowers were produced on the deeper soils.

Growth curves for the plants grown on the two soils at the different depths are shown in Figures VII and VIII. With the grassed Brookston soil five, six, seven and eight inches of soil above the water table produced very similar growth as measured increases in plant height. In four inches of this soil growth was retarded. On the cropped Brookston soil seven and eight inches of soil above the water table were definitely better than any shallower depth in improving growth in height throughout the entire growing period.

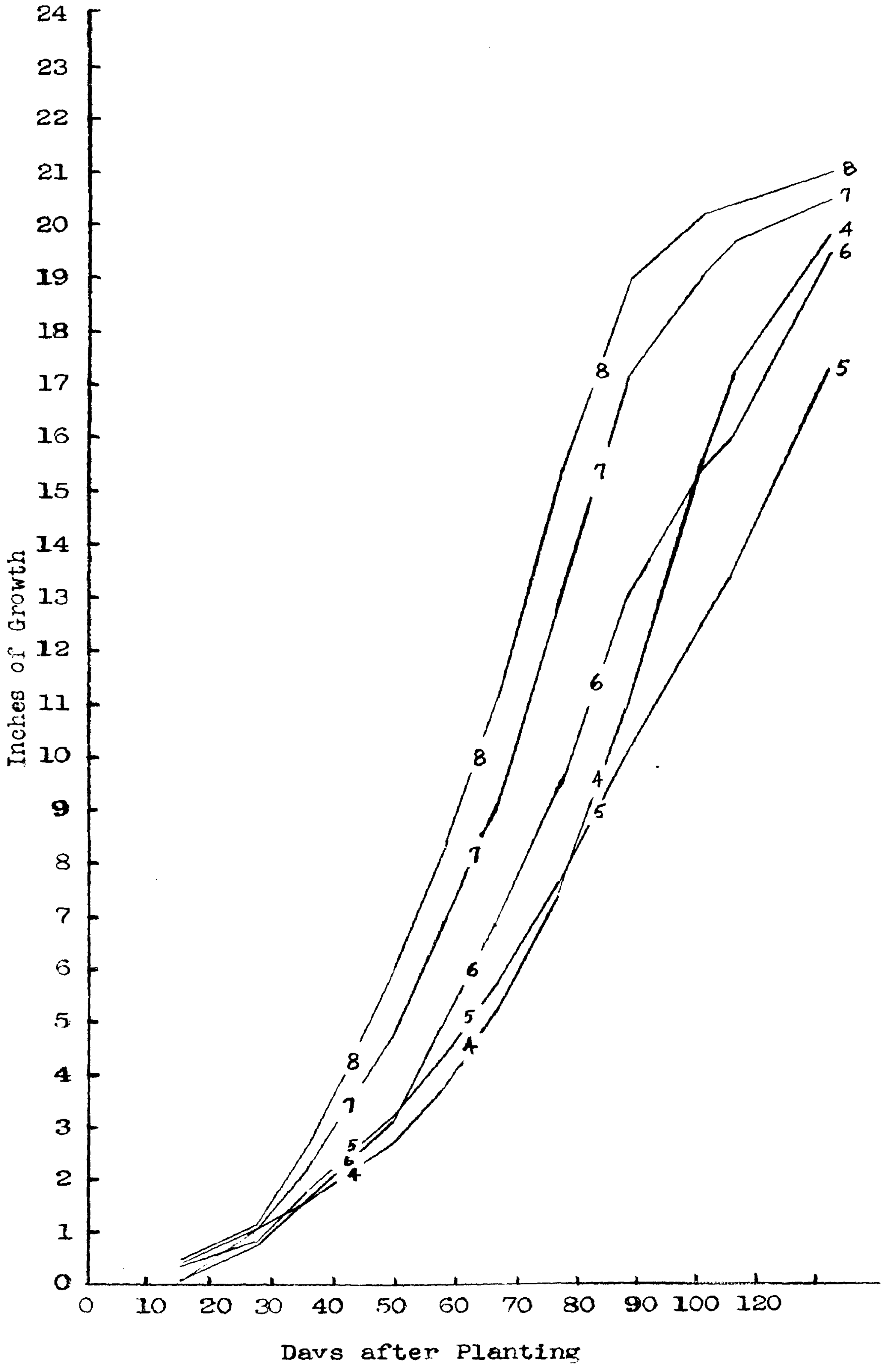
Two points should be noted particularly. First, the grassed Brookston soil produced plants which averaged more than 2.5 inches taller than those produced on the cropped Brookston, although, again, eight inches of the cropped Brookston soil was as good as four inches of the grassed Brookston. Secondly, the change in the slope of the curves for the seven and eight inch depths of the grassed Brookston and the eight inch depth of the cropped Brookston on the 37th day was related to flower development. Plants in the seven and eight inch depths of grassed Brookston soil flowered earlier but were shorter stemmed. The other extreme was represented by the four and five inch depths of cropped

Figure VII. Growth rates of Juno carnations on grassed Brookston clay loam soil at five soil heights above the water table



Inches of Growth
Days after planting
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
10
20
30
40
50
60
70
80
90
100
120
4
5
6
7
8

Figure VIII. Growth rates of Juno carnations on cropped Brookston clay loam soil at five soil heights above the water table



Inches of Growth
Days after Planting
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
0
10
20
30
40
50
60
70
80
90
100
120

Brookston soil. Flowering had just begun by the 120th day and the growth curves had not yet changed direction at that time.

Green weights of the tops increased steadily from the shallowest to the deepest tiles in both soils with the exception of the seven inch depth of the grassed Brookston which dropped down somewhat because of two lighter plants. Again there was an overlap so that the eight inch depth of the cropped Brookston soil yielded better than the four inch depth of the grassed Brookston.

The pattern was similar when total breaks and bottom breaks were considered except that the overlap varied somewhat depending upon the characteristic measured. The overlap indicated that five inches of the grassed Brookston and eight inches of the cropped Brookston produced generally comparable results. It was evident that less than five inches of soil above the water table depressed growth even with the grassed Brookston clay loam which is undoubtedly one of the best greenhouse soils in Michigan.

Soil tests did not show great nutrient differences at any time although nutrient availability is so inextricably related to soil water and soil air that some differences undoubtedly did exist. The conclusion was reached that the increase in growth in the deeper tiles was due primarily to the more favorable soil water-air relationships existing in them.

In February it was noted that water was disappearing from the pans at unequal rates so measurements of the water added to each pan were started. Each pan was 16 x 40 inches in size and contained four tiles. The amounts of water added over a three and one-half month period are shown in Table 18. A number of conclusions may be drawn from these data. For example, the quantity of water used was directly related to depth in the less well aggregated soil but was relatively independent of depth in the highly aggregated soil. In the well aggregated grassed Brookston soil the pore spaces were larger, the water did not rise as high in the columns and considerably less water was used. A total of 167 gallons of water was added to the pans holding the tiles of grassed Brookston soil and 209 gallons was added to the cropped Brookston---a difference of 42 gallons. The difference was attributed to greater surface evaporation in the cropped Brookston due to its poorer aggregation and consequent increased capillarity. If water was limiting at any time growth should have been greatest in the cropped Brookston and poorest in the grassed Brookston. However, because such was not the case, soil aeration was believed to be the more important. Thus, in the cropped Brookston soil aeration was limited because too much water was drawn into the root zone. This, in view of the smaller pore space, reduced the oxygen in the soil below the optimum for the carnation. As the soil layer above the water table became deeper,

TABLE 18

INCHES OF WATER ADDED TO PANS CONTAINING SOIL COLUMNS OF VARYING HEIGHTS

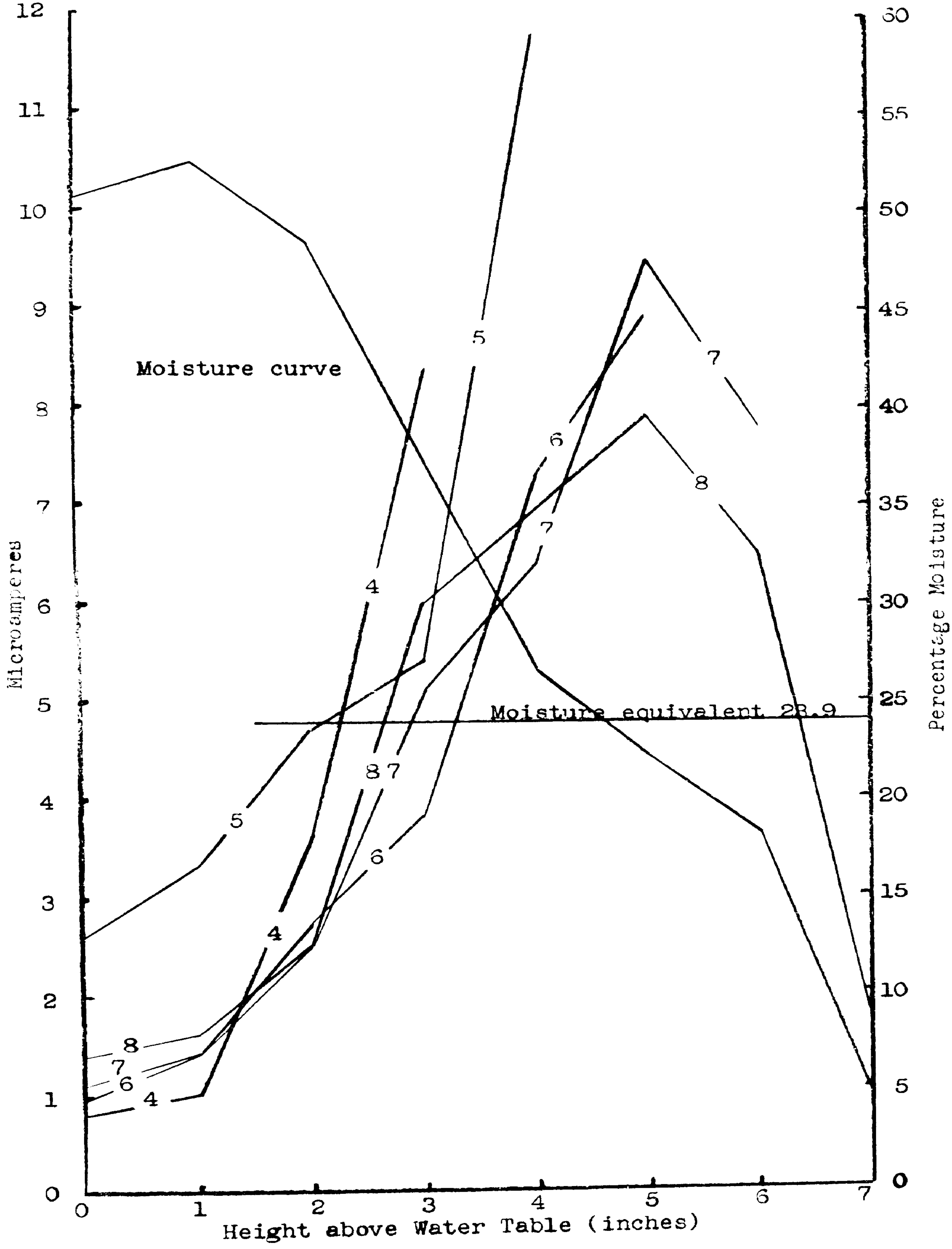
MONTH	GRASSED BROOKSTON Height of Soil Column						CROPPED BROOKSTON Height of Soil Column					
	4	5	6	7	8	Total	4	5	6	7	8	Total
February*	1.3	1.8	1.8	1.6	1.5	8.0	1.8	1.4	3.3	3.8	5.0	15.3
March	4.8	5.5	5.3	4.8	4.1	24.5	4.8	5.6	8.0	8.1	9.9	36.4
April	6.9	7.1	7.0	5.6	5.8	32.4	6.4	5.8	8.3	7.5	6.8	34.8
May	7.3	8.1	7.0	6.3	6.1	34.8	7.9	7.8	8.8	7.6	6.5	38.6
Total	20.3	22.5	21.1	18.3	17.5	99.7	20.9	20.6	28.4	27.0	28.2	125.1

*Month incomplete - measurements begun February 15 the moisture films in the soil column became thinner and allowed more air to diffuse into the soil. Consequently, a more satisfactory ratio between soil air and soil water was attained in the upper layers of the taller columns. This was directly reflected in increased growth and development.

A number of plants were removed from the tiles and the soil was carefully washed from the roots. No roots were found in either soil in the first two inches above the water table. The root growth was almost horizontal in the four inch tiles as the effective root area was no more than two inches thick. In the eight inch tiles the effective root area was less than six inches thick because of a half inch or more of relatively dry soil at the surface. The roots were longer in the deeper tiles but did not appear to differ greatly in the total amount present. This agrees with the work of Durell (9) who found with the tomato that slight aeration sufficed for optimum growth of roots and yield of fruits but the highest rate of aeration produced the greatest dry weight of stems and leaves. If this same relationship holds true for the carnation then the highest rate of aeration should produce the highest quality flowers if other factors are not limiting. The data presented indicate that in general the heaviest plants and the longest stems did occur on the deepest soils which were also the best aerated.

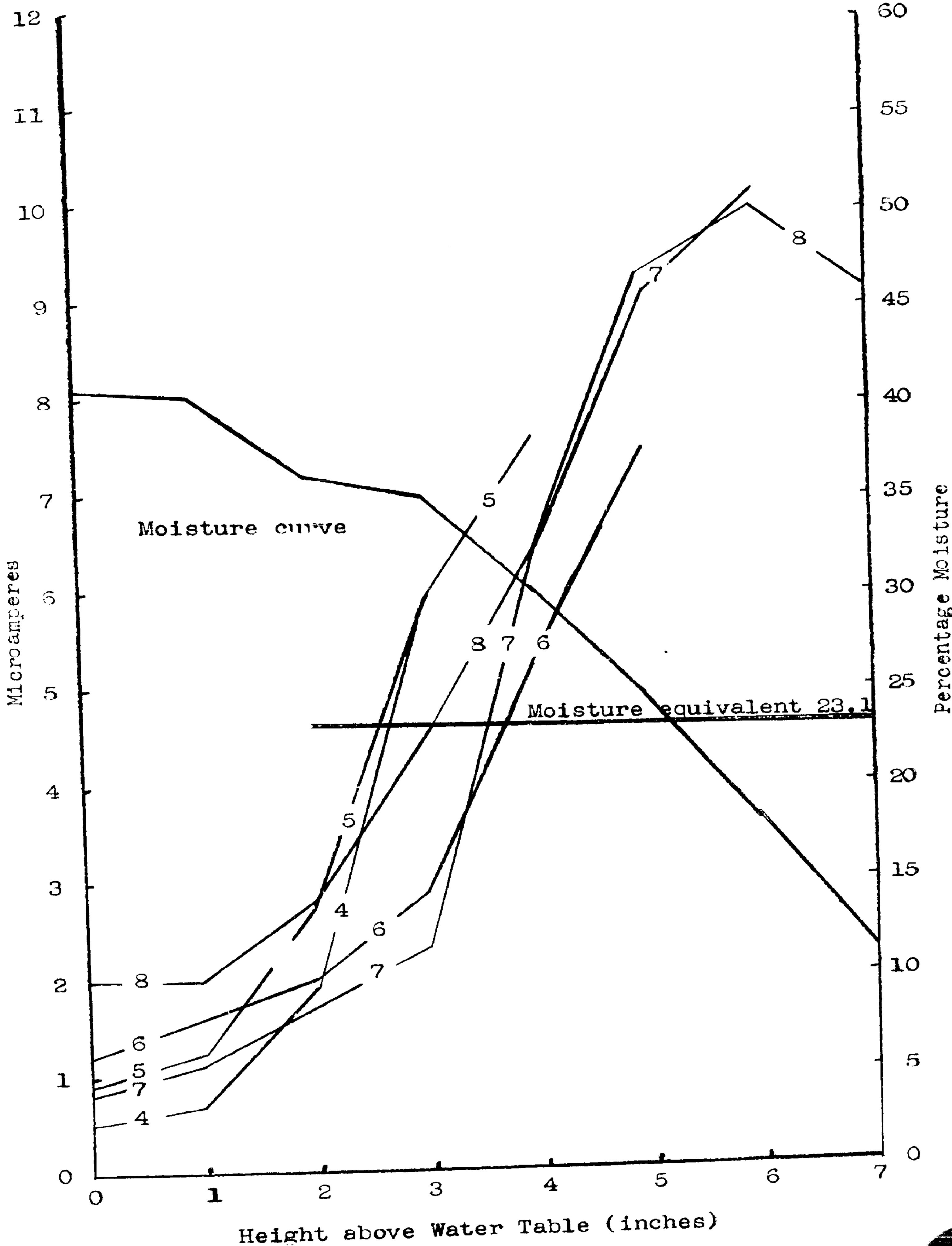
Figures IX and X present the oxygen diffusion data for

Figure IX. Grassed Brookston clay loam. The relationship between oxygen diffusion rates in microamperes at one inch intervals in soil columns of varying heights above the water table and the moisture percentage curve



Microamperes
Percentage Moisture
Height above Water Table (inches)
Moisture curve
Moisture equivalent 23.9
0
1
2
3
4
5
6
7
8
9
10
11
12
0
5
10
15
20
25
30
35
40
45
50
55
60

Figure X. Cropped Brookston clay loam. The relationship between oxygen diffusion rates in microamperes at one inch intervals in soil columns of varying heights above the water table and the moisture percentage curve



Microamperes
Percentage Moisture
Height above Water Table (inches)
Moisture curve
Moisture equivalent 23.1
0
1
2
3
4
5
6
7
8
9
10
11
12
0
5
10
15
20
25
30
35
40
45
50
55
60

the two soils as obtained with the method developed by Lemon and Erickson (15) and also shows the moisture curves obtained at varying depths in a sampling of the tiles. In slope, these moisture curves are similar to those obtained for the constant water level bench during the first experiment (Figure 2). The steeper the slope the better the aeration status of the soil. Near the water table the moisture was high and the oxygen diffusion rate was low. As the distance above the water table increased the moisture percentage decreased and the rate of oxygen diffusion increased except near the surface of the taller tiles.

Lemon and Erickson used the tomato as their test plant and concluded that readings of seven to eight microamperes of current indicated the minimum for satisfactory tomato growth. The tomato is very sensitive to poor aeration while a plant such as rice is very tolerant to lack of soil oxygen. The carnation appears to lie between these extremes in its sensitivity to poor aeration. As no roots were found in the zero to two inch distance above the water table aeration in this zone was definitely limiting. Eight of the ten values obtained two inches above the water table were below three microamperes. One, however, was 3.6 and one, 4.7. Each value is the mean of twenty readings as five electrodes were used and there were four replications. Perhaps for carnation the minimum reading should be five microamperes or above.

The moisture equivalents for the two soils were as follows: grassed Brookston, 23.9%; cropped Brookston, 23.1%. In the tiles the moisture equivalent was attained 4.5 inches above the water table for the grassed Brookston and 5.2 inches above the water table for the cropped Brookston. Thus, oxygen diffused further into the grassed Brookston and the area where aeration and moisture were both adequate was greater.

These data confirm the statement made by Cannon and Free (6) that the members of one and the same root system may have varying relations to oxygen owing to differences of the oxygen content of the various soil strata. Lemon and Erickson (15) more recently showed highly significant differences between diffusion rate and depth in the soil and also between diffusion rate and aggregate size.

The general pattern of increasing oxygen toward the soil surface produces a system similar to that constructed by Went (33) to show that a portion of the roots of tomato grown in nutrient solution needed to develop in a well aerated media in order to produce caulocaline which he believed essential for stem growth. The pattern shown by carnation, however, was somewhat different. In this case, increasing soil aeration had less effect upon the increase in height of the main stem than upon the green weights and upon the lateral bud development. Cook, Erickson and Krone (8) reported a similar much branched growth pattern for snapdragon when the soil aeration was increased but did not attempt to explain it.

Perhaps, until further studies have been made, it is sufficient to state that improving soil aeration either inactivated the growth substance produced in the apical shoot or reduced its concentration sufficiently that it stimulated rather than inhibited the development of lateral buds. Moreover, while removal of the apical growing point is total in its effect, aeration control, once enough becomes known about it, may offer a partial stimulus that can be varied. For instance, the commercial propagator is interested in a large number of strong bottom breaks for cuttings but the flower grower wants enough strong bottom breaks to insure continued good production but not so many that he obtains a "grassy" type of growth which reduces quality or requires extra pruning.

Summary of results. 1. Two varieties of carnations were grown in tiles set on end in pans of water to approximate conditions existing in a constant water level bench. Two soils were used at different heights above the water table to study the effect of varying the physical soil characteristics and the depth of soil in the bench upon the growth and development of carnations. Various growth criteria were recorded including height increases, green weights, number, weights and lengths of total breaks and bottom breaks, and bud and flower counts.

2. The variety Achilles was pinched to leave four nodes per plant. In the grassed Brookston soil growth of the pinched plants was similar when the depth of the soil over the water table was five inches or more. In the cropped Brookston soil best growth was obtained in the deepest soil (eight inches above water table) and there was no indication that the optimum had been reached.

3. The variety Juno which was unpinched was not harvested until buds were well developed and some flowers were present. The earliest flowers appeared on plants growing in the deepest columns of the grassed Brookston soil. The stems, however, were somewhat shorter than on later flowers produced in shallower depths of that soil.

4. In terms of plant height, which would indicate directly the stem length of the cut flowers, the unpinched plants were tallest on the five and six inch columns of the grassed Brookston soil. On the cropped Brookston soil the seven and eight inch soil columns produced taller plants than any of the shallower tiles. The most consistent differences were between soils as the plants on the grassed Brookston averaged 2 2/3 inches taller than the plants on the cropped Brookston.

5. Green weights, total breaks and bottom breaks varied directly with the depth of the soil column in both soils. This was concluded to be due to more favorable relationships between soil water and soil air in the deeper soil columns.

6. With the platinum electrode method as developed by Lemon and Erickson the rate of oxygen diffusion through the films of soil moisture should produce a current reading of at least five microamperes for satisfactory aeration around the roots of carnation.

7. With unpinched carnation plants increasing the soil aeration caused an increase in growth and development of lateral buds or breaks. Apparently adequate soil aeration furnishes oxygen for a biochemical reaction which either inactivates the growth substance produced by the apical bud or reduces its concentration to such an extent that it becomes stimulating. The suggestion is made that aeration control may in time be useful in varying the morphological growth of carnation.

C. Nutritional Requirements of the Carnation

Methods and results. In the fall of 1950 a study was made of the effect of varying levels of nitrogen, phosphorus and potassium upon the growth of carnations in pots. Ninety-six eight inch asphalt coated clay pots were used. In each pot the drainage hole was covered with several layers of cheesecloth prior to filling the pot with soil. The soil used was Oshtemo sandy loam which is low in fertility and organic matter and has a low base exchange capacity. Five thousand grams of air dry soil and five grams of $CaCO_3$ were placed in each pot.

A factorial design was used containing four levels of nitrogen, three levels of phosphorus and four levels of potassium. Monocalcium phosphate was mixed into the proper pots prior to planting to give 0, 5 and 10 parts per million of phosphorus in the soil extract. Potassium was supplied by K_2SO_4 applied in solution to give 0, 15, 30 and 60 parts per million in the soil extract. Nitrogen was furnished by a combination of NH_4NO_3 and $NaNO_3$ in solution to produce 0, 25, 50 and 100 parts per million in the soil extract. All testing was done with the Simplex test kit as developed by Spurway and Lawton (26).

Carnation plants of the variety Northland were planted in the pots in August after the lime and monocalcium phosphate had been mixed with the soil in all except the check treatments. The nitrate and potassium salts were applied in early September after the plants had become established in the pots. The $NaNO_3$ for the two replications came from different containers and within a few days all of the plants except the nitrogen checks in one complete replication were severely injured and subsequently died. Prior to death the plants bleached out and were almost white. Although the cause was never definitely determined it was thought that one of the bottles may have contained $NaNO_2$ or some other toxic salt instead of $NaNO_3$. Thus the data obtained were from only one set of plants. On this account the study was terminated on December 31st, somewhat sooner than had been planned.

During the months of November and December 39 flowers were produced on 48 plants. These consisted of 13 extras, 21 No. 1's and 5 splits. The distribution of blossoms at each level of the nutrients studied is shown in Table 19.

Because of the small amount of data obtained its value is limited. However, the effect of phosphorus on the production of flowers was notable. Nitrogen when absent was also decidedly limiting. Potassium appeared to have little effect during the short duration of this experiment.

The results obtained in this study agree with the ranges recommended by Post (19) who suggests 25 to 150 parts per million of nitrate, 5 to 10 parts per million of phosphorus and 25 to 50 parts per million of potassium. It may be that an even higher rate of phosphate fertilization would be beneficial but this was not investigated.

TABLE 19

THE INFLUENCE OF VARYING LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM UPON YIELDS OF CARNATION FLOWERS

PPM	Cornell Grade Extra	No. 1	Total	Splits
NITROGEN				
0	0	2	2	0
25	2	7	9	0
50	4	6	10	1
100	7	6	13	4
PHOSPHORUS				
0	1	1	2	0
5	5	7	12	2
10	7	13	20	3
POTASSIUM				
0	2	5	7	1
15	2	5	7	1
30	6	3	9	1
60	3	8	11	2

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APPENDIX

Tabulated results of yields obtained and measurements made during a greenhouse experiment on carnation plants grown in three soils and under three methods of watering, with Analyses of Variance

TABLE 20

TOTAL YIELDS OF NORTHLAND CARNATIONS PER SQUARE FOOT OF BENCH

Source	Soil	Constant Water Level Replication 1	2	Subirrigation Replication 1	2	Surface Watered Replication 1	2	Average
		METHOD OF WATERING						
Munt	Grassed Brookston	15.98	21.26	20.14	20.25	20.36	22.50	20.08
	Cropped Brookston	17.33	16.65	19.91	20.93	22.39	18.45	19.28
	Oshtemo Sandy Loam	20.59	21.83	19.58	21.04	20.81	21.26	20.85
Source Average		17.97	19.91	19.88	20.74	21.19	20.74	20.07
MSC	Grassed Brookston	20.16	16.56	19.71	18.99	18.54	21.69	19.28
	Cropped Brookston	21.33	20.79	17.37	17.64	14.85	21.69	18.95
	Oshtemo Sandy Loam	14.67	15.21	20.34	19.98	17.55	22.77	18.42
Source Average		18.72	17.52	19.14	18.87	16.98	22.05	18.88
Total Average		18.34	18.72	19.51	19.81	19.08	21.39	
Bench Average		18.53		19.66		20.24		
		Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam		
Soil Average		19.68		19.12		19.64		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	176.18		
Soils	2	2.40	1.20	2.31
Replications	3	16.70	5.57	10.71**
Benches	2	18.11	9.06	17.81**
Soils x benches	4	7.58	1.90	3.65
Error a (replications x soils)	6	3.13	0.52	
Sources	1	12.75	12.75	2.05
Soils x sources	2	7.27	3.64	0.59
Benches x sources	2	0.64	0.32	0.05
Soils x benches x sources	4	51.64	12.91	2.08
Error b	9	55.96	6.22	

TABLE 21

COMMERCIAL YIELDS OF NORTHLAND CARNATIONS PER SQUARE FOOT OF BENCH

Source	Soil	Constant Water Level Replication 1	Constant Water Level Replication 2	Subirrigation Replication 1	Subirrigation Replication 2	Surface Watered Replication 1	Surface Watered Replication 2	Average
Munt	Grassed Brookston	15.19	18.68	18.56	18.79	19.13	21.49	18.64
	Cropped Brookston	15.64	14.29	18.34	19.69	21.60	17.55	17.85
	Oshtemo Sandy Loam	18.23	18.90	17.21	18.23	16.88	18.34	17.97
Source Average		16.35	17.29	18.04	18.90	19.20	19.13	18.15
MSC	Grassed Brookston	16.02	13.05	16.29	14.76	15.21	15.48	15.14
	Cropped Brookston	14.49	15.84	12.96	13.86	12.42	17.28	14.48
	Oshtemo Sandy Loam	7.65	9.45	13.50	16.02	11.88	14.85	12.23
Source Average		12.72	12.78	14.25	14.88	13.17	15.87	13.95
Total Average		14.54	15.04	16.14	16.89	16.19	17.50	
Bench Average		14.79		16.52		16.84		
		Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam		
Soil Average		16.89		16.16		15.10		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	322.98		
Soils	2	19.51	9.76	10.38*
Replications	3	7.59	2.53	2.69
Benches	2	29.33	14.67	15.61**
Soils x benches	4	4.25	1.06	1.13
Error a (replications x soils)	6	5.63	0.94	
Sources	1	159.30	159.30	40.43**
Soils x sources	2	10.60	5.30	1.35
Benches x sources	2	0.91	0.46	0.12
Soils x benches x sources	4	50.39	12.60	3.20
Error b	9	35.47	3.94	

LSD for soils and benches: At 5% level, 0.98; at 1% level, 1.48

TABLE 22

YIELDS OF SPECIAL GRADE NORTHLAND CARNATIONS PER SQUARE FOOT OF BENCH

		METHOD OF WATERING						
Source	Soil	Constant Water Level		Subirrigation		Surface Watered		
		Replication		Replication		Replication		Average
		1	2	1	2	1	2	
Munt	Grassed Brookston	0.79	0.34	1.24	2.48	1.24	2.14	1.37
	Cropped Brookston	1.01	1.24	2.81	0.34	0.23	0.79	1.07
	Oshtemo Sandy Loam	1.01	0.68	0.56	0.45	0.00	0.68	0.56
Source Average		0.94	0.75	1.54	1.09	0.49	1.20	1.00
MSC	Grassed Brookston	0.72	0.72	0.36	0.18	0.45	1.08	0.59
	Cropped Brookston	0.36	0.45	0.63	0.63	0.54	0.72	0.56
	Oshtemo Sandy Loam	1.08	0.54	0.09	0.63	0.18	0.09	0.44
Source Average		0.72	0.57	0.36	0.48	0.39	0.63	0.53
Total Average		0.83	0.66	0.95	0.79	0.44	0.92	
Bench Average		0.75		0.87		0.68		
Soil Average		Grassed Brookston 0.98		Cropped Brookston 0.81		Oshtemo Sandy Loam 0.50		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	13.69		
Soils	2	1.42	0.71	2.03
Replications	3	0.84	0.28	0.80
Benches	2	0.22	0.11	0.31
Soils x benches	4	1.81	0.45	1.29
Error a (replications x soils)	6	2.09	0.35	
Sources	1	2.04	2.04	7.56*
Soils x sources	2	0.66	0.33	1.22
Benches x sources	2	0.81	0.41	1.52
Soils x benches x sources	4	1.40	0.24	0.89
Error b	9	2.40	0.27	

TABLE 23

YIELDS OF FANCY GRADE NORTHLAND CARNATIONS PER SQUARE FOOT OF BENCH

Source	Soil	Constant Water Level Replication 1	Constant Water Level Replication 2	Subirrigation Replication 1	Subirrigation Replication 2	Surface Watered Replication 1	Surface Watered Replication 2	Average
Munt	Grassed Brookston	2.48	2.81	4.05	4.61	4.61	5.29	3.98
	Cropped Brookston	2.25	2.59	2.81	4.50	4.84	4.39	3.56
	Oshtemo Sandy Loam	3.26	2.48	3.15	1.91	2.14	1.91	2.48
Source Average		2.66	2.63	3.34	3.07	3.86	3.66	3.34
MSC	Grassed Brookston	2.52	1.71	1.35	1.35	1.62	1.44	1.67
	Cropped Brookston	1.08	1.35	0.45	1.44	1.89	2.52	1.46
	Oshtemo Sandy Loam	0.63	0.72	1.53	2.34	2.07	2.61	1.65
Source Average		1.41	1.26	1.11	1.71	1.86	2.19	1.59
Total Average		2.04	1.94	2.22	2.69	2.86	3.03	
Bench Average		1.99		2.46		2.94		
Soil Average		Grassed Brookston 2.82		Cropped Brookston 2.51		Oshtemo Sandy Loam 2.06		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	56.11		
Soils	2	3.48	1.74	6.96*
Replications	3	0.77	0.26	1.04
Benches	2	5.46	2.73	10.92**
Soils x benches	4	1.86	0.47	1.88
Error a (replications x soils)	6	1.51	0.25	
Sources	1	27.49	27.49	109.96**
Soils x sources	2	3.90	1.95	7.80*
Benches x sources	2	0.96	0.48	1.92
Soils x benches x strains	4	8.39	2.10	8.40**
Error b	9	2.29	0.25	

LSD for soils and benches: at 5% level, 0.49; at 1% level, 0.74

TABLE 24

YIELDS OF EXTRA GRADE NORTHLAND CARNATIONS PER SQUARE FOOT OF BENCH

		METHOD OF WATERING						
Source	Soil	Constant Water Level		Subirrigation		Surface Watered		
		Replication		Replication		Replication		Average
		1	2	1	2	1	2	
Munt	Grassed Brookston	7.99	8.21	7.20	5.51	7.88	6.30	7.18
	Cropped Brookston	6.30	6.08	7.65	9.45	9.34	7.20	7.67
	Oshtemo Sandy Loam	7.88	7.76	6.41	5.96	4.16	5.40	6.26
Source Average		7.39	7.35	7.09	6.97	7.13	6.30	7.04
MSC	Grassed Brookston	3.87	3.51	1.53	1.98	1.62	1.98	2.42
	Cropped Brookston	3.69	2.70	0.81	1.98	1.98	2.97	2.36
	Oshtemo Sandy Loam	1.62	2.16	1.53	3.69	1.80	3.06	2.31
Source Average		3.06	2.79	1.29	2.55	1.80	2.67	2.36
Total Average		5.23	5.07	4.19	4.76	4.46	4.49	
Bench Average		5.15		4.48		4.47		
		Brookston, Grassed		Brookston, Cropped		Oshtemo Sandy Loam		
Soil Average		4.80		5.01		4.29		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	243.50		
Soils	2	3.35	1.68	2.02
Replications	3	1.05	0.35	0.42
Benches	2	3.63	1.82	2.19
Soils x benches	4	8.03	2.01	2.42
Error a (replications x soils)	6	4.95	0.83	
Sources	1	196.94	196.94	266.14**
Soils x sources	2	2.82	1.41	1.91
Benches x sources	2	0.83	0.42	0.57
Soils x benches x sources	4	15.21	3.80	5.14*
Error b	9	6.69	0.74	

TABLE 25

YIELDS OF "SPEFEX" NORTHLAND CARNATIONS PER SQUARE FOOT OF BENCH

Source	Soil	METHOD OF WATERING						
		Constant Water Level		Subirrigation		Surface Watered		
		Replication		Replication		Replication		Average
		1	2	1	2	1	2	
Munt	Grassed Brookston	11.25	11.36	12.49	12.60	13.73	13.73	12.53
	Cropped Brookston	9.56	9.00	13.28	14.29	14.40	12.38	12.15
	Oshtemo Sandy Loam	12.15	10.91	10.13	8.33	6.30	7.99	9.30
Source Average		10.99	10.42	11.97	11.74	11.48	11.37	11.33
MSC	Grassed Brookston	7.11	5.94	3.24	3.51	3.69	4.50	4.67
	Cropped Brookston	5.13	4.50	1.89	4.05	4.41	6.21	4.37
	Oshtemo Sandy Loam	3.33	3.42	3.15	6.66	4.05	5.76	4.40
Source Average		5.19	4.62	2.76	4.74	4.05	5.49	4.48
Total Average		8.09	7.52	7.36	8.24	7.76	8.43	
Bench Average		7.81		7.80		8.10		
		Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam		
Soil Average		8.60		8.26		6.85		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	549.65		
Soils	2	20.63	10.32	22.93**
Replications	3	4.60	1.53	3.40
Benches	2	0.69	0.35	0.78
Soils x benches	4	16.79	4.20	9.33**
Error a (replications x soils)	6	2.72	0.45	
Sources	1	422.51	422.51	315.31**
Soils x sources	2	17.03	8.52	6.36*
Benches x sources	2	8.14	4.07	3.04
Soils x benches x sources	4	44.51	11.13	8.31
Error b	9	12.03	1.34	

LSD for soils: at 5% level, 0.67; at 1% level, 1.02

TABLE 26

YIELDS OF NUMBER 1 GRADE NORTHLAND CARNATIONS PER SQUARE FOOT OF BENCH

		METHOD OF WATERING						
Source	Soil	Constant Water Level		Subirrigation		Surface Watered		
		Replication		Replication		Replication		Average
		1	2	1	2	1	2	
Munt	Grassed Brookston	3.94	6.98	6.08	5.51	5.40	7.54	5.91
	Cropped Brookston	5.51	5.18	4.84	5.06	6.75	4.95	5.38
	Oshtemo Sandy Loam	5.85	7.20	6.64	9.45	8.55	9.34	7.84
Source Average		5.10	6.45	5.85	6.67	6.90	7.28	6.38
MSC	Grassed Brookston	7.56	6.39	11.34	7.29	9.54	9.00	8.52
	Cropped Brookston	7.92	9.99	8.91	7.65	6.93	9.72	8.52
	Oshtemo Sandy Loam	3.96	5.40	9.00	7.83	6.39	7.11	6.62
Source Average		6.48	7.26	9.75	7.59	7.62	8.61	7.89
Total Average		5.79	6.86	7.80	7.13	7.26	7.94	
Bench Average		6.32		7.47		7.60		
		Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam		
Soil Average		7.21		6.95		7.23		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	116.46		
Soils	2	0.59	0.30	0.35
Replications	3	6.18	2.06	2.40
Benches	2	11.84	5.92	6.88*
Soils x benches	4	11.12	2.78	3.23
Error a (replications x soils)	6	5.14	0.86	
Sources	1	20.42	20.42	9.00*
Soils x sources	2	34.08	17.04	7.51
Benches x sources	2	3.71	1.86	0.82
Soils x benches x sources	4	2.94	0.74	0.33
Error b	9	20.44	2.27	

LSD for benches; at 5% level, 0.93

TABLE 27

YIELDS OF NUMBER 2 GRADE NORTHLAND CARNATION PER SQUARE FOOT OF BENCH

Source	Soil	Constant Water Level Replication 1	Constant Water Level Replication 2	Subirrigation Replication 1	Subirrigation Replication 2	Surface Watered Replication 1	Surface Watered Replication 2	Average
Munt	Grassed Brookston	0.00	0.34	0.00	0.68	0.00	0.23	0.21
	Cropped Brookston	0.57	0.11	0.23	0.34	0.45	0.23	0.32
	Oshtemo Sandy Loam	0.23	0.79	0.45	0.45	2.02	1.02	0.83
Source Average		0.27	0.41	0.23	0.49	0.82	0.49	0.45
MSC	Grassed Brookston	1.35	0.72	1.71	3.96	1.98	1.98	1.95
	Cropped Brookston	1.44	1.35	2.16	2.16	1.08	1.35	1.59
	Oshtemo Sandy Loam	0.36	0.63	1.35	1.53	1.44	1.98	1.22
Source Average		1.05	0.90	1.74	2.55	1.50	1.77	1.59
Total Average		0.66	0.66	0.98	1.52	1.16	1.13	
Bench Average		0.66		1.25		1.15		
Soil Average		Grassed Brookston 1.08		Cropped Brookston 0.96		Oshtemo Sandy Loam 1.02		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	25.93		
Soils	2	0.09	0.05	0.19
Replications	3	0.86	0.29	1.07
Benches	2	2.42	1.21	4.48
Soils x benches	4	2.48	0.62	2.30
Error a (replications x soils)	6	1.64	0.27	
Sources	1	11.55	11.55	67.94**
Soils x sources	2	2.83	1.42	8.35**
Benches x sources	2	2.09	1.05	6.18*
Soils x benches x sources	4	0.40	0.10	0.59
Error b	9	1.57	0.17	

TABLE 28

YIELDS OF NORTHLAND REJECTS PER SQUARE FOOT OF BENCH

Source	Soil	Constant Water Level Replication 1	Constant Water Level Replication 2	Subirrigation Replication 1	Subirrigation Replication 2	Surface Watered Replication 1	Surface Watered Replication 2	Average
Munt	Grassed Brookston	0.79	2.59	1.58	1.46	1.24	1.01	1.45
	Cropped Brookston	1.69	2.36	1.58	1.24	0.79	0.90	1.43
	Oshtemo Sandy Loam	2.36	2.93	2.36	2.81	3.94	2.93	2.89
Source Average		1.61	2.63	1.84	1.84	1.99	1.61	1.92
MSC	Grassed Brookston	4.14	3.51	3.42	4.23	3.33	6.21	4.14
	Cropped Brookston	6.84	4.95	4.41	3.78	2.43	4.41	4.47
	Oshtemo Sandy Loam	7.02	5.76	6.84	3.96	5.67	7.92	6.20
Source Average		6.00	4.74	4.89	3.99	3.81	6.18	4.94
Total Average		3.81	3.68	3.37	2.91	2.90	3.90	
Bench Average		3.75		3.14		3.40		
		Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam		
Soil Average		2.79		2.95		4.54		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	136.10		
Soils	2	22.49	11.25	30.41**
Replications	3	3.69	1.23	3.32
Benches	2	2.22	1.11	3.00
Soils x benches	4	7.37	1.84	4.97*
Error a (replications x soils)	6	2.21	0.37	
Sources	1	81.81	81.81	57.61**
Soils x sources	2	0.57	0.29	0.20
Benches x sources	2	0.77	0.39	0.27
Soils x benches x sources	4	2.15	0.54	0.38
Error b	9	12.82	1.42	

LSD for soils; at 5% level, 0.61; at 1% level, 0.93

TABLE 29

THE NUMBER OF NORTHLAND SHORTS PER SQUARE FOOT OF BENCH

Source	Soil	Constant Water Level Replication 1	Constant Water Level Replication 2	Subirrigation Replication 1	Subirrigation Replication 2	Surface Watered Replication 1	Surface Watered Replication 2	Average
Munt	Grassed Brookston	0.00	0.56	0.00	0.11	0.11	0.11	0.15
	Cropped Brookston	0.11	0.34	0.11	0.11	0.23	0.00	0.15
	Oshtemo Sandy Loam	0.34	0.79	0.23	0.79	1.58	1.35	0.85
Source Average		0.15	0.56	0.11	0.34	0.64	0.49	0.38
MSC	Grassed Brookston	1.26	0.72	2.16	1.35	0.90	2.52	1.49
	Cropped Brookston	2.70	0.81	1.53	1.26	0.99	2.61	1.65
	Oshtemo Sandy Loam	4.32	3.51	4.50	1.44	3.96	5.40	3.86
Source Average		2.76	1.68	2.73	1.35	1.95	3.51	2.33
Total Average		1.46	1.12	1.42	0.84	1.30	2.00	
Bench Average		1.29		1.13		1.65		
		Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam		
Soil Average		0.82		0.90		2.35		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	73.68		
Soils	2	17.83	8.92	46.95**
Replications	3	2.81	0.94	4.95
Benches	2	1.67	0.84	4.42
Soils x benches	4	2.32	0.58	3.05
Error a (replication x soils)	6	1.14	0.19	
Sources	1	34.16	34.16	40.67**
Soils x sources	2	5.12	2.56	3.05
Benches x sources	2	0.22	0.11	0.13
Soils x benches x sources	4	0.89	0.22	0.26
Error b	9	7.52	0.84	

LSD for soils; at 5% level 0.44; at 1% level, 0.66

TABLE 30

YIELDS OF NORTHLAND SPLITS PER SQUARE FOOT OF BENCH

Source	Soil	Constant Water Level Replication 1	Constant Water Level Replication 2	Subirrigation Replication 1	Subirrigation Replication 2	Surface Watered Replication 1	Surface Watered Replication 2	Average
		METHOD OF WATERING						
Munt	Grassed Brookston	0.68	2.03	1.46	1.35	1.13	0.90	1.26
	Cropped Brookston	1.58	2.03	1.46	1.13	0.56	0.90	1.28
	Oshtemo Sandy Loam	2.03	1.91	2.14	2.03	2.25	1.58	1.99
Source Average		1.43	1.99	1.69	1.50	1.31	1.13	1.51
MSC	Grassed Brookston	2.52	2.79	1.17	2.79	2.25	3.69	2.54
	Cropped Brookston	3.96	3.96	2.79	2.52	1.35	1.71	2.72
	Oshtemo Sandy Loam	2.34	2.07	1.62	2.43	1.26	2.43	2.03
Source Average		2.94	2.94	1.86	2.58	1.62	2.61	
Total Average		2.19	2.47	1.77	2.04	1.47	1.87	
Bench Average		2.33		1.91		1.67		
Soil Average		Grassed Brookston 1.90		Cropped Brookston 2.00		Oshtemo Sandy Loam 2.01		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	24.56		
Soils	2	0.09	0.05	0.26
Replications	3	0.93	0.31	1.63
Benches	2	2.66	1.33	7.00*
Soils x benches	4	3.84	0.96	5.05*
Error a (replications x soils)	6	1.15	0.19	
Sources	1	7.56	7.56	23.63**
Soils x sources	2	3.54	1.77	5.53*
Benches x sources	2	0.55	0.28	0.88
Soils x benches x sources	4	1.39	0.35	1.09
Error b	9	2.85	0.32	

LSD for benches; 25 5% level, 0.44

TABLE 31
THE EFFECT OF TREATMENT ON THE GREEN WEIGHT OF NORTHLAND CARNATIONS
(Weights in Grams)

Source	Soil	METHOD OF WATERING: Constant Water Level, Replication 1	Constant Water Level, Replication 2	Subirrigation, Replication 1	Subirrigation, Replication 2	Surface Watered, Replication 1	Surface Watered, Replication 2	Average
Munt	Grassed Brookston	385.7	452.3	484.0	586.8	564.8	526.3	500.0
	Cropped Brookston	488.0	517.3	601.9	465.5	501.8	490.1	510.8
	Oshtemo Sandy Loam	471.6	434.0	468.5	500.9	440.8	518.6	472.4
Source Average		448.4	467.9	518.1	517.7	502.5	511.7	494.4
MSC	Grassed Brookston	380.9	365.9	458.3	482.6	479.3	501.3	444.7
	Cropped Brookston	551.9	525.8	444.6	541.6	521.8	567.0	525.5
	Oshtemo Sandy Loam	416.0	415.4	429.3	524.3	427.1	446.2	443.1
Source Average		449.6	435.7	444.1	516.2	476.1	504.8	471.1
Total Average		449.0	451.8	481.1	517.0	489.3	508.3	
Bench Average		450.4		499.0		498.8		
		Grassed Brookston		Cropped Brookston		Oshtemo Sandy Loam		
Soil Average		472.4		518.1		457.7		

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	Ratio
Total	35	115,179.2		
Soils	2	23,815.4	11,907.7	9.85*
Replications	3	4,959.8	1,653.3	1.37
Benches	2	18,811.9	9,406.0	7.78*
Soils x benches	4	20,890.5	5,222.6	4.32
Error a (replications x soils)	6	7,253.6	1,208.9	
Sources	1	4,890.6	4,890.6	2.05
Soils x sources	2	7,503.7	3,751.9	1.58
Benches x sources	2	948.8	474.4	0.20
Soils x benches x sources	4	4,675.7	1,168.9	0.49
Error b	9	21,429.2	2,381.0	

LSD for soils and benches; 2 at 5% level, 34.7

TABLE 32

THE EFFECT OF WATERING METHODS ON THE AGGREGATION OF THE GRASSED BROOKSTON CLAY LOAM SOIL

Treatment	Replication	Depth in Bench	% over 4 mm	2 to 4mm	1 to 2mm	0.5 to 1mm	0.25 to 0.5mm	0.1 to 0.25mm	% less than 0.1 mm
Original soil			18.45*	17.70	14.48	14.19	14.40	4.25	16.53
Constant water level	1	0-1	35.96	12.00	8.04	10.54	16.34	8.52	8.60
		2-5	45.82	6.72	7.06	9.46	13.80	1.66	15.48
	2	0-1	17.02	11.76	12.20	16.90	17.72	3.36	21.04
		2-5	33.88	13.32	10.44	11.34	13.78	2.12	15.12
Sub-irrigation	1	0-1	18.82	11.20	11.60	14.18	21.06	5.72	17.42
		2-5	24.38	13.46	10.56	11.22	17.18	4.48	18.72
	2	0-1	13.84	10.38	9.48	13.16	19.24	1.90	32.00
		2-5	20.48	11.18	7.46	11.20	19.38	14.50	15.80
Surface watered	1	0-1	36.36	10.52	7.94	10.24	15.38	6.00	13.56
		2-5	34.44	10.08	8.82	11.14	15.86	3.00	16.66
	2	0-1	37.44	12.66	7.64	9.28	13.60	8.20	11.18
		2-5	35.96	12.68	7.74	10.28	14.00	1.40	17.94

** Aggregate Size

* Each value is the average of two 50 gram samples expressed as per cent

TABLE 33

THE EFFECT OF WATERING METHODS ON THE AGGREGATION OF THE CROPPED BROOKSTON CLAY LOAM SOIL

Treatment	Replication	Depth in Bench	**% over 4mm	2 to 4mm	1 to 2mm	0.5 to 1mm	0.25 to 0.5mm	0.1 to 0.25mm	% less than 0.1mm
Original soil			3.26*	6.95	9.05	14.34	20.21	11.50	34.69
Constant water level	1	0-1	28.22	7.04	4.14	7.64	14.38	2.62	35.96
		2-5	36.34	7.32	5.86	8.82	12.52	1.38	27.76
	2	0-1	34.38	6.50	4.58	7.42	13.08	5.06	28.98
		2-5	33.86	8.64	5.18	8.38	14.02	8.48	21.44
Sub-irrigation	1	0-1	27.92	5.68	3.70	6.76	14.66	13.14	28.14
		2-5	27.68	6.56	5.04	8.66	15.68	7.24	29.14
	2	0-1	16.58	8.18	5.42	10.08	16.36	2.58	40.80
		2-5	22.26	9.86	5.92	10.12	16.14	2.28	33.42
Surface watered	1	0-1	19.96	7.50	7.10	12.78	18.80	15.06	18.80
		2-5	25.42	8.74	4.04	7.58	14.82	3.42	35.98
	2	0-1	6.12	7.28	5.46	9.50	18.20	2.88	50.58
		2-5	25.10	9.42	5.10	7.66	13.76	3.36	35.60

** Aggregate Size
* Each value is the average of two 50 gram samples expressed as per cent