T H E S I S

SOME OF THE EFFECTS OF ADDITIONS OF CLAY AND PEAT TO CARNATION SOILS

Submitted by

C. William Sauer

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY C. WILLIAM SAUER

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BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

[redacted]

Major Professor

[redacted]

Head of Department

Examination Satisfactory

Committee on Final Examination

[redacted]

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Chapter I

INTRODUCTION

Since the carnation was introduced into the state of Colorado, its production has grown steadily until today the yearly carnation crop is valued over three million dollars (7). Such a value represents the production of many millions of flowers, a certain percentage of which must be sold at reduced prices or discarded entirely because of inferior quality. Many factors contribute to the production of low-quality flowers. As far back as 1915 authorities recognized soil troubles as a factor (5).

Greenhouse operators have learned by experience that sandy or light-textured soils cause fewer problems in carnation production than finer-textured soils. In an effort to alleviate the problems accompanying the use of fine-textured soils, some growers are now using an extremely porous soil. Gomness (9) found in a survey of the soil types used in 40 Colorado carnation ranges that 55 per cent had a clay content of less than 10 per cent and that 18 per cent of the ranges surveyed had a clay content of 5 per cent or less.

Growers are confronted with the possibility of root injury when fertilizer is applied, because of the low base exchange capacity of these sandy soils. Rapid drainage which causes excessive leaching loss of the fertilizer elements is also a problem of these soils.

There are two apparent solutions to this problem. The sandy soil could be replaced by a soil with finer texture. Such an operation is complicated by the difficulty in obtaining a desirable soil and by the prohibitive cost of a complete soil change. As an alternative, the incorporation of small amounts of clay and peat might improve the properties of the sandy soil. Since clay and humus are the active portions of the soil (1), the addition of either or both of these substances should increase the base exchange capacity, the water-holding capacity, the number of water stable aggregates, and other physical properties affected by an increase in colloidal-sized soil particles. The cost of incorporating a few pounds of clay or peat into a bench of soil is small in proportion to the cost involved in a complete soil change.

In light of the preceding discussion, the problem was outlined in the following manner.

Problem

What are some of the effects on carnation production obtained from the addition of varying amounts of

bentonite clay and peat, either separately or together, to various soils?

Problem analysis.--Before answering the major question, it is necessary to answer the following:

1. Is there an optimum content of clay in a soil for the production of carnations?

2. How will carnation plants be affected when bentonite clay is incorporated into the soil in amounts varying up to 20 per cent by weight?

3. How will carnation plants be affected when peat is incorporated into the soil in amounts varying up to 10 per cent?

4. How will the carnation plants be affected when varying amounts of both peat and bentonite clay are added to the soil?

5. How will the responses obtained from the addition of the bentonite clay and peat differ as the texture of the original soil is changed?

Delimitations.--In this study any differences in the carnation plants produced by the treatments were based upon four criteria: 1) the total number of flowers produced per plot, 2) an average of the individual weights of each flower produced on any one plot, 3) a total weight of plant material remaining at the conclusion of the study, and 4) the number of weeks required from planting time to produce 51 per cent of the total number of flowers

cut. The data were gathered from 120 individual plots containing 480 White Sim carnation plants. The results included all the flowers produced by these plants between September 1, 1952, and March 27, 1953. The experiment was conducted at the research greenhouses of the Colorado A. and M. Experiment Station. This study was limited to a study of two soils, each of which was representative of a soil type often found in commercial greenhouses in this area. The soils included a sample of the Valentine loamy sand series which was obtained southeast of Greeley, Colorado, and a sandy loam soil of unknown series found in the table mountain area west of Denver, Colorado.

In an effort to eliminate as many variables as possible, the following procedures were followed. Each soil mixture was mechanically mixed and pasteurized with steam after it had been placed on the bench. The supply of available plant nutrients and water was maintained at a sufficiently high level in all plots to minimize the effects from these factors.

Definition of terms.--Bentonite is used as a synonym for bentonite clay. This clay is a calcium saturated, expanding type clay which was obtained from a natural deposit of bentonite northwest of Fort Collins, Colorado.

Peat refers to a sedge peat from the high mountain valleys of Colorado. It is fairly well decomposed

and contains approximately 40 per cent organic matter.

The average weight of all flowers produced on any one plot was used as the criterion of quality. The flowers were cut at a uniform level, eliminating the possibility of variation due to height of cutting.

Clay level refers to that portion of the total oven dry weight of a soil which is composed of particles with a diameter smaller than 0.002 mm.

Chapter II

REVIEW OF LITERATURE

Although it is generally theorized that soil texture is important in the production of any crop, there has been little work actually published to substantiate such a theory. Since this is especially true with greenhouse crops, this review will be primarily concerned with the effect of soil texture on crops other than those normally grown in a greenhouse.

In general, the physical make-up of a soil is determined by a certain combination of its structure, consistency, porosity, cohesion, moisture, and texture. Of these six, texture is generally considered the one constant or unchangeable property of a given soil.

In the production of field crops any alteration in the texture would require incorporating into the soil many tons of the sand, silt, or clay. Except for extreme cases, the expense of such an operation would be prohibitive. However, in a greenhouse where most of the soil must be transported in from the field, the incorporation of certain texture-altering materials would require little increase in cost and conceivably could be of value.

This experiment was concerned with the study of the effects produced by changing a light sandy-textured greenhouse soil by the addition of clay and peat. Such a practice was first suggested in 1935 by Wilde (19), who stated that the deleterious effects of a coarse-textured soil might be offset by the addition of clay, peat, or forest mulch. Since that time little research has been reported on the results obtained from an actual alteration of soil texture. Instead, workers in this field have been primarily interested in the effects of soil texture on plant growth.

Stephenson (18) found that the heavier-textured soils have a greater base exchange capacity. This work was later confirmed by Harris and Drew (10) who also reported an increase in the water-retaining capacity in heavier-textured soils.

An experiment on the effect that the incorporation of equal volumes of peat have on the moisture-absorbing and retaining capacities of two soil types, a clay loam and a loamy fine sand, was carried on by Feustel and Byers (8). In both soils the water-holding capacity was increased at least 40 per cent. However, due to the proportional increase of the wilting coefficient, the addition of peat to the heavy soil was of little benefit. In the case of the sandy soil, though, it was their opinion that

the addition of peat resulted in a large enough increase in the moisture-holding capacity to be of value.

Russell (16) reported a study of the effect of texture on root growth of lupines grown in media of coarse sand, fine sand, silt, and kaolin. He concluded that the coarse sand and kaolin media were much better than either the fine sand or silt because of increased aeration.

Dunn and Lyford (6) attempted to find the exact effect of soil texture on plant growth. These workers ran exhaustive studies, using many types of plants and many soil textures. It was their opinion that yields are likely to be low in soils with very coarse textures, even if adequate moisture and nutrients are provided. The general conclusion of this work was that the effect of texture on plant growth is minor compared with the effect that texture has on aeration, moisture supply, structure, and other physical properties that are all-important in controlling plant growth.

O'Neal (13) concurred with the work reported by Dunn and Lyford. He maintained that texture affected soil permeability and that texture had affected not only the aggregation, but also the visible pores in a soil.

Gomness (9), working with Colorado greenhouse soils, could find no statistical correlation of texture with soil aeration. He did point out that his study was a survey of the conditions existing in 40 commercial ranges

and too many factors were uncontrolled. Gomness also did extensive work on the effect texture has on the quality of growth of carnations. Again he was unable to obtain any positive correlation between the two.

In work on the effect of soil texture on the growth of ponderosa pine, Holtby (11) found a significant increase in height of mature trees which were produced on clay soils.

Link and Culvert (12) reported a significant increase in the growth of Briarcliff roses grown in a media of half sand and half peat over roses which were grown in soil-peat mixtures or soil alone. They suggested that the difference was due to a more uniform moisture content and improved aeration.

Although Post and Howland (14) could find no significant differences in rose production on soils to which peat had been incorporated, these soils did remain loose and friable even at the end of three years, while the soils which contained no peat were compressed and hard. In addition, there was a large increase in root growth in the soils to which peat had been incorporated.

Ray and Shanks (15) studied effects of the incorporation into a greenhouse soil of manure, hay, stover, blue grass sod, sand, and cinders on the growth of carnations and roses. They were unable to obtain any significant differences in either carnation or rose production

when organic matter had been added to the soil, but they did get an increase in aeration on soil mixtures which contained the different types of organic matter as opposed to soil alone.

In a similar study, Gomness (9) was able to find a significant correlation between soil organic matter and the quality of carnations produced on these soils. He found that the higher the organic content of a greenhouse soil, the better the quality. Gomness also reported a significant positive correlation between organic matter content of a soil and pore space.

Chapter III

METHODS AND MATERIALS

A recent survey of soils in use in Colorado greenhouses (9) indicated that many of the soils were extremely sandy. The use of these poorly buffered soils which have a low base exchange capacity complicates the culture of greenhouse crops. To obtain information on the value of the addition of clay and organic matter to such soils, the following experiment was designed.

Preliminary studies

The first year's work consisted of preliminary studies covering a wide range of clay content in soils. This study was designed primarily to yield some information on which more detailed research could be based. Clay additions of 0, 10, 20, 30, and 50 per cent by weight were made to a sandy loam soil, which had an initial clay content of 15 per cent. There was also one mixture in which 100 per cent clay was used as the growing medium. Ten per cent peat by weight was added to one half of the mixtures; the other half received no additional organic matter. The soil mixtures were placed in 6-inch pots and pasteurized with steam. One rooted carnation cutting was planted in

each pot. Each treatment consisted of a total of 12 pots. After the carnations were grown for 4 months and harvested, determinations of total growth were made for the mixtures.

General procedures

Two soils were chosen to represent the two major soil types used for carnation production in Colorado. They were a sample of the Valentine loamy sand series obtained southeast of Greeley, Colorado, and a sandy loam found in the table mountain area near Golden, Colorado. The mechanical analyses of these soils by the Bouyoucos method (3) showed that the Valentine loamy sand contained approximately 5.2 per cent clay, 11.8 per cent silt, and 83.0 per cent sand. The sandy loam contained 16.5 per cent clay, 18.0 per cent silt, and 65.5 per cent sand. The soils contained 1.30 and 2.85 per cent organic matter, respectively, according to the soil organic matter determination outlined by Smith and Weldon (17).

Using these soils as the basic components of each mixture, the following soil, clay, and peat combinations were prepared on the basis of total weight of the mixture. Each combination was thoroughly mixed mechanically and pasteurized with steam. The clay was a sample of nearly pure calcium saturated bentonite which had been finely ground to permit an even dispersion throughout the

mixture. The peat was a finely-ground, low-grade, native peat with an organic matter content of 40 per cent.

Per cent original soil	Per cent clay added	Per cent peat added
100	0	0
95	5	0
95	0	5
90	10	0
90	5	5
90	0	10
85	15	0
85	10	5
85	5	10
80	20	0
80	15	5
80	10	10
75	20	5
75	15	10
70	20	10

Each set of soil mixtures contained 3 levels of added peat, 0, 5, and 10 per cent; and 5 levels of added clay, 0, 5, 10, 15, and 20 per cent of the total weight. In order that each treatment could be replicated 4 times, 120 individual plots were constructed in two benches 40 feet long by $3\frac{1}{2}$ feet wide. This was accomplished by

dividing each bench into 60 plots, 21 inches long and 16 inches wide, as shown in Figure 1. The dividers between the plots were constructed in such a manner that intermixing of soil or soil water was at a minimum.

To minimize the differences due to the availability of plant nutrients and soil moisture, these factors were maintained as near optimum as possible for all mixtures. Potassium was supplied every two months at the rate of 1 pound per 100 square feet. The nitrate content was maintained between 25 and 50 ppm. by liquid feeding each time the plot was watered. The acid soluble phosphorus content was in excess of 25 ppm. Soil tests were taken at regular intervals as a check on the availability of the nitrogen, phosphorus, and potassium contents of the soil mixtures. Each plot was watered when the soil moisture tension reached approximately 3 to 4 inches of mercury.

Six carnation cuttings were planted in each plot on July 1, 1952. As soon as each plant had become firmly established, the top portion was removed to promote lateral branching. The carnations were grown in a manner similar to that followed in commercial greenhouse ranges with one exception. No mulch of any type was used on the soil surface as such a practice would have affected the organic matter content of the mixtures.

Fig. 1.--Position of the various soil mixtures in randomized block arrangement.

20	8	15	30	27	4	13	2	12	23	26	9	21	18	16	1	7	14	29	19	11	25	3	5	17	6	22	10	28	2
15	26	23	24	9	12	1	28	19	7	17	11	2	30	21	25	16	3	10	5	8	6	29	13	20	22	4	18	27	14

12	1	23	3	25	16	13	19	20	5	21	26	9	17	10	27	6	30	14	11	28	2	24	7	22	8	29	4	15	18
29	27	1	20	10	21	11	8	14	25	2	18	4	23	30	7	17	13	26	22	24	9	28	15	16	12	6	3	5	19

INDIVIDUAL PLOTS ARE 21" X 16"

*NUMBERS 1-15 ARE MIXTURES OF THE VALENTINE SAND

*NUMBERS 16-30 ARE MIXTURES OF THE SANDY LOAM SOIL

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Although each plot contained a total of 6 plants, records were kept on only the 4 inside plants of each plot, as shown in Figure 2. The 2 outside plants in each plot were of the variety William Sim and the 4 test plants were of its color sport, White Sim. The practice of using the 4 inside plants on plots of this type was suggested by Beach (2) to reduce the variation in plant responses due to position of the plant.

Flowers were cut 3 times a week. The number of flowers cut from each plot and their individual weights were recorded at this time. To establish the green weight measurement on each plot, a measurement of the amount of plant material that remained at the conclusion of the experiment was needed. Since the state of turgidity of the individual plants is important when the green weight of plant material is taken, a special effort was made to weigh all plants at the same state of turgidity. Each plot was thoroughly watered 12 hours before weights were taken to allow plants to reach the maximum turgidity. Plants were cut off at the soil line and weighed the night of March 27, 1953.

An arbitrary measurement was established to ascertain the effect of soil texture on the speed of carnation growth. The number of weeks from planting time required to produce 51 per cent of total production was determined for each plot.

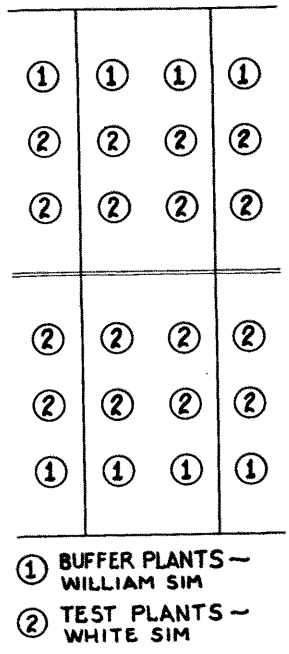

Fig. 2.--Position of test plants and buffer plants in each plot.

Study of some physical properties of soil mixtures

Since these prepared soils had been mixed only 8 months at the time the experiment was completed, an examination of a few of the physical properties of the mixtures was made to obtain some indication of future performance.

The organic matter content of the soils was determined by the method outlined by Smith and Weldon (17). The resulting mechanical analysis was made by the Bouyoucos method (3). The procedure outlined by Christiansen (4) was used to determine the percolation rate of each soil mixture.

Effects of addition of clay and peat as soil amendments on total number of irrigations required

Since irrigation of greenhouse carnations is normally done by hand, this process makes up a large share of the total labor required to produce a crop of carnations. Any decrease in the number of irrigations required during the growing of the crop would result in a corresponding decrease in the cost of production. The number of irrigations given each plot was recorded to determine what effects additions of peat and clay have on the water requirement of these soils. The only basis for determining when a plot needed water was the judgment of the author.

Statistical methods

The randomized block design was used for this experiment. Each treatment was replicated 4 times. The data were analyzed by the analysis of variance.

Chapter IV

ANALYSIS OF DATA

Results of preliminary studies

The first year's work consisted of a study of the effects of growing carnations in soils containing wide ranges of clay content. Clay additions of 0, 10, 20, 30, and 50 per cent were made to a sandy loam soil. There was also one mixture in which 100 per cent clay was used as the growing media. One half of the mixtures received 10 per cent peat by weight and the other half received no peat. The results are shown in Table 1.

Table 1.--PRELIMINARY STUDIES--THE EFFECT OF VARYING CLAY CONTENTS IN A SOIL ON THE GROWTH OF CARNATIONS.

Per cent clay added	Total weight[a] in grams	Per cent clay added	Total weight[a] in grams
0	548.6	30	548.7
10	544.9	50	522.4
20	507.5	100	356.3

[a]Total weight is the oven dry weight of 12 plants in each level

The addition of clay up to 50 per cent of the total weight produced no real differences in growth. The carnations grown in 100 per cent clay, however, showed a definite decrease in growth. There was little variation between the addition of 10 per cent peat and no additional peat. The pots containing 10 per cent peat produced a total of 1532.8 grams of carnation growth, while those without peat produced 1501.8 grams.

Results of second year studies

Three levels of native peat and 5 levels of clay were added to 2 soil types commonly found in Colorado carnation ranges. The following 4 criteria were established to measure the differences between treatments: 1) total number of flowers produced per mixture, 2) average weight of flowers, 3) total amount of plant material remaining on the plots at the conclusion of the experiment, and 4) a measurement of the effect of various treatments on speed of carnation growth. The last measurement was established as the number of weeks required to produce 51 per cent of the flowers.

Table 2 is a condensation of the results of each measurement on all 30 mixtures. The averages in the table are for 4 replications of each treatment.

Table 2.--EFFECTS OF ADDING DIFFERENT AMOUNTS OF CLAY AND PEAT TO SOILS ON NUMBER OF FLOWERS PRODUCED, AVERAGE WEIGHT OF FLOWERS, GREEN WEIGHT AT CONCLUSION OF EXPERIMENT, AND NUMBER OF WEEKS REQUIRED TO PRODUCE 51 PER CENT OF CROP.

Soil mixture	Mixture percentages: Per cent peat	Per cent clay	Per cent soil	Average no. of flowers produced	Average wt. of flowers in grams	Average green weight at conclusion in grams	Average no. of weeks required to produce 51 per cent of crop
Valentine sand							
1	0	0	100	20.7	22.39	1138.07	25.75
2	0	5	95	18.2	23.30	823.27	27.25
3	0	10	90	18.7	24.02	745.66	28.50
4	0	15	85	19.0	22.65	750.68	27.50
5	0	20	80	18.0	23.77	734.08	29.00
6	5	0	95	19.2	22.51	869.08	26.50
7	5	5	85	14.5	23.12	825.88	28.25
8	5	10	80	18.2	22.67	1008.73	26.50
9	5	15	75	17.2	21.35	1069.13	26.75
10	5	20	70	19.5	22.95	829.88	28.25
11	10	0	90	18.5	21.42	781.83	27.25
12	10	5	85	16.5	21.05	906.53	26.75
13	10	10	80	17.2	20.87	962.20	25.25
14	10	15	75	20.0	23.55	775.90	28.75
15	10	20	70	19.2	21.90	833.50	27.50

Table 2.--EFFECTS OF ADDING DIFFERENT AMOUNTS OF CLAY AND PEAT TO SOILS ON NUMBER OF FLOWERS PRODUCED, AVERAGE WEIGHT OF FLOWERS, GREEN WEIGHT AT CONCLUSION OF EXPERIMENT, AND NUMBER OF WEEKS REQUIRED TO PRODUCE 51 PER CENT OF CROP.--Cont.

Soil mixture	Mixture percentages: Per cent peat	Per cent clay	Per cent soil	Average no. of flowers produced	Average wt. of flowers in grams	Average green weight at conclusion in grams	Average no. of weeks required to produce 51 per cent of crop
Sandy loam							
16	0	0	100	19.0	21.61	1014.33	26.25
17	0	5	95	21.7	22.49	1030.08	26.75
18	0	10	90	20.7	22.69	1158.65	26.25
19	0	15	85	17.2	22.63	921.25	26.75
20	0	20	80	21.2	22.26	1005.32	27.25
21	5	0	95	21.7	22.19	1000.58	27.00
22	5	5	90	20.0	21.93	924.45	26.50
23	5	10	85	20.2	21.91	999.58	26.50
24	5	15	80	20.0	23.29	941.13	27.00
25	5	20	75	17.7	21.45	953.72	25.75
26	10	0	90	20.5	22.94	791.37	28.00
27	10	5	85	15.5	21.30	1006.10	26.00
28	10	10	80	19.7	21.68	835.85	26.75
29	10	15	75	17.5	22.33	896.55	27.25
30	10	20	70	19.7	21.90	847.40	26.25

Effects on carnation growth after addition of peat as a soil amendment

The yield data obtained from the addition of peat to Valentine sand and sandy loam soils are shown in Table 3. The addition of 10 per cent peat caused a reduction in mean weight of flowers and residual green weight when compared to mixtures containing no additional peat. Both reductions were severe enough to be significant at odds of 19 to 1. The addition of 5 per cent peat produced no significant differences from the control.

Table 3.--EFFECTS OF ADDITION OF PEAT TO SOILS ON CARNATION GROWTH.

Per cent peat added	Mean number of flowers per plot	Mean weight of flowers in grams	Mean green weight at conclusion in grams	Mean number of weeks to produce 51 per cent of crop
0	19.48	22.78	932.14	27.13
5	18.85	22.34	942.21	26.90
10	18.45	21.90	863.72	27.02
L.S.D. at 5 per cent level	NS	.55	64.01	NS

Effects on carnation growth after addition of clay as a soil amendment

The results of adding clay to the Valentine sand and sandy loam soils are shown in Table 4. The addition

of clay up to 20 per cent of the total weight had little effect on any of the measurements. There was a trend toward a decrease in residual green weight when either 15 or 20 per cent clay was added to the soil. This difference was not large enough to be considered statistically significant, nor was this trend obtained in any of the other 3 measurements.

Table 4.--EFFECTS OF ADDITION OF CLAY TO SOILS ON CARNATION GROWTH.

Per cent clay added	Mean number of flowers per plot	Mean weight of flowers in grams	Mean green weight at conclusion in grams	Mean number of weeks to produce 51 per cent of crop
0	19.96	22.18	932.54	26.79
5	17.75	22.20	919.38	26.91
10	19.17	22.31	951.78	26.71
15	18.50	22.64	892.44	27.33
20	19.25	22.37	867.32	27.33
L.S.D. at 5 per cent level	NS	NS	NS	NS

Effect of the two soil types on carnation growth

There was a wide variation in the productiveness of the sandy loam and Valentine sand soils, as shown in Table 5. The sandy loam soil showed a significant increase in number of flowers produced, residual green weight, and a

significant decrease in number of weeks required to produce 51 per cent of the crop. Only the average weight per bloom was not affected by the soil type used.

Table 5.--EFFECT OF THE TWO SOIL TYPES ON CARNATION GROWTH.

Soil type	Mean number of flowers per plot	Mean weight of flowers in grams	Mean green weight at conclusion in grams	Mean number of weeks to produce 51 per cent of crop
Valentine sand	18.33	22.50	870.29	27.35
Sandy loam	19.52	22.18	955.09	26.68
L.S.D. at 5 per cent level	1.12	NS	52.20	.47

Effect of the interaction between peat levels and soil types on carnation growth

Table 6 was compiled to show the effects of different peat levels on each soil. Residual green weight was the only growth factor with differences wide enough to be statistically significant. The addition of 10 per cent peat decreased growth more from sandy loam than from Valentine sand. Five per cent peat added to the Valentine sand significantly increased the green weight at the conclusion of the experiment. The residual green weight from the sandy loam soil decreased with each addition of peat.

Table 6.--EFFECT ON CARNATION GROWTH OF ADDING PEAT AS AN AMENDMENT TO EACH SOIL STUDIED.

Soil used and per cent peat added	Mean number of flowers per plot	Mean weight of flowers in grams	Mean green weight at conclusion in grams	Mean number of weeks to produce 51 per cent of crop
Valentine sand				
0	18.95	23.23	838.35	27.60
5	17.75	22.52	920.54	27.25
10	18.30	21.76	851.99	27.20
Sandy loam				
0	20.00	22.34	1025.92	26.65
5	19.95	22.16	963.89	26.55
10	18.60	22.03	875.46	26.85

Effect of the interaction between peat levels and clay levels on carnation growth

This interaction between peat levels and clay levels produced significant variation in the residual green weight and speed of growth measurements (Table 7). In both instances the greatest differences were found between the addition of 0 and 20 per cent clay, when no peat was added. There was also a wide difference between no addition of peat and 10 per cent addition, when no clay was added. These variations proved to be significant when individual comparisons were made.

The interaction had little effect on the number of flowers produced or the average weight of these flowers.

Table 7.--EFFECTS ON CARNATION GROWTH OF THE INTERACTION BETWEEN PEAT AND CLAY WHEN BOTH WERE ADDED TO SOILS.

Per cent clay added	Mean number of flowers per plot	Mean weight of flowers in grams	Mean green weight at conclusion in grams	Mean number of weeks to produce 51 per cent of crop
No addition of peat				
0	19.88	22.00	1076.20	26.00
5	20.00	22.89	926.68	27.00
10	19.75	23.35	952.15	27.40
15	18.13	22.64	835.96	27.10
20	19.63	23.01	869.70	28.10
5 per cent addition of peat				
0	20.50	22.35	934.83	26.70
5	17.25	22.53	875.16	27.40
10	19.25	22.29	1004.15	26.50
15	18.63	22.32	1005.12	26.90
20	18.63	22.20	891.80	27.00
10 per cent addition of peat				
0	19.50	22.18	786.60	27.60
5	16.00	21.17	956.31	26.40
10	18.50	21.27	899.02	26.30
15	18.75	22.94	836.23	28.00
20	19.50	21.90	840.45	26.90

Effect of the interaction between clay levels and soils on carnation growth

Table 8 is a compilation of the results obtained when the various clay percentages were added to each soil.

The addition of either 15 or 20 per cent clay delayed production on Valentine sand, while the same addition of clay had little effect on the sandy loam soil. These differences proved to be significant when individual comparisons were made within this interaction. The interaction between clay levels and soils produced no real differences in number of flowers, weight of flowers, or green weight at the conclusion of the experiment.

Table 8.--EFFECTS ON CARNATION GROWTH OF ADDING CLAY AS AN AMENDMENT TO EACH SOIL STUDIED.

Soil used and per cent clay added	Mean number of flowers per plot	Mean weight of flowers in grams	Mean green weight at conclusion in grams	Mean number of weeks to produce 51 per cent of crop
Valentine sand				
0	19.50	22.11	929.66	26.50
5	16.42	22.49	851.89	27.42
10	18.08	22.53	905.53	26.92
15	18.75	22.52	865.23	27.67
20	18.92	22.88	799.15	28.25
Sandy loam				
0	20.42	22.25	935.43	27.08
5	19.08	21.91	986.88	26.42
10	20.25	22.10	998.03	26.50
15	18.25	22.76	919.64	27.00
20	19.58	21.87	935.48	26.42

Study of some physical properties of soil mixtures

Clay and organic matter contents.--The clay contents of the various soil mixtures at the conclusion of the work are shown in Table 9. The discrepancy between the percentage clay added and actual clay recovered possibly lies in the fact that, although the clay was finely ground, many particles were larger than 2 microns, the upper size limit of the clay separate.

Table 9.--PER CENT SAND, SILT, AND CLAY IN SOIL MIXTURES AT CONCLUSION OF EXPERIMENT.

Soil mixture number	Per cent clay added	Average clay percentage	Average silt percentage	Average sand percentage
Valentine sand				
1,6,11	0	5.2	11.8	83.0
2,7,12	5	10.3	10.8	78.9
3,8,13	10	13.4	9.8	76.8
4,9,14	15	15.3	10.5	74.2
5,10,15	20	18.5	9.8	71.7
Sandy loam				
16,21,26	0	16.5	18.0	65.5
17,22,27	5	19.6	19.0	61.4
18,23,28	10	21.6	19.7	58.7
19,24,29	15	22.2	18.9	58.9
20,25,30	20	24.6	18.4	57.0

The average organic matter content of the mixtures at the conclusion of the experiment is shown in Table 10. The Smith and Weldon (17) determination of soil organic matter was employed.

Table 10.--PER CENT ORGANIC MATTER RECOVERED FROM SOIL MIXTURES AT THE CONCLUSION OF THE EXPERIMENT.

Soil mixture numbers	Per cent peat added	Per cent organic matter recovered
Valentine sand		
1-5	0	0.91
6-10	5	3.79
11-15	10	5.62
Sandy loam		
16-20	0	2.72
21-25	5	4.17
26-30	10	6.56

Effects of the addition of clay and peat on the percolation rate of the two soils.--An apparatus similar to the one described by Christiansen (4) was set up to measure the effect of clay and peat additions on the percolation rates of these soil mixtures. The addition of either material reduced the percolation rates of the mixtures (Table 11). Clay caused greater decreases in percolation rates than peat.

Table 11.--EFFECTS OF ADDITIONS OF CLAY AND PEAT ON THE PERCOLATION RATE OF 2 SOILS.

Soil mixture number	Per cent clay added	Per cent peat added	Average percolation rate in c.c. of H_2O per hour over a 6-hour period
Valentine sand			
1	0	0	350.0
2	5	0	309.6
3	10	0	215.6
4	15	0	160.0
5	20	0	109.0
6	0	5	426.0
7	5	5	230.3
8	10	5	187.0
9	15	5	132.7
10	20	5	66.2
11	0	10	251.3
12	5	10	212.7
13	10	10	103.4
14	15	10	92.3
15	20	10	58.7
Sandy loam			
16	0	0	235.0
17	5	0	221.7
18	10	0	131.0
19	15	0	63.9
20	20	0	52.0
21	0	5	169.8
22	5	5	97.0
23	10	5	86.3
24	15	5	81.3
25	20	5	81.0
26	0	10	250.6
27	5	10	131.7
28	10	10	77.5
29	15	10	75.3
30	20	10	45.6

Effects of the addition of clay and peat as soil amendments on the total number of irrigations required

The number of irrigations required by each plot was recorded throughout the experiment. Additions of peat decreased the number of irrigations required (Table 12).

Table 12.--EFFECT OF THE ADDITION OF PEAT ON THE NUMBER OF IRRIGATIONS REQUIRED TO PRODUCE A CROP OF CARNATIONS.

Per cent peat added	Mean number of irrigations required
0	27.25
5	25.72
10	24.15

Clay produced an opposite effect (Table 13). Each addition of clay up to 15 per cent caused a distinct increase in the number of waterings required.

Table 13.--EFFECT OF THE ADDITION OF CLAY ON THE NUMBER OF IRRIGATIONS REQUIRED TO PRODUCE A CROP OF CARNATIONS.

Per cent clay added	Mean number of irrigations required
0	23.37
5	24.42
10	25.62
15	27.75
20	27.46

Chapter V

DISCUSSION

In 1935, Wilde (19) suggested that the deleterious effects of a poor-textured soil might be offset by additions of clay, peat, or forest mulch. To examine such a suggestion further, this experiment was set up, using 3 different peat and 5 different clay levels on 2 soils.

The addition of native peat seemed to have a variable effect on the growth of carnations. An addition of 5 per cent by weight had little effect on either carnation yield or quality, with one exception (Table 6). The addition of 5 per cent peat to the Valentine sand resulted in a significant increase in the green weight measurement taken at the conclusion of the experiment. Since this measurement was established as an indication of the future flower production, the addition of peat might have increased carnation growth had this work been carried over a longer period of time. The 10 per cent addition of peat resulted in a severe reduction in the productiveness of the soil mixtures. These plots showed highly significant decreases in total number of flowers produced and average weight per bloom (Table 3). Such data were not in agreement with findings of Gomness (9), who reported a direct

correlation of soil organic matter and carnation quality; i.e., he found that the higher the organic matter content in a soil, the better the quality of the carnations produced on this soil. There are several possible explanations for these contradictory data. First, the organic matter content of a large part of the soils studied by Gomness had been built up gradually over a period of years, while the comparatively large additions of peat used in this work resulted in a sharp rise in soil organic matter content. Second, the 3.20 per cent organic matter, which was the highest percentage reported by Gomness, was considerably less than the 6.56 per cent organic matter recovered from the sandy loam soil after 10 per cent peat had been added.

The additions of clay produced little effect on the carnation growth indicating that carnations are tolerant to wide ranges of clay content in a soil. There were significant decreases in the residual green weight and speed of growth measurements when either 15 or 20 per cent clay was added without an addition of peat (Table 7).

The simultaneous addition of peat and clay reduced yield or quality less than separate additions of either material. This indicated modifying effects of one material on the other. However, in no instance did this simultaneous addition of both materials increase carnation yield or quality over the untreated soils.

Although the determination of the percolation rate of each mixture was merely a sideline of the major problem, and far from complete, some interesting facts were noted. The addition of native peat decreased the rates of percolation of the soil mixtures. Clay had an even more pronounced effect on soil permeability. Each succeeding addition of clay produced a mixture with a percolation rate lower than the mixture preceding it. Since clay is known to be very cohesive when wet, this decrease may have been caused by some of the macropores of the soil being sealed off by the clay, in which case less water could move through the soil.

Some interesting data were also obtained from the irrigation records of this work. The addition of peat resulted in a marked decrease in number of irrigations required during the experiment. This decrease was probably due to the moisture-retaining capacity of the peat as suggested by Feustel and Byers (8). It should be pointed out that the plots containing 10 per cent peat actually received less water than plots to which no peat had been added. Therefore, since tensiometers were not used to determine moisture tension, a lack of available water in these plots may have caused the reduction noted in the yield and quality.

The addition of clay resulted in an increase in number of irrigations required during the experiment.

Table 13 shows an increase in number of irrigations with each increase in clay content. Although clay, like peat, has a high moisture-retaining capacity, it also increases the wilting coefficient of the mixtures. In this manner, less water was available to the plants even though more moisture was retained in the soil.

In the final analysis the use of peat as a soil amendment seemed to have little beneficial effect on the particular soils studied in this work. However, there still remains the possibility that the use of small amounts of peat may have proved beneficial had this experiment been carried over a longer period of time. Such a possibility was at least implied in the results of Table 6, where the addition of 5 per cent peat produced a significant increase in the green weight at the conclusion of the experiment.

The use of clay seemed to have little value as a soil amendment. Additions of 5 and 10 per cent clay did not affect quality or growth measurements, but these additions decreased the permeability of both soils. Small amounts of clay could be of value in reducing excess leaching from coarse soils.

The differences in productivity of the two soils emphasize the importance of soil selection for greenhouse use.

Suggestions for further study

In the course of this investigation, several questions arose which seem to be important enough to warrant further research.

1. The effects of composting, for a few years, soil mixtures which contain various amounts of peat and clay should be studied. It is possible that composting the peat and clay with the soil would produce a soil mixture with far different properties from those obtained on a short-term experiment.

2. An evaluation of different peat types as soil amendments might yield some worth-while information.

3. An effort should be made to determine whether or not carnations can be grown in mixtures of clay and peat or clay, peat, and sand, thereby eliminating the wide variability found in greenhouse soils.

4. A more accurate study should be made to determine if the addition of peat to a soil decreases the number of irrigations required without reducing the yield or quality.

Chapter VI

SUMMARY

Additions of native peat at the rate of 0, 5, and 10 per cent by weight and 0, 5, 10, 15, and 20 per cent of bentonite clay were incorporated into 2 soils. The soils were samples of a sandy loam obtained from the table mountain area west of Denver, Colorado, and a Valentine sand obtained near Greeley, Colorado. Four criteria of measurement were established to determine differences between the various soil mixtures. These included: 1) the total number of flowers produced, 2) the average weight of flowers, 3) the green weight of the plants remaining at the conclusion of the experiment, and 4) a measurement of the rate of growth in each soil mixture. The percolation rate and the number of irrigations required by each soil mixture were also noted.

The use of native peat as a soil amendment produced a variable effect on carnation growth and development. In general, the 5 per cent addition of native peat produced little difference when compared to plots containing no additional peat. A significant increase in green weight was noted when 5 per cent peat was added to the Valentine sand soil. The addition of 10 per cent peat

caused significant decreases in average weight of flowers and residual green weight when compared with plots containing no peat. The decrease in growth was not as apparent when both clay and peat were added to each soil. The decrease in growth after the addition of 10 per cent peat was more significant on the sandy loam soil than on the Valentine sand.

The use of clay as a soil amendment produced little effect on carnation yield and quality. The additions of either 15 or 20 per cent clay reduced the rate of growth and the green weight measurements when no peat was incorporated into the soil.

The percolation rate of each mixture was reduced by the addition of either peat or clay.

The addition of clay increased the number of irrigations, while the addition of peat caused a decrease in irrigation required during the experiment.

A P P E N D I X

APPENDIX LIST OF TABLES

Table A.--TABLE OF VARIANCE FOR TOTAL NUMBER OF CARNATIONS.

Source of variation	D.F.	Mean squares	F-value observed	F-value 5 per cent point
Replications	3	22.78	2.39	2.70
Peat levels	2	10.68	1.12	3.09
Soils	1	42.01	4.41*	3.94
Clay levels	4	16.76	1.76	2.46
Peat X soils	2	9.16	----	----
Peat X clay	8	7.82	----	----
Soils X clay	4	9.51	----	----
Soils X clay X peat	8	32.35	3.40**	2.03
Error	87	9.52		
TOTAL	119			

Table B.--TABLE OF VARIANCE FOR AVERAGE WEIGHT OF CARNATIONS.

Source of variation	D.F.	Mean squares	F-value observed	F-value 5 per cent point
Replications	3	15.37	9.92**	2.70
Peat levels	2	7.80	5.03**	3.09
Soils	1	3.00	1.94	3.94
Clay levels	4	.80	----	----
Peat X soils	2	3.45	2.23	3.09
Peat X clay	8	2.75	1.77	2.03
Soils X clay	4	1.63	1.05	2.46
Soils X clay X peat	8	2.44	1.58	2.03
Error	87	1.55		
TOTAL	119			

Table C.--TABLE OF VARIANCE FOR GREEN WEIGHT OF CARNATIONS.

Source of variation	D.F.	Mean squares	F-value observed	F-value 5 per cent point
Replications	3	219,792.93	10.63**	2.70
Peat levels	2	72,860.72	3.53*	3.09
Soils	1	215,540.19	10.43**	3.94
Clay levels	4	26,566.93	1.29	2.46
Peat X soils	2	80,303.09	3.89*	3.09
Peat X clay	8	52,999.68	2.56*	2.03
Soils X clay	4	18,650.27	.90	2.46
Peat X soil X clay	8	51,370.90	2.49*	2.03
Error	87	20,670.97		
TOTAL	119			

Table D.--TABLE OF VARIANCE FOR SPEED OF CARNATION GROWTH.

Source of variation	D.F.	Mean squares	F-value observed	F-value 5 per cent point
Replications	3	3.15	1.86	2.70
Peat levels	2	.51	----	----
Soils	1	13.34	7.89**	3.94
Clay levels	4	2.14	1.26	2.46
Peat X soils	2	.92	----	----
Peat X clay	8	4.05	2.40*	2.03
Soils X clay	4	4.65	2.75*	2.46
Soils X clay X peat	8	2.01	1.19	2.03
Error	87	1.69		
TOTAL	119			

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