STUDIES ON GROWING CERTAIN VEGETABLE PLANTS IN VARIOUS CONTAINERS

THESIS FOR THE DEGREE OF M. S.

Charles Fuller

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THESIS

Vegetable gardening

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THESIS

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Studies on Growing Certain Vegetable Plants in Various Containers.

Introduction:

Seventeen major truck crops with a value of more than $250,000,000.00 were grown in the United States in 1928. Of this lot, a large number are started as seedlings in individual containers and later transplanted in the greenhouse for forcing or out of doors for field or garden crops. This method of handling plants is a common practice with progressive growers. Many types of plant containers are used for this purpose, and growers and investigators have observed, under certain conditions, that the containers appear to have a direct influence on the plants grown in them. For instance, plants grown in paper containers have a tendency to become yellow, as though suffering from an inadequate supply of nitrogen, when heavy types of soil are used. Root injury also has been attributed to the influence of the container, and peat planting pots have been reported by some, as having a deleterious effect on plant growth, while others claim they have unusual merit as containers in which to start plants.

Review of Literature:

Knott (1) compared the growth of tomatoes started in certain types of peat pots and in clay pots. In all cases the more desirable type of growth occurred in the clay pots. Plunging peat pots in soil or peat moss increased the growth but did not secure satisfactory results. When peat pots were soaked in liquid manure there was no marked increase in size of plants. On the other hand, when an amount of liquid manure equivalent to that taken up by the peat pots was added to soil in clay pots a 20 per cent increase in size of plants occurred.

Thompson (2), working with peat pots and growing ten different crops, reports peat pots to be less satisfactory than clay pots in the same experiment. The roots failed to penetrate the peat and the high acid content of these pots was considered as a contributory cause for the unfavorable results. Other workers, Koyler (3) and Edmond (4), obtained somewhat favorable results. In some cases plants grown in peat pots were earlier and more vigorous than those grown in other types of plant containers.

Another investigator, Laurie (5), reports that even though peat pots were satisfactory from a cultural standpoint, their use would be neither economical nor practical for greenhouse floral crops. Better or equivalent results may be obtained by judicious use of bulk peat either as a component of the soil or as a mulch on the bench or greenhouse beds. Another writer (6) states plants were grown in two types of peat pots and in fiber and clay pots placed on open ground in shady places and covered with sand. Roots grew freely through the peat pots and to some extent through the fiber pots. More nitrates were needed for the peat pots than for other types of pots. This additional plant nutrient supply was compensated for by the ease and rapidity with which the peat pots could be handled when transplanting.

Krebs (7) reports unsatisfactory results with cabbage and muskmelons when grown in "Growell" peat pots, but found they grew excellent tomato plants. Growell Pot Company Inc. (8) claim the acid condition in the "Growell" pots is favorable for horticultural farming; they are sterile, free of fungus and weed seed; and are highly absorptive, being capable of holding ten or fifteen times their weight in moisture. The peat has an affinity for ammonia or will readily absorb any nutrient solution desirable for the type of plants to be grown. J. F. M. (9), a grower, reports satisfactory results growing tomato plants in plunged "Growell" peat pots. Knott (10) in discussing paper pots states that a gradual yellowing of foliage occurs with a subsequent check in plant growth. This condition is more prevalent when heavy types of soil are used; moisture is held in contact with the paper and decay is more rapid than when porous sandy soils are used. This worker suggests that perhaps bacteria working in the decaying paper rob the plants of nitrate, thus causing the yellowing foliage and poor growth. Both growers (11) and other investigators have noted conditions similar to those reported by Knott, and in addition report difficulty in removing the paper bands or pots when transplanting and that more careful handling is necessary than for plants grown in clay pots. Edmond and Lewis (12), after experimenting with a nutrient solution on cabbage, show that growth, time of maturity and quality of plants are directly influenced by the presence of readily available nutrients. They suggest, from their results, that gradually

available nutrient materials may be applied in combination early in the season with satisfactory results. Crist (13) found the variety of lettuce with which he worked to be more sensitive to alkalinity than to acidity, and states that any detrimental effects of untreated acid soil seemed to be due more to improper nutrient conditions than to the acidity itself.

Experiment With Lettuce

Materials and Methods:

Grand Rapids forcing lettuce was grown in flats from which plants of uniform size and vigor were selected and grown in several types of plant containers, namely: Clay pots, paper pots, "Neponset" paper pots, "Fertex" fiber pots, paper bands, wood bands, "Peco" peat pots, "Growell" peat pots and "Fertex Sparkling Red" pots.

Twenty pots were included in each treatment. The potted plants were placed on a greenhouse bench from March 2 until April 6, a period of 35 days. On April 6, 10 plants from each group, selected as representative, were cut and weighed. The remaining 10 plants of each group were transplanted into the cold frame bed, remaining there from April 6 until May 5, a period of 29 days.

The peat pots and "Fertex" fiber pots were set into the cold frame bed with the plants. Other types of containers were removed from the ball of roots and soil and no fragments of paper or wood went into the bed with the plants.

The time plants were in pots (March 2 until April 6) is designated in tables and discussions as the "potting stage" and the period they were grown in the cold frame (April 6 to May 5) is designated as the "cold frame stage." The containers with various methods of treating them are listed in table 1.

Table 1. Containers and Treatments Included in the Lettuce Experiment

Series No.	Containers	Treatments
1.	Clay pots (4")	Untreated check.
2.	"Neponset" paper pots	Untreated.
3.	"Growell" peat pots	Untreated.
4.	Paper bands	Untreated.
5.	"Peco" peat pots	Untreated.
6.	Paper pots	Untreated.
7.	"Fertex" fiber pots	Untreated.
8.	Beechwood bands	Untreated.
9.	Basswood bands	Untreated.
10.	"Fertex Sparkling Red" Pots	Untreated. (Clay pot substitute)
11.	"Neponset" paper pots	Paraffin treated.
12.	Paper bands	Paraffin treated.
13.	Paper pots	Paraffin treated.
14.	Beechwood bands	Paraffin treated.
15.	Paper pots	Lime treated.
16.	"Growell" peat pots	Lime treated.
17.	"Peco" peat pots	Lime treated.
18.	Paper bands	Lime treated.
19.	"Neponset" paper pots	Lime treated.
20.	Beechwood bands	Lime treated.
21.	"Peco" peat pots	Soaked in nutrient solution before using.
22.	"Neponset" paper pots	Peco nutrient treatment on plants.
23.	Paper bands	Peco nutrient treatment on plants.
24.	Paper pots	Peco nutrient treatment on plants.
25.	"Fertex" fiber pots	Peco nutrient treatment on plants.
26.	Clay pots (4")	Peco nutrient treatment on plants.
27.	Beechwood bands	Peco nutrient treatment on plants.
28.	"Growell" peat pots	Soaked in nutrient solution before using.
29.	"Neponset" paper pots	Growell nutrient treatment on plants
30.	Paper bands	Growell nutrient treatment on plants
31.	Paper pots	Growell nutrient treatment on plants
32.	"Fertex" fiber pots	Growell nutrient treatment on plants
33.	Clay pots (4")	Growell nutrient treatment on plants
34.	Beechwood bands	Growell nutrient treatment on plants
35.	"Peco" peat pots	Plunged in sand.
36.	"Growell" peat pots	Plunged in sand.

Note: 20 containers were included in each treatment; 4" size being used throughout.

Nutrient Solution.

A nutrient solution which was found satisfactory by Edmond and Lewis (12) in an earlier experiment with cabbage, was used in this experiment. The solution was made up as follows:

1. Calcium nitrate ($Ca(NO_3)_2$)------200 grams
   Potassium nitrate (KNO_3)-------- 50 grams
   Potassium chloride (KCl)-------- 25 grams
   Made up to 2 liters.
2. Monopotassium phosphate (KH_2PO_4)50 grams---made up to 2 liters.
3. Magnesium sulphate ($MgSO_4$)-------50 grams--made up to 2 liters.

The above stock solutions were prepared for application by placing 100 cc. of each in a 7-liter jar, with ordinary tap water added to fill jar. Iron was supplied by adding 14 cc. of a one per cent solution of ferrous citrate to each 7 liters of solution.

Treating Pots.

Nutrient Treatments.

Ten "Peco" peat pots and 10 "Growell" peat pots were selected at random from the peat pots used in the experiment. These pots were thoroughly saturated with the nutrient solution described above. The peat pots were allowed to dry, drip free, were weighed separately, and the average weight per pot was calculated and recorded as indicated in Table 2.

Table 2. Average Dry Weights of Peat Pots and Average Weights of Peat Pots Saturated with Nutrient Solution.

	Average dry weight per pot	Average weight per pot after nutrient treatment	Nutrient solution taken up by pots.	Percentage increase in weight.
	gr.	gr.	gr.	
1. "Peco" peat pots	43.6546	338.6825	295.0279	575.8
2. "Growell" peat pots	31.2465	164.5379	134.1887	329.4

All peat pots were treated before using. The weight of the nutrient solution absorbed, as shown in the table, was used as a basis for making nutrient treatments on other types of containers. Treatments on other types of containers were started two weeks after plants were potted.

In one series, each plant was treated with nutrient solution equivalent to that absorbed by "Peco" peat pots, applying 50cc. on alternate days until the amount designated in Table 2 had been applied. (In discussions, and in tables these treatments are designated as "Peco Nutrient Treatment"). A similar series of treatments were made, based on the amount of nutrient solution absorbed by "Growell" peat pots, and are designated in tables and discussions as "Growell Nutrient Treatment."

Lime Treatments.

Lime treatments were made by thoroughly soaking the containers in a saturated lime ($CaCO_3$) solution.

Paraffin Treatments.

Paraffin treatments were made by dipping the containers into a tank of melted paraffin.

Determination of pH. Values of Containers and Other Materials Used.

Seven containers were selected at random from among each of the various types of containers used. These containers were oven treated at 95°C. for a period of 36 to 48 hours, after which they were finely pulverized and a sample taken from each and placed in a closed specimen bottle to be used in making the pH. determinations. Three grams of each sample were placed in separate beakers with 150 cc. of distilled water. The contents of the beakers were stirred vigorously to moisten thoroughly all particles of the sample, thus insuring maximum extraction. After a period of 24 hours the extracts were filtered off and used in making the pH. determinations. Other materials used were treated the same as the containers. Paraffin-treated containers were excluded from the oven treatment. The Colorometric Method of determining pH. values was used.

An average of the pH values of each type of container or material used is shown in Table No. 3.

Table No. 3. Showing pH. Values of Containers and Materials Used.

Container or Material	Treatments	pH. Reading
1. Clay pots	New-Unused	7.8
2. Basswood bands	Untreated	6.6
3. Beechwood bands	Untreated	5.7
4. "Neponset" paper pots	Untreated	6.8
5. Paper bands	Untreated	5.9
6. "Fertex" fiber pots	Untreated	8.4
7. Clay pots	Old-Used	6.6
8. "Peco" peat pots	Untreated	4.0
9. "Peco" peat pots	Lime treated	6.9
10. "Peco" peat pots	Nutrient treated	6.0
11. "Peco" peat pots	Used	4.5
12. "Growell" peat pots	Untreated	4.5
13. "Growell" peat pots	Lime treated	6.5
14. "Growell" peat pots	Nutrient treated	6.0
15. Beechwood bands	Paraffin treated	5.6
16. Beechwood bands	Lime treated	6.5
17. "Neponset" paper pots	Paraffin treated	6.6
18. "Neponset" paper pots	Lime treated	7.8
19. Potting soil	Untreated	7.0
20. Potting soil 1/5 lime treated Michigan peat		7.5
21. Michigan peat	Untreated	4.8
22. Michigan peat	Lime treated	7.1
23. German peat	Lime treated	7.0
24. German peat	Untreated	3.7
25. Nutrient Solution		6.6
26. Paper pots-Used-Decayed		7.1
27. "Peco" peat pots-Used-Plunged in neutral sand		4.6

Plate I. Figs.1-4.- Lettuce plants grown in ordinary potting soil in (1) untreated clay pots, (2) untreated "Peco" peat pots, (3) untreated "Growell" pots and (4) untreated "Neponset" paper pots.

Presentation of Results.

The results set forth in this paper are based primarily on: A. The comparative average weight of plants at the end of the potting stage, or when removed from the containers and set into the cold frame bed; B. The comparative weight of plants at the end of the cold frame stage, or at the time the plants were harvested; C. The percentage of increase in weight of plants during the cold frame stage, or the increase in weight of plants after they were removed from the direct influence of the containers.

The results with untreated containers are shown in table 4.

Table 4. Influence of Untreated Containers on Growth of Lettuce.

No.	Containers	Treatments	Average weight per plant at end of potting stage gr.	Average weight per plant at end of cold frame stage gr.	Percentage of increase in weight during the cold frame stage
1.	Clay pots (Check)	Untreated	9.55	213.5	2135.6
2.	"Neponset" paper pots	Untreated	3.15	147.8	4592.0
3.	"Growell" peat pots	Untreated	3.61	127.7	3437.3
4.	"Fertex Sparkling Red"[1]	Untreated	4.13	153.3	3369.7
5.	Paper bands	Untreated	6.90	230.0	3233.3
6.	"Peco" peat pots	Untreated	8.00	235.9	2848.7
7.	Paper pots	Untreated	5.94	172.5	2040.4
8.	"Fertex" fiber pots	Untreated	12.66	264.3	1908.7
9.	Beechwood bands	Untreated	20.26	321.9	1488.8
10.	Basswood bands	Untreated	26.03	368.0	1313.7

1. A pot devised as a substitute for clay pots.

Discussion:

"Fertex" fiber pots (No. 8) and wood bands (No. 9 and

No. 10) produced markedly heavier plants than clay pots (No. 1) during the potting stage, while the clay pots (check) produced heavier plants during this stage than other types of containers. Plants grown in "Fertex" fiber pots and in wood bands also produced heavier plants during the cold frame stage and showed lower percentages of gain after being removed from the effects of the containers, than did plants grown in untreated clay pots. In other words clay pots had a slightly retarding effect on plant growth when compared with "Fertex" fiber pots and wood bands.

The wood bands contained a greater volume of soil than other containers and it is claimed that nutrients are contained in the "Fertex" fiber pots. These conditions no doubt have been responsible for the more vigorous growth of plants in "Fertex" fiber pots and wood bands. Beechwood bands decayed to some extent and the soil adhered badly to the wood resulting in some root pruning when removing this container from the ball of soil. Basswood bands remained free from decay or fungus attack during the potting stage. The soil did not adhere to the wood, but separated cleanly and no root injury occurred. The basswood bands were clean, unharmed, and in excellent condition for further use while the beechwood bands broke apart readily when removed from the ball of soil and were useless. The superior results secured with basswood bands (No. 10) over beechwood bands (No. 9) may be attributed to the fact that basswood bands withstood decay, thus reducing bacterial or fungus development and the clean separation of soil and wood resulted in less disturbance of roots when transplanting.

"Neponset" pots, paper pots, peat pots, and paper bands show a decidedly retarding effect on growth of plants during the potting stage, when compared with plants grown in clay pots. In each case the percentages of increase in size of plants during the cold frame stage is markedly greater, indicating that these containers to have a more deleterious effect on plant growth than untreated clay pots.

Apparently the greater the retarding effect, that is, the smaller the plants were in the containers during the potting stage the greater was the percentage of increase in weight when the plants were removed from the influence of the container. In other words there was no long continued residual effect from these containers, as the plants, when removed from their immediate influence, at once began to make rapid growth.

These results conclusively indicate that containers have a direct influence on the plants grown in them. This influence is deleterious to a marked degree in certain of the containers. Those containers having the least retarding effect on the growth of lettuce plants during the potting stages also produced the heavier more profitable plants when harvested at the end of the cold frame stage.

Nutrient Treated Containers.

A series of containers were soaked in nutrient solution before using and the results compared with nutrient treated plants grown in similar containers and in untreated containers, as shown in Table No. 5.

Table No. 5. Comparing the Growth of Lettuce Plants in Nutrient-Treated Containers with Nutrient-treated Plants and Untreated Containers.

No.	Containers Treatments	Average weight per plant at end of potting stage gr.	Average weight per plant at end of cold frame stage gr.	Percentage increase in weight during cold frame stage
1.	Clay pots Untreated (Check)	9.55	213.5	2135.6
2.	Clay pots-with "Peco" nutrient treatment on plants	18.11	299.7	1554.5
3.	Clay pots-with "Growell" nutrient treatment on plants	11.60	259.4	2136.2
4.	"Peco" peat pots untreated	8.00	235.9	2848.7
5.	"Peco" peat pots soaked in nutrient solution before using	16.66	351.0	2006.8
6.	"Growell" peat pots untreated	3.61	127.7	3437.7
7.	"Growell" peat pots soaked in nutrient solution before using	13.20	230.7	1647.7
8.	Beechwood bands untreated	20.26	321.9	1438.8
9.	Beechwood bands with "Peco" nutrient treatment on plants	30.26	415.0	1271.4
10.	Beechwood bands with "Growell nutrient treatment on plants	22.90	325.6	1321.8
11.	Paper bands--untreated	6.90	230.0	3233.3
12.	Paper bands-with "Peco" nutrient treatments on plants	20.63	375.8	1721.6
13.	Paper bands-with "Growell" nutrient treatments on plants	20.12	358.8	1683.3
14.	Paper pots-untreated	5.94	172.5	2040.4
15.	Paper pots-with "Peco" nutrient treatments on plants	19.80	366.2	1749.4
16.	Paper pots-with "Growell" nutrient treatments on plants	19.02	291.3	1431.5
17.	"Neponset" paper pots--untreated	3.15	147.8	4592.0
18.	"Neponset" paper pots-with "Peco" nutrient treatments on plants	5.14	208.2	3989.5
19.	"Neponset" paper pots with "Growell" nutrient treatments on plants	4.03	185.3	4495.5
20.	"Fertex" fiber pots-untreated	12.66	264.3	1908.7
21.	"Fertex" fiber pots-with "Peco" nutrient treatments on plants	18.00	304.0	1588.8
22.	"Fertex" fiber pots-with "Growell" nutrient treatments on plants	17.32	276.0	1493.5

Plate II. Figs. 5-8.- Lettuce plants grown in ordinary potting soil in (5) untreated clay pots, (6) untreated paper bands, (7) untreated paper pots and (8) untreated beechwood bands.

Discussion:

Nutrient treatments have resulted in marked increases in weight of plants during the potting stage, when compared with plants grown in untreated containers, in every case, excepting with "Neponset" paper pots. These gains are most pronounced on peat and paper containers. "Neponset" paper pots gave very unsatisfactory results untreated, or with nutrients applied on plants (No. 17, No. 18 and No. 19), yet marked increases in percentages of gain occurred during the cold frame stage, after removal from the influence of the pot.

The heaviest plants grown during the potting stage and during the cold frame stage and the lowest percentage of gain in weight after removing the influence of the containers is shown for wood bands (No. 8, No. 9, and No. 10), indicating these containers to have less influence on plant growth, under conditions of this experiment, than other containers used.

The percentage of increases is much less pronounced when nutrients were used than for untreated containers and it appears that any deleterious effect on plant growth that may be due to the containers themselves may be overcome, to a considerable degree, by the use of nutrients. In other words the materials of which the containers are made may, through absorption, deprive the plants of the necessary nutrients, thus causing the plants to appear subnormal in size. Soil organisms active in breaking down the materials of which the containers are made may utilize the nutrient materials to such an extent as to retard plant growth. It appears to be a definite nutrient problem for when nutrients are provided, plant development proceeds in a normal manner.

Effect of Containers on Yield and Cash Value of Produce.

Calculations were made from the data in Tables 4 and 5 to show the comparative value of untreated containers and nutrient-treated containers, based on yield and cash returns from each. Nutrient treatments were made as described on page 7. The plants were all grown in containers for an equal length of time and in the cold frame for an equal period. When harvested at the end of the cold frame stage the lettuce was sold for .075 cents per pound. Comparative yields in pounds and cash returns for lettuce from untreated and treated containers are shown in table 5-A.

Plate III. Figs. 9-12.- Lettuce plants grown in ordinary potting soil in (9) untreated clay pots, (10) untreated "Fertex" fiber pots, (11) untreated "Fertex Sparkling Red" pots and (12) untreated basswood bands.

Table 5-A. Comparative Yields and Cash Returns from Lettuce Plants Grown in Untreated Containers and in Nutrient Treated Containers; with Percentage of Increase in Cash Value of Produce Due to the Nutrient Treatments.

No. Containers.	Yield 10 plants lbs.	Cash returns 10 plants	Yield 10 plants lbs.	Cash returns 10 plants	Percent of increase in cash returns due to nutrient treatments.
1. Beechwood bands	7.08	$0.531	8.14	0.609	12.80
2. Basswoos bands	8.09	.607	8.09	.607	Untreated
3. Paper bands	5.06	.379	8.09	.607	37.56
4. "Peco" peat pots	5.19	.389	7.72	.580	32.93
5. Paper pots	3.97	.284	7.23	.542	47.60
6. "Fertex" Fiber pots	5.81	.435	6.38	.518	16.02
7. Clay pots (Check)	4.70	.353	6.15	.416	23.59
8. "Growell" peat pots	2.81	.210	5.07	.380	44.77
9. "Neponset" paper pots	3.25	.243	4.33	.325	25.23
10. "Fertex Sparkling Red" pots	3.37[1]	.245	3.37	.245	Untreated

1 Clay pot substitute

There is no doubt but that under conditions of this experiment, untreated wood bands have produced outstandingly better lettuce plants than other untreated containers used; with basswood bands producing remarkably heavier plants than the beechwood bands. Plants grown in beechwood bands show satisfactory gains from nutrient treatments. The remarkable response of plants, grown in paper and peat containers, to nutrient treatments seems to indicate that these types of containers must have a constant supply of readily available nutrients present if profitable plants are produced. Plants grown in untreated basswood bands show practically as great a yield and cash return as those grown with nutrient treatments in beechwood bands. From these results, it appears, the plants grown in the wood bands were making nearly maximum growth, therefore, they show less response to the nutri-

ent application than plants retarded or set back because of the influence of the containers in which they were grown. "Fertex" fiber pots, "Peco" peat pots and paper bands show yields above the average of the untreated containers. Plants grown in the "Fertex" fiber pots made comparatively small response to nutrient treatments and have yielded above the average in the nutrient-treated series. Clay pots have yielded below the average in both the untreated series and the nutrient-treated series.

From the results of this experiment lettuce plants were most satisfactory when started in wood bands and paper bands indicating, perhaps, that band types of containers are more satisfactory for certain plants than pots.

Lime-Treated Containers.

A series of containers were soaked in a solution of lime ($CaCO_3$) until thoroughly saturated and the results compared with untreated containers.

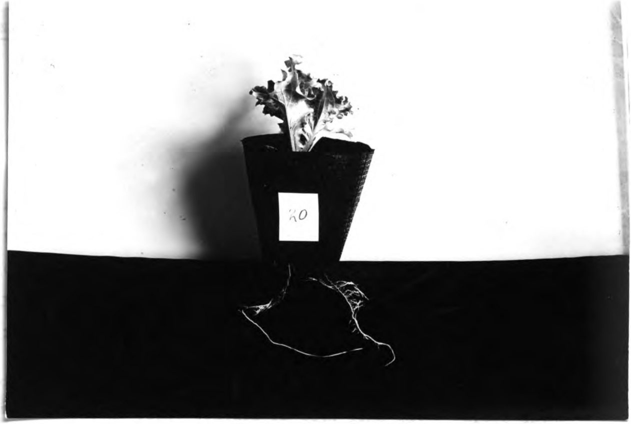


Plate V. Fig 20.- Showing characteristic top and root growth of lettuce plants grown in "Growell" peat pots, plunged in sand during the potting stage.

Table 6.- Effect on Growth of Lettuce of Treating Various Plant Containers with Lime

No.	Containers	Treatments	~~Average~~ weight per plant at end of potting stage gr.	Average weight per plant at end of cold frame stage gr.	Percentage of increase in weight during cold frame stage	pH. Reading
1.	Paper pots	Lime treated	4.61	274.4	5852.2	6.6
2.	Paper pots	Untreated	5.94	172.5	2040.4	5.9
3.	Paper bands	Lime treated	5.33	205.3	3750.4	6.6
4.	Paper bands	Untreated	6.90	230.0	3233.3	5.9
5.	"Neponset" paper pots	Lime treated	3.48	76.6	2101.1	7.6
6.	"Neponset" paper pots	Untreated	3.15	147.8	4592.0	6.8
7.	Beechwood bands	Lime treated	16.33	341.4	1990.6	6.5
8.	Beechwood bands	Untreated	20.26	321.9	1488.8	5.7
9.	"Peco" peat pots	Lime treated	5.62	212.0	3824.4	6.9
10.	"Peco" peat pots	Untreated	8.00	235.9	2848.7	4.0
11.	"Growell" peat pots	Lime treated	3.33	181.1	5338.4	6.6
12.	"Growell" peat pots	Untreated	3.61	127.7	3437.3	4.5

Discussion:

Treating plant containers with lime water before using has in nearly every case raised the pH. value of the containers near to that commonly considered the optimum (slightly acid) for growth of lettuce; yet in general a retarding influence on plant growth has been evident during the potting stage, when compared with untreated containers. Correspondingly greater percentages of increase in weight of plants occurred during the cold frame stage after removal of the effects of the containers.

From these results it is evident that lettuce may be grown in relatively low acid media under certain conditions, such, for instance, as the untreated peat planting pots (No. 10 and No. 12).

The "Peco" peat pots in this instance had a pH. value of 4.0, yet when plunged in neutral sand and used to grow lettuce during the potting stage the pH. value was raised from 4.0 to 4.6 (No. 27-Table #2). It appears that the acidity of the containers was not greatly changed during the potting stage and probably would not be changed to any extent during the cold frame period; therefore, the low pH. values had a less deleterious effect on plant growth than those just below the neutral point as in treatment No. 9 and No.11.

Lime treatments in themselves probably have created a more nearly optimum condition in the containers for the activity of soil organisms. Consequently, they have consumed correspondingly greater amounts of available nutrients in the lime-treated pots, thus retarding plant growth during the potting stage. When, however, the plants were all placed in the cold frames under conditions in which plant nutrients were abundant plants grown in lime-treated containers or in lime-treated planting pots, in general, show remarkably greater percentages of increase in weight than plants grown in untreated containers. It, therefore, appears that the pH. factor of a container may be only indirectly responsible for poor plant growth and in any case the condition may be readily overcome by the presence of nutrient materials. This is indicated by results with nutrient-treated containers (treatments 5 and 7, table 5) wherein it is shown that any detrimental effect that may be due to the low acid reaction of the peat pots is overcome to a marked degree by nutrients.

On the other hand, "Fertex" fiber pots (treatments 21 and 22, table 5) with alkaline reaction show also an increase in weight of plants when nutrients are applied.

Plate V. Fig 21.- Showing characteristic top and root growth of lettuce plants grown in "Peco" peat pots plunged in sand, during the potting stage.

Paraffin-Treated Containers.

Certain investigators have suggested that yellowing foliage and poor growth of plants in paper containers as possibly being due to the consumption of nutrients by the bacteria in the decaying paper. To prevent the decay of containers and possibly eliminate yellowing foliage and poor plant growth, several types of containers were dipped in melted paraffin before using and the effect on plant growth compared with untreated containers (Table 7).

Table 7.- Comparative Results Obtained with Lettuce Using Paraffin-Treated and Untreated Containers.

No.	Containers	Treatments.	Average weight per plant at end of cold frame stage gms.	Average weight per plant at end of cold frame stage, gms.	Percentage of increase in weight during cold frame stage
1.	"Neponset" paper pots--	paraffin treated	3.61	173.3	4700.6
2.	"Neponset" paper pots--	untreated	3.15	147.8	4592.0
3.	Paper bands	paraffin treated	6.36	214.6	3274.2
4.	Paper bands	untreated	6.90	230.0	3233.3
5.	Paper pots	paraffin treated	6.28	184.0	2256.6
6.	Paper pots	untreated	5.94	172.5	2040.4
7.	Beechwood bands	paraffin treated	15.91	325.7	1947.1
8.	Beechwood bands	untreated	20.26	321.9	1488.8

The paraffin-treated containers remained clean and free from decay or discoloration throughout the potting stage. (See #47 Plate VI, #52 Plate VII and #57 Plate VIII). In no instance noted did roots penetrate the paraffin-treated materials. These treatments, however, had a slightly retarding effect on plant growth during the potting stage, when compared with untreated containers. In every case plants grown in paraffin-treated containers show a greater percentage of increase in weight during the cold frame stage or after removal from the direct influence of the containers than is shown for plants grown in untreated containers.

Slight discoloration of roots occurred in paraffin-treated "Neponset" pots and in paper pots, due, no doubt, to the fact that drainage vents were not made in these containers after dipping in paraffin. Further, it is probable the paraffin treatments reduced aeration of soil and roots which together with the lack of drainage have been factors causing the unsatisfactory results with paraffin-treated containers.

Peat Pots Plunged in Sand.

Knott[1] concludes plunging peat pots in soil or peat moss did not give satisfactory results. In this experiment peat pots were plunged in neutral sand and compared with untreated peat pots. The results are shown in Table 8.

Table 8.- Comparative Results with Lettuce Grown in Plunged Peat Pots and Untreated Peat Pots.

No.	Container	Treatments	Average weight per plant at end of potting stage, gms.	Average weight per plant at end of cold frame stage, gms.	Percentage of increase in weight during cold frame stage
1.	"Peco" peat pots,	plunged in sand	4.00	177.0	4325.0
2.	"Peco" peat pots,	untreated	8.00	235.9	2848.7
3.	"Growell" peat pots,	plunged in sand	4.83	185.4	3738.5
4.	"Growell" peat pots,	untreated	3.61	127.7	3437.3

Seven-inch clay pots were used for this experiment. The peat pots were soaked in tap water, allowed to dry until they could be handled without crushing, at which time the plants were set into them. Moistened sand was placed in the bottom of the clay pots. The peat pots with plants were placed in the clay pots and more moistened sand filled in around and just covering the peat pots (Figs. 60 and 62, plate IX).

Untreated "Peco" peat pots (No.2) grew better plants than when plunged in sand, as in No.2, during the potting stage. A reverse condition occurred with "Growell" peat pots (No. 3 and No. 4), in which case the plunged pots produced better plants during the potting stage. It is evident, however, that plunging peat pots in this experiment had a greater retarding effect on plant growth, as in both cases the plants grown in plunged pots during the potting stage show greater percentages of increase in weight during the cold frame stage when all were under similar conditions.

Plate VI. Figs 45-49.- A series of lettuce plants grown in "Neponset" pots. Number 45 was treated with lime before using; number 46 was untreated; number 47 was paraffined before using; the plants in number 48 received the "Growell" nutrient treatment; the plants in number 49 received the "Peco" nutrient treatment. Note the relatively small differences between the plants.

Roots grew freely through the "Peco" peat pots (Fig.21, Plate V), but did not spread into the sand. The roots coming through the peat were coarse with few fibrous or hairy roots present. A few coarse rhizome-like roots penetrated through the "Growell" peat pots. (Fig. 20, Plate V). These too, clung around the pot and did not spread into the sand. It often appeared that roots only penetrated the "Peco" peat pots through thin or porous spots as in Figure 21, plate V. In this particular case the only roots appearing on the outer surface of the pot came through the fissure-like crevice just above the pointer.

The fact that the sand used in this experiment was slightly alkaline may have been a factor in preventing more of a root distribution outside the peat pots. These results may indicate that lettuce has a marked sensitiveness to alkalinity, as has been shown by Crist.[13]

Study of Tops and Roots at End of Potting Stage.

Tops of plants grown in wood bands, clay pots and "Fertex" fiber pots were normal in color and texture. Those grown in containers receiving nutrients were noticeably darker green than normal—plants grown in nutrient treated "Neponset" containers being excepted. The tops of plants grown in other types of containers were light in color with thin opaque-like texture, with a decided yellowing of plants grown in "Neponset" paper pots.

A study of the roots of plants cut for weighing at the end of the potting stage showed a yellowing or brownish discoloration of roots when in contact with decaying paper material. This condition was reduced remarkably on nutrient treated plants. The roots penetrated the paper materials freely and discoloration was most pronounced where fungus growth was most abundant, indicating, possibly, a relation between the fungus development and the discolored roots. It was further noted that marked discoloration of roots occurred when the growing points of roots came into contact with the red coloring matter in the "Neponset" paper pots. Observations made in this case showed that roots penetrating these pots would, upon reaching the colored material, turn at right angles, pushing between the layers of paper rather than penetrating through the colored outer layer. As the plants grown in the "Neponset" containers were generally poor, regardless of treatments, it is possible the coloring material may have had a toxic effect on plants that even nutrients were unable to overcome.

No root injury was noted in wood bands.

Roots ramified throughout the peat pots freely but did not come through to the outer surface to any considerable extent, except at the bottoms of the pots where moisture was retained by the boards upon which the pots were placed. Discolored roots noted in the "Peco" peat pots were more pronounced at the point where roots passed from the ball of soil into the peat material than after penetrating the peat. In this case discoloration of roots may have been due to chemical reactions between the acid peat and neutral soil.

No root injury or discoloration was noted in "Growell" peat pots, yet root ramification was free in the peat material. The character of the root development within the peat material and the fact that no root injury or discoloration was noted in the "Growell" peat would seem to indicate that acidity, within certain limits at least, may have had only an indirect effect on plant growth.

In brief, it has been shown (Table 5) that peat containers having relatively low pH. values and "Fertex" fiber pots with alkaline reaction both give rise to marked increases in percentages of weight of plants produced, when nutrients were used. Therefore, when nutrients are available in sufficient quantities to promote optimum plant growth the pH. value of a container within certain limits is not a factor limiting the growth of lettuce plants.

Photographic comparisons of lettuce plants grown in different containers and with different treatments are shown in Plates I to X, inclusive.

Plate VII. Figs. 50-54.- A series of lettuce plants grown in paper bands. Number 50 was treated with lime before using; number 51 was untreated; number 52 was paraffined before using; the plants in number 53 were given the "Peco" nutrient treatment; the plants in number 54 were given the "Growell" nutrient treatment. Note the well preserved condition of the paraffined pot and also the very much larger size of the nutrient-treated plants.

Pot Extract Experiment.

Materials and Methods:

This experiment was conducted to determine, if possible, the reason why containers seem to have a direct influence on the growth of the plants they support. Extracts were made of several types of containers and other materials and applied on growing plants. The plants used in this experiment, Grand Rapids forcing lettuce, were started in propagating sand. Seedlings of uniform size were selected and transplanted in propagating sand in 4" new clay pots.

Two hundred twenty plants were potted and divided into 22 lots of 10 each for subjection to treatments, as shown in table 9. Each treatment included 10 plants; therefore, 10 containers of each kind were coarsely ground, and divided into 10 equal portions by weight, from which fresh extracts were made to be available for alternate daily treatments over a period of 20 days. Michigan peat and German peat were used in weights equivalent to the weight of 10 "Peco" peat pots. The media used in making the soil extract and soil plus one-fifth Michigan peat were used in weights equivalent to the weight of new clay pots.

The extracts were made by placing a one-tenth portion of each material into separate porcelain containers and adding to each a liter of distilled water. The materials were agitated frequently to bring about the greatest possible extraction.

When needed for treatments the extracts were drained off through a wire screen (16 to 1" mesh) and distilled water added to bring the volume up to 1000 c.c., or enough to make one treatment of 100 c.c. on each of the 10 plants.

Plan of Treatments.

Plants were potted March 24, 1929, and nutrient solution such as used in the experiment with containers was applied, 100 c.c. per plant, on alternate days on all plants until 10 treatments had been given. On April 15, 1929, extract treatments were started, applying 100 c.c. per plant on alternate days until 10 treatments had been made. Nutrient treatments were continued over this period on 3 sets of 10 pots each. Each pot was placed in a separate tray to prevent loss of nutrients and extracts. From May 5 to May 26 tap water only was applied to all containers. The pots were shifted about at intervals to eliminate or equalize any possible advantage due to location.

Presentation of Results.

The different extracts, nutrient solution and water only were compared as to their effects on height and weight of lettuce plants at the end of a given period. The results are shown in Table 9.

Table 9- Growth of Lettuce Plants as Influenced by Various Pot Extracts.

No.	Extracts.	End of extract treatments: Average height per plant in centimeters	End of tap water treatments[3]: Average height per plant in centimeters	Average weight per plant when harvested end of tap water treatment gms.	pH. value of extracts	Percentage of increase in heighth of plants during the tap water treatment
1.	Nutrient Solution	17.93	23.95	127.5	6.6	+33.51
2.	"Peco" peat pots	13.15	10.94	30.8	4.0	-20.20
3.	Michigan peat.	13.63	11.43	30.8	4.8	-19.23
4.	"Growell" peat pots	12.06	9.52	25.4	4.5	-26.68
5.	German peat.[1]	11.73	9.52	25.4	3.7	-22.16
6.	Tap Water	12.06	10.16	25.4	---	-18.70
7.	Soil Solution	11.73	10.78	134.0	7.0	- 8.81
8.	Nutrient solution	17.60	23.95	124.7	6.6	+36.06
9.	"Fertex" fiber pots	11.25	8.30	19.5	8.4	-35.54
10.	Clay pots (new)	10.46	7.62	19.5	7.8	-37.27
11.	Clay pots (used)	14.60	13.15	42.2	6.6	-11.02
12.	"Neponset" paper pots	10.91	9.52	22.7	6.8	-14.60
13.	Paper pots (new)	10.94	8.07	19.5	5.9	-34.32
14.	Beechwood bands	11.73	8.40	19.5	5.7	-39.64
15.	Basswood bands	11.73	7.62	16.8	6.6	-53.93
16.	Nutrient solution	17.78	24.58	132.9	6.6	+38.24
17.	Distilled water[1]	11.88	11.09	25.4	---	- 7.12
18.	Paper pots (used-decayed)	11.88	9.19	19.5	7.1	- 29.26
19.	"Peco" pots (used)	10.94	9.67	22.7	4.5	- 13.13
20.	Michigan peat (lime treated)	12.52	9.52	25.4	7.1	- 31.51
21.	"Peco" peat pots (lime treated)	11.10	7.62	19.5	6.9	- 45.66
22.	Potting soil and 1/5 Mich. peat.[2]	10.95	8.89	21.6	7.5	- 11.92

1 pH. determinations were not made on tap water or distilled water.

2 Extract No.22, was taken from pots in which cabbage had been grown; the soil having been mixed with 1/5 its volume of lime-treated Michigan peat when prepared for the cabbage.

3 All plants averaged 8.86 centimeters in height when extract treatments were begun.

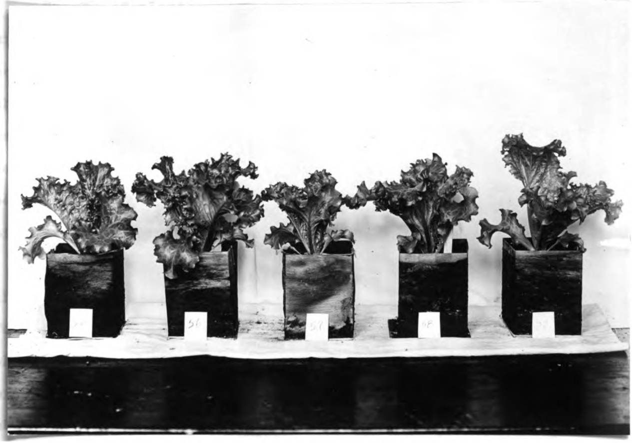


Plate VIII. Figs.55-59.- A series of lettuce plants grown in beechwood bands. Number 55 was treated with lime before using; number 56 was untreated; number 57 was paraffined before using; the plants in number 58 were given the "Growell" nutrient treatment; the plants in number 59 were given the "Peco" nutrient treatment.

Discussion.

Growth of plants was uniform during the period nutrient treatments were made; it slowed up perceptibly during the period extract treatments were made, and the plants actually shrunk in size during the following period in which only tap water applications were made. In several cases shrinkage was so great that plants were smaller than at the end of the period of nutrient treatments, or had shrunk below the average of 8.86 centimeters.

The decrease in size of plants was due to an actual shrinkage of the leaves. A yellow cast appeared on the foliage soon after starting the extract treatments. In those cases showing plants smaller at the end of the extract experiment than at the close of the nutrient applications shrinkage was in evidence before completing the series of extract treatments.

Effects of Extracts on Plant Growth

As would be expected, the extracts from various materials showed different results. With plants uniform in size when extract treatments were started, nutrient treatments Nos. 1, 8 and 16 stimulated the plants that they showed marked gains during the period tap water was used. Plants treated with extracts from used clay pots, No. 11, showed greater gains in height during the period of extract treatments than plants treated with other extracts. The plants were also

heavier when harvested at the end of the tap water treatment. A 11.02 per cent loss in height of plants occurred with plants treated with extracts from used clay pots during the period tap water treatments only were made. Clay pots having been used several times will have absorbed quantities of plant nutrients. These nutrients presumably were directly responsible for the small shrinkage of plants treated with this extract.

Plants treated with an extract of potting soil (No. 7) show the smallest percentage of loss following the period of extract treatments and ranked second in average weight per plant.

Woodbands and "Fertex" fiber pots, all showing outstandingly good results in the untreated series of the pot experiment (Table 4), have shown a remarkably high percentage of shrinkage during the period of tap water treatments. The nutrient materials capable of extraction from the wood bands is so small as to have had no stimulating effect on plant growth. A deleterious result occurred which may have been due to a small amount of toxic material in the extract. Under conditions of the containers experiment this toxic material was absorbed by the soil, consequently very little checking in plant growth occurred.

Untreated "Fertex" pots (No. 8, table 4) produced excellent plants. The "Fertex" pots extracts had a decidedly retarding effect; plants were smaller at the end of the tap

water treatment than at time of completing the nutrient treatment. A shrinkage of 35.54% in height occurred during the tap water treatments. There appeared to be a glue or sizing filler in these containers which may have acted as a factor retarding growth of plants treated with this extract. Extracts No. 12 from "Neponset" paper pots which gave very unsatisfactory results in the containers experiment show results in the extract experiment very similar to those secured with water only (No. 6 and 17). These pots appear as though treated with a light oil or paraffin. The material floated freely during the short periods given to making the extracts; the water was not discolored, and as a result, any toxic substances present may have not been made available.

Distilled water treatment (No.17) following the period of nutrient treatments, show a remarkably small disturbing effect on the growth of plants. The percentage of decrease (7.12%) in height of plants is smaller than for any of the extracts.

Plants treated with extracts of "Peco" peat pots (No.2) and extracts of Michigan peat (No.3) made greater gains during the period of extract treatments and were heavier when harvested than plants treated with other extracts (used clay pots extracts being excluded). Extracts from lime treated "Peco" peat pots (No.21) and extracts from

lime-treated Michigan peat (No.20) have given less satisfactory results than extracts from the same materials untreated. Plants treated with extracts of "Growell" peat pots (No.4) and bulk German peat (No.5) showed a greater percentage of shrinkage and were lighter in weight when harvested than plants treated with extracts from "Peco" peat pots (No.2) and bulk Michigan peat (No.3).

Extract No.22, from used soil (potting soil containing 1/5 lime treated Michigan peat in which cabbage had been grown) showed a comparatively small percentage of decrease (11.92%) in height of plants. The only plant lost in the entire experiment was carried under this treatment--the loss was due apparently to a fungus attack on roots at surface of soil.

Extracts from used "Peco" peat pots (No.19) resulted in but small shrinkage in height of plants when compared with plants treated with extracts from new "Peco" peat pots (No.2) indicating perhaps that the readily available nutrients had been washed out during the period of use.

Plants treated with extracts of used paper pots (No.18) (decayed paper pots removed from plants when setting in cold frames) showed greater gain during the period of extract treatments and were heavier when harvested than were plants treated with extracts from new paper pots (No.13).

Plants treated with extracts from new clay pots (No.10) made less growth than plants treated with other extracts during the period extract applications were made and a shrinkage of 37.27% in heighth of plants occurred during the tap water treatments.

Effect of pH. Factor on Plant Growth

To what extent the pH. of the extracts used has influenced plant growth is doubtful; however, Table 10 presents some interesting data on this question.

Table 10.- Some Effects of pH. on Growth of Lettuce Seedlings.

No.	Extracts of:	Percentage of shrinkage in height of plants during the tap water treatments	Average weight per plant when harvested end of tap water treatments, gms.	pH. value of extracts
1.	Basswood bands	53.93	16.8	6.6
2.	Lime-treated "Peco" peat pots	45.66	19.5	6.9
3.	Beechwood bands	39.64	19.5	5.7
4.	New Clay pots	37.27	19.5	7.8
5.	Clay pots (used)	11.02	47.2	6.6
6.	Tap water	18.70	25.4	---
7.	"Fertex" fiber pots	35.54	19.5	8.4
8.	New paper pots	34.32	19.5	5.9
9.	Lime-treated Michigan peat	31.51	25.4	7.1
10.	Decayed paper pots used	29.26	19.5	7.1
11.	Potting soil 1/5 lime-treated Michigan peat (used)	11.92	21.6	7.5
12.	Distilled water	7.12	25.4	---

Plate IX. Figs. 60-64.- Lettuce plants grown in (60) "Growell" peat pots plunged in sand in large clay pots, (61) untreated "Growell" peat pots, (62) "Peco" peat pots plunged in sand in large clay pots, (63) untreated "Peco" peat pots and (64) ordinary clay pots.

It was assumed when starting these studies that, perhaps, the acidity of certain containers may have been a factor retarding growth of plants. In the above table high percentage of decrease in height of plants, and light weight of plants seem to be more or less closely related to neutral or slightly alkaline pH. values. Exceptions occur; for instance, extracts from beechwood bands (No.3) and from new paper pots (No.8) have a rather low acid reaction yet plants produced show high percentages of decrease in height and light weights when harvested. New and used clay pots present a further exception. During their period of use the used clay pots (No.5) have absorbed quantities of nutrients. These nutrients given up in the extracts have stimulated plant growth, producing heavy plants and reducing the percentage of decrease in height of plants to a remarkable degree. The new clay pot material (No.4) having no nutrients produced plants of light weight with a high percentage of shrinkage in height.

The results shown in the above table indicate that neutral or slightly alkaline pH. values, in general, have a greater retarding effect on growth of lettuce plants than lower pH. values, as has been claimed by Crist[13].

The results with the new and used clay pots show that when other conditions were similar, the effects of the pH. value of a medium on plant growth may be limited to some extent by the presence of nutrients. Evidence was presented

in the containers experiment showing that pots of relatively low acid reaction and those of neutral pH. value produced remarkably better plants when nutrient treatments were made than when untreated. In other words, the pH. factor, within certain limits, had only an indirect influence on the growth of lettuce plants. When available nutrients were present in sufficient quantities to promote normal growth, the pH. factor within these limits was not important.

Following the carry-over stimulating effects of the nutrient treatments there occurred, shortly after starting the extract treatments, a decided checking in growth of plants. This check in plant growth may have been due to toxic.materials liberated in the extracts, to unbalanced nutrient conditions, to a complete lack of nutrients, or perhaps to all three conditions. Many of the extracts showed an acid reaction; lettuce plants grew better when treated with extracts from peat pots having a comparatively low acid reaction, than when treated with extracts from the same containers lime-treated. Therefore, the checking effects of these extracts on plant growth cannot be directly attributed to acidity. From the results with the nutrient solution in this experiment and in the preceeding experiment with containers, it is safe to conclude that a balanced plant nutrient may be depended on to overcome largely any checking effect the containers may have on the growth of lettuce plants.

Plate X. Figs. 70-72.- Lettuce plants grown in (70) untreated basswood bands, (71) untreated beechwood bands and (72) ordinary clay pots. Note the well-preserved condition of the basswood band, compared with fungus-infected condition of the beechwood band.

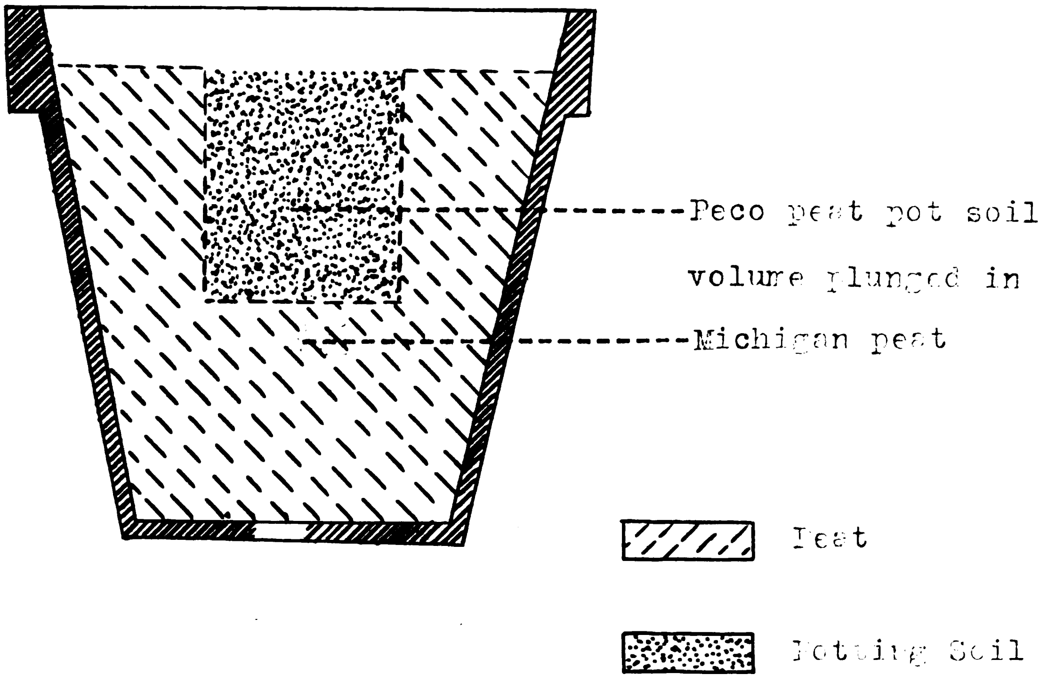
Experiment with Cabbage.

Materials and Methods.

The experiment with babbage was conducted primarily to compare peat pots with clay pots and with bulk peat used as a component of potting soil; and to compare the effects of different volumes of soil on the growth of the plants supported.

"Growell" peat pots, "Peco" peat pots and bulk Michigan peat were used in the experiment. The capacities of the "Growell" and "Peco" peat pots were used as a measure for the soil used in the volume experiment. The accompanying diagram shows method of plunging soil volumes in peat. Golden Acre cabbage was seeded in flats and seedlings of uniform size were selected for potting. The same nutrient solution was used, and treatments were made the same as described for the lettuce experiment; i.e., plants receiving "Peco" nutrient treatments received nutrients equivalent to the amount absorbed by "Peco" peat pots, and plants receiving "Growell" nutrient treatments received nutrients equivalent to the amount absorbed by "Growell" peat pots.

To determine comparative growth all plants were measured at the time of being placed in the cold frame for hardening. Ten plants were cut from each series and weighed, as a second means of determining comparative growth of plants under the different treatments. Plants were potted February 23, 1929 and placed in the cold frame for hardening March 25, after a period of 31 days.



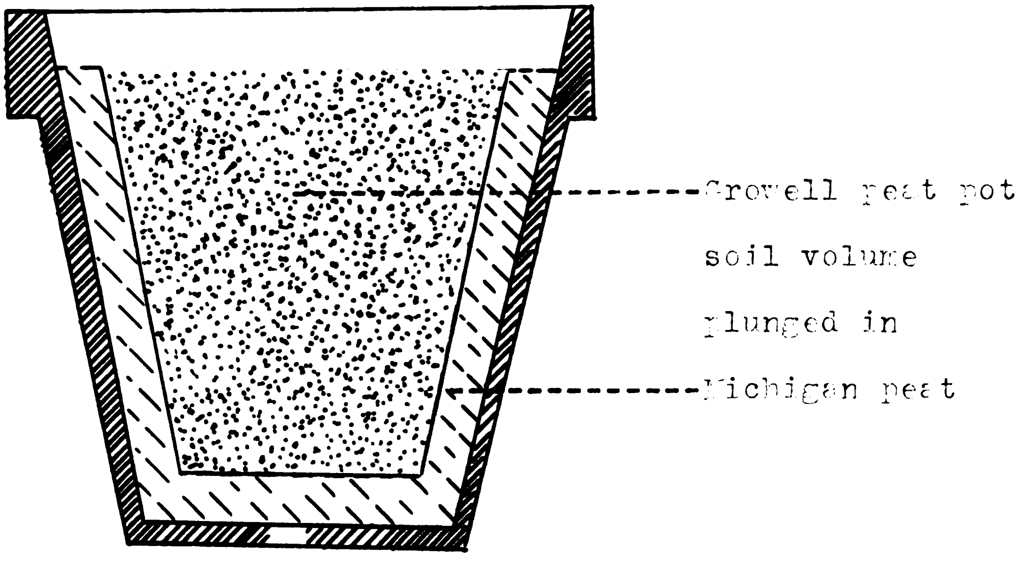


Diagram showing method of arranging soil volumes in peat in 4" clay pots.

A similar arrangement of materials was made in treatments in which sand was used in place of peat.

Presentation of Results.

Peat planting pots, clay pots, and bulk peat (used as a component of potting soil) were compared as to their effects on the growth of potted cabbage plants. Small and large volumes of soil, under different conditions; treated with nutrient solution and untreated were also studied as to their comparative effects on plant growth. The results are shown in Tables 11 and 12.

Plate XI. Figs. 1-3.- Cabbage plants grown in ordinary potting soil in (1) untreated "Growell" peat pots, (2) untreated clay pots and (3) untreated "Peco" peat pots.

Table 11.-Comparative Results with Cabbage Plants Grown in Clay Pots, in Peat Pots and in Potting Soil Mixed with Bulk Peat.

No.	Containers Treatments	Heighth per plant when placed in cold frame,* cms.	Average of 10 plants Weight per plant when placed in cold frame, gms.	Percent of gain in weight compared with the clay pots (check)
1.	Clay pots--potting soil untreated (check)	14.27	8.10	0.0
2.	Clay pots--"Peco" nutrient treatments on plants	18.68	20.16	+ 148.88
3.	Clay pots--"Growell" nutrient treatments on plants	17.60	15.33	+ 89.25
4.	Clay pots--potting soil 1/5 untreated Michigan peat	15.96	12.66	+ 56.29
5.	Clay pots--potting soil 1/5 treated Michigan peat	11.17	7.70	- 4.93
6.	Clay pots--potting soil 1/5 untreated Michigan peat with "Peco" nutrient treatments on plants	19.92	20.90	+ 158.02
7.	Clay pots--potting soil 1/5 untreated "Growell nutrient treatments on plants	18.71	15.90	- 96.29
8.	"Peco" peat pots-- untreated	10.46	5.33	- 34.19
9.	"Peco" peat pots-- soaked in nutrient solution before using	15.24	10.21	+ 26.04
10.	"Peco" peat pots-- soaked in lime solution before using	13.97	6.53	- 18.14
11.	"Growell" peat pots-- untreated	12.70	7.00	- 13.58
12.	"Growell" peat pots-- soaked in nutrient solution before using	15.93	9.40	+ 16.04
13.	"Growell" peat pots-- soaked in lime before using	11.32	5.03	- 37.90

* Average for 20 plants + Averages for 10 plants

Discussion:

Clay Pots Vs. Peat Pots

Clay pots with untreated potting soil (Check No. 1) produced plants 34.19 per cent heavier than untreated "Peco" peat pots (No. 8) and 13.58 per cent heavier than untreated "Growell" peat pots (No. 11). When peat pots were soaked in nutrient solution before using the nutrient treated "Peco" peat pots (No. 9) produced plants 26.04 per cent heavier than those grown in clay pots (No. 12) were 16.04 per cent heavier than those grown in the check container. However, when "Peco" nutrient treatments were applied on plants grown in clay pots (No. 2) an increase in weight of plants of 148.88 per cent occurred when compared with the check (No. 1) and a gain of 97.45 per cent occurred over plants grown in nutrient treated "Peco" peat pots (No. 9). "Growell" nutrient treatments on plants grown in clay pots (No. 3) resulted in a gain of 89.25 per cent in weight of plants when compared with the check, and plants receiving "Growell" nutrient treatments in clay pots (No. 3) were 63.08 per cent heavier than those grown in "Growell" peat pots soaked in nutrient solution before using (No. 12). Plants grown in nutrient-treated "Peco" peat pots were 41.60 per cent heavier than plants grown in untreated "Peco" peat pots (No. 8) while nutrient treatments on "Growell" peat pots produced plants 34.28 per cent heavier than those grown in untreated "Growell" peat pots (No. 11).

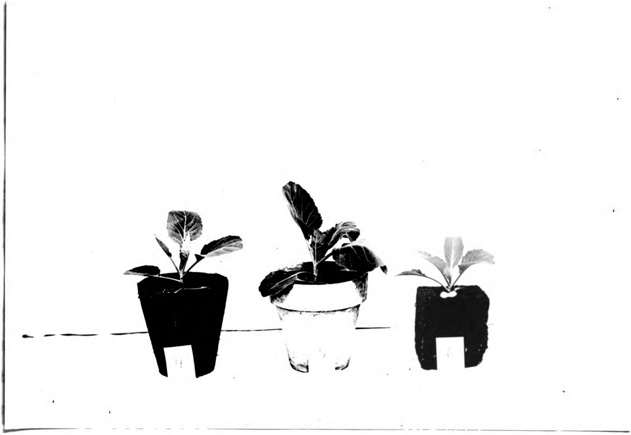


Plate XII. Figs. 4-6.- Cabbage plants grown in (4) ordinary soil in untreated "Growell" peat pots, (5) soil to which was added one-fifth part Michigan peat in clay pots and (6) ordinary soil in untreated "Peco" peat pots.

From these results, it appears that more satisfactory cabbage plants may be grown in untreated soil in clay pots than in untreated peat pots under similar conditions. Nutrients have a marked stimulating effect on growth of potted plants in both clay and peat containers. When applied on plants in clay pots nutrients produced outstandingly heavier and thriftier plants than an equivalent amount of nutrients absorbed in peat pots before using. In this experiment cabbage plants grown in untreated clay pots were outstandingly better than when grown in peat pots. Nutrients applied on cabbage plants grown in clay pots showed a remarkably greater stimulating effect on plant growth than an equivalent amount of the same nutrient absorbed by peat pots before using. From these results it is evident, under certain conditions, that clay pots are superior to peat pots as containers in which to start cabbage plants.

Bulk Peat as a Component of Potting Soil vs. Potting Soil in Clay Pots

Bulk Michigan peat was used in this experiment and the results show that potting soil to which has been added 1/5 untreated Michigan peat (No. 4), produced plants 56.29 per cent heavier than plants grown in untreated potting soil alone in clay pots (Check No. 1). When nutrients were applied on plants grown in potting soil and 1/5 untreated Michigan peat, the "Peco" nutrient treatment (No. 6) resulted in a gain of 158.02 per cent in weight of plants over those grown in clay pots (Check), while the "Growell" nutrient treatment (No. 7) produced plants 96.29 per cent heavier than those grown in the check treatment.

Nutrient treatments applied on potting soil and 1/5 untreated Michigan peat (No. 6 and No. 7) did not stimulate plant growth to any marked degree over similar nutrient treatments on plants grown in potting soil alone (No. 2 and No. 3). "Peco" nutrient treatments on potting soil and 1/5 untreated Michigan peat increased the weight of plants 65.08 per cent over plants grown in the same materials untreated (No. 4) while "Growell" nutrient treatments (No. 7) produced plants 20.06 per cent heavier than those grown in potting soil and 1/5 untreated Michigan peat (No. 4).

<u>Bulk Peat as a Component of Potting Soil vs. Peat Pots.</u>

Potting soil to which was added 1/5 untreated Michigan peat (No. 4) produced plants 132.52 per cent heavier than those grown in untreated "Peco" peat pots (No. 8) and 80.08 per cent heavier than plants grown in untreated "Growell" peat pots (No. 11). "Peco" nutrient treatments on plants grown in potting soil and 1/5 untreated Michigan peat (No. 6), increased the weight of plants 104.70 per cent over plants grown in "Peco" peat pots (No. 9) which had absorbed an equivalent amount of nutrient treatment (No. 7) resulted in a gain of 122.34 per cent in weight of plants over those grown in "Growell" peat pots which had absorbed an equivalent amount of nutrients.

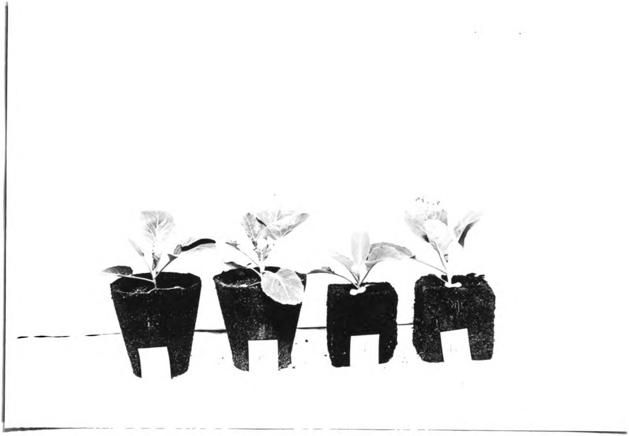


Plate XIII. Figs. 7-10.- Cabbage plants grown in (7) untreated "Growell" peat pots, (8) "Growell" peat pots soaked in a nutrient solution before using, (9) untreated "Peco" peat pots and (10) "Peco" peat pots soaked in a nutrient solution before using.

Lime treatments on peat pots and on Michigan peat (Nos. 5, 10 and 13) resulted in a marked reduction in weight of plants, when compared with plants grown in the same materials untreated (No. 4, 8 and 11).

Under the conditions of this experiment bulk peat as a component of the potting soil produced markedly heavier plants than potting soil alone. When nutrients were used the gain in weight of plants resulting from including 1/5 Michigan peat in the potting soil was not great enough to be significant when compared with plants grown in nutrient-treated potting soil. Potting soil and 1/5 Michigan peat with nutrient treatments produced materially heavier plants than the same material untreated. Untreated bulk peat as a component of potting soil produced outstandingly better plants than those grown in untreated peat pots. When nutrients were used on potting soil and 1/5 Michigan peat there occurred a marked gain in weight of plants, when compared with those grown in peat pots which had absorbed equivalent amounts of nutrients.

These results indicate that a given amount of bulk peat mixed with the potting soil may be expected to produce better cabbage plants than potting soil alone or peat pots under similar conditions. A given amount of nutrients applied on plants grown in potting soil containing a given amount of bulk peat resulted in marked gains in weight over

Plate XIV. Figs. 11-14.- Cabbage plants grown in (11) "Peco" peat plots treated with lime water before using, (12) untreated "Peco" peat pots, (13) untreated "Growell" peat pots and (14) "Growell" peat pots treated with lime water before using.

plants grown in peat pots which had absorbed an equivalent amount of nutrients.

Effects of Soil Volume on Growth of Potted Plants

A series of experiments was conducted to determine the effects of the soil **capacity** of a container on the growth of the plant supported and likewise the comparative effects of nutrient treatments under different conditions. The measurements and weights shown in Table 12, were taken at the time the plants were placed in the cold frame for hardening.

Plate XV. Figs. 15-18.- Cabbage plants grown in (15) a volume of potting soil equivalent to that of a "Peco" pot and plunged in sand in a clay pot, (16) untreated "Peco" peat pots, (17) untreated "Growell" peat pots and (18) a volume of potting soil equivalent to that of a "Growell" pot and plunged in sand in a clay pot.

Table 12.- Effects of Soil Volume and Nutrient Treatments on the Growth of Potted Cabbage Plants.

No.	Containers	Treatments.	Centimeters Heighth per plant when placed in cold frame* cms.	Weight per plant when placed in cold frame* gms.	Percent of gain or loss compared with the clay pots (check)
1.	Clay pots	--potting soil untreated (check)	14.27	8.10	0.0
2.	Clay pots	--"Peco" nutrient treatments on plants	18.08	20.16	+148.88
3.	Clay pots	--"Growell" nutrient treatments on plants	17.60	15.33	+ 89.25
4.	"Peco" peat pots	--untreated	10.46	5.33	- 34.19
5.	"Peco" peat pots	--soil volume plunged in untreated Michigan peat	18.08	19.12	+ 136.04
6.	"Peco" peat pots	--soil volume plunged in treated Michigan peat.	18.71	16.05	+ 98.14
7.	"Peco" peat pots	--soil volume plunged in untreated Michigan peat with "Peco" nutrient treatments on plants	20.77	27.55	+ 240.12
8.	"Peco" peat pots	--plunged in propagating sand.	11.73	7.21	- 10.98
9.	"Peco" peat pots	--soil volume plunged in propagating sand with "Peco" nutrient treatment on plants	12.39	7.63	- 6.16
10.	"Peco" peat pots	--soil volume plunged in propagating sand	11.97	7.03	- 13.22
11.	"Growell" peat pots	--soil volume plunged in untreated Michigan peat.	19.68	25.68	+ 220.49
12.	"Growell" peat pots	--soil volume plunged in lime treated Michigan peat.	17.78	18.22	+ 124.93
13.	"Growell" peat pots	--soil volume plunged in untreated Michigan peat with "Growell" nutrient treatments on plants	26.49	34.93	+ 331.23
14.	"Growell" peat pots	--plunged in propagating sand	10.95	5.93	- 26.91
15.	"Growell" peat pots	--soil volume plunged in propagating sand with "Growell" nutrient treatments on plants	14.69	9.75	+ 20.37

Table 12- continued.

16. "Growell" peat pots--soil volume plunged in propagating sand.	10.27	7.68	-5.46
17. "Growell" peat pots--untreated	12.70	7.00	-13.58
18. "Growell" peat pots-soaked in nutrient solution before using.	15.93	9.40	+16.04
19. "Peco" peat pots--soaked in nutrient solution before using	15.24	10.21	+26.04

* Average of 20 plants + Average of 10 plants

Plate XVI. Figs. 19-21.- Cabbage plants grown in ordinary clay pots filled with (19) one-half ordinary potting soil and one-half Michigan peat that had been treated with lime, (20) four-fifths ordinary potting soil and one-fifth Michigan peat that had been treated with lime and (21) ordinary potting soil.

Discussion:

When the volume of soil contained in a peat pot is removed from the effects of the pots and plunged in untreated Michigan peat the greater volume of soil from the "Growell" peat pots (No. 11) produced plants 220.49 per cent heavier than plants grown in clay pots (check, No. 1). Plants grown in "Peco" peat pots soil volume (No. 5) plunged in untreated Michigan peat were only 136.04 per cent heavier than plants grown in the check container. When "Growell" nutrient treatments were applied on plants grown in "Growell" peat pots soil volume plunged in untreated Michigan peat (No. 13) a gain of 351.23 per cent in weight of plants occurred, when compared with plants grown in the potting soil (check, No. 1). This treatment also showed an increase of 271.59 per cent in weight of plants over plants grown in "Growell" peat pots (No. 18) which had absorbed an equivalent amount of nutrients before using. The "Peco" peat pots soil volume plunged in untreated Michigan peat with "Peco" nutrient treatments on plants (No. 7) produced plants 240.12 per cent heavier than plants grown in the check treatment and 169.83 per cent heavier than plants grown in nutrient treated "Peco" peat pots (No. 19).

"Growell" peat pots soil volume plunged in untreated Michigan peat with "Growell" nutrient treatments on plants resulted in an increase in weight of plants of 127.85 per cent, when compared with plants grown in clay pots

Plate XVII. Figs. 22-25.- Cabbage plants grown in clay pots lined with sand and containing (22) untreated potting soil equivalent in volume to that of a "Peco" peat pot, (23) potting soil of the same volume but treated with "Peco" nutrient solution, (24) potting soil equivalent in volume to that of a "Growell" peat pot but treated with "Growell" nutrient solution and (25) untreated potting soil of the same volume.

"Growell" nutrient treatments on plants (No. 3) while the "Peco" peat pots soil volume plunged in untreated Michigan peat with "Peco" nutrient treatments on plants produced plants only 36.65 per cent heavier than those grown in clay pots with "Peco" nutrient treatments on plants (No. 2).

Peat pot soil volumes plunged in sand have given very poor results in contrast with the outstanding results secured by plunging peat pot soil volumes in Michigan peat. These contrasting results are, no doubt, due to the fact that the nutrients readily washed out of the sand and hence, did not stimulate plant growth to any great extent over the sand treatments receiving no nutrients. On the other hand, the Michigan peat readily absorbed the nutrients and they were available to promote rapid growth of plants grown in the soil volumes plunged in the peat.

Soil volumes in sand and nutrient treatments on soil volumes in sand have given negative results in weights of plants when compared with the check treatment (No. 1), excepting "Growell" peat pots soil volume plunged in propagating sand with "Growell" nutrient treatments on plants (No. 15), which shows an increase of 20.37 per cent in weight of plants over those grown in the check treatment. The "Growell" soil volume in this treatment was great enough to retain nutrients in sufficient quantities to stimulate

Plate XVIII. Figs. 26-27.- Cabbage plants grown in a volume of ordinary potting soil equivalent to that of a "Growell" peat pot and plunged in Michigan peat in clay pots. Number 26 was untreated soil and number 27 was treated with "growell" nutrient solution.

Figs. 28-29.- Cabbage plants grown in a volume of ordinary potting soil equivalent to that of a "Peco" peat pot and plunged in Michigan peat in day pots. Number 28 was untreated soil and number 29 was treated with "Peco" nutrient solution.

greater plant growth than occurred in the untreated potting soil in the check container (No. 1).

These results indicate that in every instance the greater volume of soil has produced heavier plants than the smaller volume of soil, similar treatments considered. Greater soil volume with smaller nutrient treatments gave better results than greater nutrient treatments on smaller volumes of soil. Nutrient treatments on peat pot soil volumes gave better results than equivalent amounts of nutrients applied on plants grown in potting soil only, in clay pots, or an equivalent amount of nutrients absorbed by peat pots. In general the soil volume seems to have greater influence on the growth of cabbage plants under conditions of this experiment than other factors.

Effects of Plunging Peat Pots in Sand

The peat pots in this experiment were plunged in 7 inch pots, as described in the lettuce experiment, to compare the growth of plants in plunged peat pots, unplunged peat pots, and peat pot soil volumes plunged in sand.

Plunging "Peco" peat pots in sand (No. 8) had but little beneficial results over untreated "Peco" peat pots (No. 4) while a detrimental result occurred from plunging "Growell" peat pots in sand (No. 14) when compared with untreated "Growell" peat pots (No. 17). "Peco" peat pots soil volumes plunged in sand (No. 10) produced better plants than untreated "Peco" peat pots

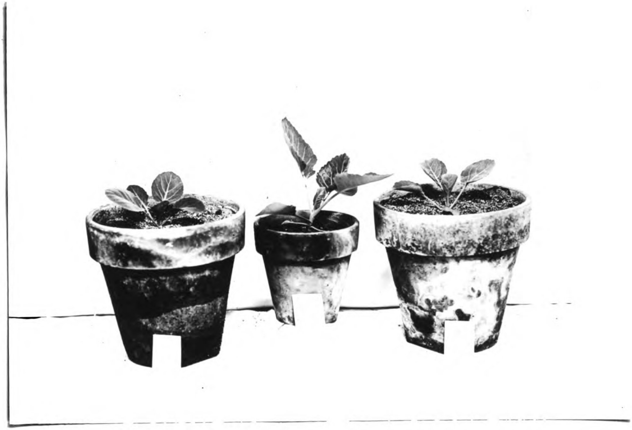


Plate XIX. Figs. 30-32.- Cabbage plants grown in (30) untreated "Peco" peat pots plunged in sand, (31) ordinary clay pots and (32) untreated "Growell" peat pots plunged in sand. All contained ordinary potting soil.

(No. 4), but "Peco" peat pots plunged in sand (No. 8) yielded heavier plants than the "Peco" peat pots soil volume plunged in sand. On the other hand, "Growell" peat pots soil volume plunged in sand (No. 16) produced heavier plants than were grown in "Growell" peat pots plunged in sand (No. 14) or in untreated "Growell" peat pots (No. 17). In all instances these treatments have resulted in poorer growth than was obtained with the check treatment (No. 1).

Effect of Containers and Treatments on Tops and Roots

Leaves and stems of plants receiving nutrient treatments, and plants grown in soil containing bulk peat, were normal in color, excepting nutrient treatments on sand (Nos. 9 and 15, table 12). Plants in untreated peat pots and in untreated potting soil in clay pots had a light purple cast on stems characteristic of slightly hardened cabbage plants. Plants in other containers and with other treatments showed decidedly purple stems and leaves as though extremely hardened, while the lower leaves on the sand treatments became yellow before the plants were moved to the cold frame. Plunged peat containers produced very unsatisfactory plant growth, though an extremely vigorous root development occurred outside the peat containers (Plate XX11)

Comparative height of plants is shown in Tables 11 and 12, and Plates X1 - XX11.

Plate XX. Figs. 33-34.- Cabbage plants grown in untreated "Peco" peat pots, number 33 being plunged in sand.

General Discussion

It is evident from the results of these experiments that a liberal nutrient supply is essential in growing satisfactory lettuce and cabbage plants regardless of the type of containers used. Had the nutrient treatments been extended over a longer period no doubt even greater variation would have occurred between plants started in untreated containers and nutrient-treated containers. Possibly still greater gains would have been in evidence in the final yields had the nutrient treatments been continued after transplanting the lettuce into the cold frame.

Certain containers had a marked retarding effect on growth of lettuce plants. When the plants were removed from the immediate influence of the containers extremely rapid growth occurred. These results seem to indicate that if given sufficient time the retarded plants would produce a normal crop. Earliness, however, is an important factor in securing a profitable crop. It is, therefore, essential that the grower avoid those containers having a tendency to retard plant growth.

The soil volume experiment shows that larger volumes of soil are more productive than smaller volumes under similar conditions. When bench space is not a factor a grower may profit by starting cabbage plants in 3 inch or even 4 inch containers rather than in smaller sizes. Plants started in large containers would eliminate the labor of shifting plants once or twice from small

Plate XXI. Figs. 35-36.- Cabbage plants grown in untreated "Growell" peat pots, number 35 being plunged in sand.

to larger containers, thus reducing the cost of growing the plants.

Lime treating of acid containers had no favorable influence on the growth of lettuce plants. Lettuce plants grew satisfactorily under certain conditions in rather low acid media which is evidence that caution should be used in applying lime to soil in which lettuce plants are to be started or on which a crop of lettuce is to be grown.

The use of peat as a component of potting soil gave remarkably good results with cabbage plants.

Plate XXII. Figs. 9-10.- Cabbage plants grown in (9) "Peco" peat pots and (10) "Growell" peat pots, plunged in sand. Note the vigorous growth of roots as compared with that obtained in the lettuce experiment. (See Figs. 20 and 21).

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Conclusions and Summary

Lettuce plants were grown in several types of containers, and in sand cultures treated with extracts of containers, and of other materials. Cabbage plants were grown in clay and peat pots with a variation in soil, soil volume and methods of treatments.

1. The experiments with lettuce indicate that certain containers have a deleterious influence on the growth of lettuce plants.

2. The deleterious effect on growth of lettuce plants during the potting stage varied with the different types of containers used.

3. Nutrient treatments largely overcame the retarding effect of containers on growth of lettuce plants.

4. Treating the containers with lime or paraffining them did not reduce the retarding effects of the containers.

5. Band types of containers were more suitable in which to start lettuce plants than pot types of containers.

6. Bulk peat used as a component of the potting soil gave better results with cabbage than potting soil alone, or peat pots.

7. Cabbage plants made more satisfactory growth in large volumes of soil than in smaller volumes, when other conditions were similar.

8. Plunging peat pots in sand did not give satisfactory results.

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