A STUDY OF CYCLAMEN PERSICUM WITH SPECIAL REFERENCE TO ITS NUTRITION, HYPOCOTYL DEVELOPMENT, AND OPTIMUM TEMPERATURE FOR GERMINATION

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INTRODUCTION

The extensive use by florists of Cyclamen persicum as a pot plant for winter sale and certain difficulties involved in its culture made it desirable to conduct the following experiment. Although cyclamen are still used a great deal, their used as a Christmas pot plant is on the decline for several reasons: the greater certainty of a higher percentage of excellent plants from poinsettia and others; the length of the growing period of cyclamen from seed to blossom, which may be as long as sixteen months; and the small number of good plants usually obtained from a single seeding. It is believed that many of the failures in the production of cyclamen have been caused by a lack of adequate information regarding the intensity and the balance of nutrients required for optimum growth and flower production.

To secure precise information concerning the nutrient requirements of this plant; that is, the proper concentration and balance of the elements nitrogen, phosphorus, and potassium, was the major objective of this experiment.

A preliminary investigation of the optimum temperature for seed germination and of the development of the hypocotyl was also undertaken.

REVIEW OF LITERATURE

A search of all available literature reveals practically nothing on the nutrition of cyclamen. Baker (3) states only that the final soil should be a rich mixture with rotted manure and a little bone meal added. He further suggests a mixture of three parts loam, one part peat or leaf mold and one part sand.

Laurie and Kiplinger (10) suggest a mixture of light loam soil, leaf mold and well rotted manure. They further suggest that when the shift is made into 4-inch pots, and larger, additional fertilizer in the form of 4-12-4 or horn shavings be added at the rate of a 5-inch pot full to 2 bushels of soil.

Vogel and others (17) conducted an experiment with cyclamen using three different concentrations of fine complete commercial fertilizers. The percentages of nitrogen, phosphorus and potassium were from 8.09 to 28.07, 8.0 to 17.37, and 8.0 to 21.51 respectively. They found that the number of deformed buds increased concurrently with the increase of nutrient concentration. However, no definite nutrient levels were maintained in the soil.

Brown (1) stated that the presence of one element in the soil influences the absorptive powers of plants for other mineral nutrients of the soil and fertilizers. He also stated that "somewhere between the limits of excess and deficiency for the different essential elements—nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, etc. -- is the optimum range of the well-balanced mixture of nutrients which will be found to vary according to the nature of soil, variety of crops, supply of water, amount of sunshine and numerous other environmental factors."

Shear, Crane and Myers (16) have stated that "maximum growth and yield occur only upon the coincidence of optimum intensity and balance. At any level of nutritional intensity there exists a nutritional balance at which optimum growth for that intensity level will result. This means that at any given level of nutritional intensity, provided all nutrient elements are in proper balance, it is possible to obtain plants that appear normal in every respect in which all metabolic processes are probably qualitatively normal. However, maximum growth and yield result only when the proper balance of nutrient elements occur in combination with their optimum intensity."

Meyers and Anderson (12) state that, "Absence or deficiency of any of the necessary mineral elements in the soil or other substratum upon which plants are growing will sooner or later become apparent in their development. An insufficient quantity of any of the essential elements in a plant in an available form will result in the production of growth aberrations which are symptomatic of lack of an adequate internal supply of that element."

Hoagland (8) stated that high nitrate form of nitrogen may accelerate the injury produced when potassium is deficient. He also stated that it is evident that if nitrogen forms a limiting factor for growth, an increased supply will entail a greater demand for potassium and vice versa. Merrill and Greer (11), Painter et al. (13) and Sitton (14) work agree with the conclusion as presented by Hoagland.

Merrill and Greer (11) on the fertilization of tung seedlings state that "There was no response to nitrogen unless phosphorus was applied to the soil, and considering the level of precision of the experiment, it is questionable if there was an actual response to phosphorus unless nitrogen was applied."

Painter, Matthew and Brown (13) also working with tung made mention of the fact that there was no response to liberal applications of nitrogen when the level of potassium was low, in fact liberal applications of nitrogen at low potassium levels tended to aggravate the disorder.

Sitton (14) in his work with tung using nitrogen, phosphorus and potassium corroborates the finding of Merrill and Greer in the fact that better yields were obtained when high levels of nitrogen and phosphorus were combined than when high levels of either one were used with low levels of the other.

Gartner (6) working with *Primula obconica* finds that high amount of nitrogen and potassium caused stunting and chlorosis. He further states that when potassium levels were low and nitrogen high, stunting and chlorosis was not prevalent, and when the potassium was high and nitrogen low, fair plant growth was obtained. He recommended as optimum growing levels, nitrogen 35 ppm.; and potassium 20 ppm.

Fountain (4) gives as the optimum nutrient levels for the growth of coleus as follows: Nitrates 25-50 ppm.; phosphorus 10-20 ppm.; and potassium 5-15 ppm.

Fuhr (5) determined the optimum levels of nitrogen phosphorus and potassium for the growth of *Begonia semperflorens*. He recommends the ppm. requirement for nitrates, phosphorus and potassium to be 30 to 50, 5 and 30 to 50, respectively.

NUTRIENT STUDY

Plan of Procedure

In this experiment cyclamen plants were grown at all possible combinations of five levels of nitrate, five levels of potassium and four levels of phosphorus. The total number of treatments and plants was one-hundred. Nitrogen response was thus obtained from a total of twenty treatments, potassium response from an equal number, and phosphorus response from a total of twenty-five treatments. Each treatment was represented by one plant.

Soil Type

The soil chosen for this investigation was Oshtemo sand, a yellowish brown loamy sand occurring as nearly level land. Very little clay is present in the subsoil, and loose dry sand and gravel extend downward for several feet. This soil naturally dries out very easily and is low in organic matter and strongly acid in reaction. The surface soil of about three to four inches was obtained from the Rose Lake Wild Life Experimental Farm near Bath, Michigan, in Clinton County. It was chosen because of its low nutrient level, which when tested by the Spurway active test showed nitrate nitrogen, 2 parts per million; phosphorus, 0 ppm.; and potassium 2 ppm. The field from which the soil was taken had not been cultivated for several years. The soil pH was 5.5

Soil Tests

The Spurway Simplex Soil Testing Method (15) was used to test the soil samples in order to maintain the soil at a desired nutrient level. The tests were made for the "active" or available nutrients, or that material in the soil which was thought to be available to the plant. (The tests for the "reserve" nutrients were not made.) These tests were made approximately every two weeks. Additional nutrients were added to reestablish the original levels whenever the tests indicated a need.

Fixing Capacity of Oshtemo Soil

One cannot by simple calculation arrive at the quantities of nutrients necessary to establish certain levels in the soil. This is because a portion of the nutrients added is fixed into forms not available to the plants and not extracted by the reagent used in the soil testing procedure. Accordingly it was first necessary to determine the capacity of this Oshtemo sandy soil to fix nutrients into unavailable forms. The following procedure was adopted:

Twenty-four samples of 125 grams each of air dry soil were carefully weighed into glass tumblers. The samples were arranged in 12 groups of 2 each. The first 2 were left untreated while the remaining 11 pairs of samples were treated with increasing amounts of $NaNO_3$, $CaH_4(PO_4)_2$ and K_2SO_4, as shown in table 1.

The sodium nitrate was added from a stock solution which was prepared by dissolving one-tenth gram of chemically pure sodium nitrate ($NaNO_3$) in each milliliter of distilled water.

The stock solution of potassium was prepared by dissolving five-hundreths gram of chemically pure potassium sulphate (K_2SO_4) in each milliliter of distilled water.

Phosphorus was added in the dry form of monocalcium phosphate ($CaH_4(PO_4)_2$. Varying amounts were weighed out and added to the tumblers as shown in table 1. Care was taken to add the same total amount of water to each tumbler. The amount of water added was 35 ml. per 125 grams of soil.

The tumblers were covered and allowed to stand for 4 weeks, after which the samples were tested by the Spurway Method (15) to determine the quantity of nitrate, phosphorus and potassium remaining in available form.

Nutrient Levels

Nutrient levels were established as follows; Nitrate Nitrogen -- 0 ppm., 25 ppm., 50 ppm., 100 ppm. and 200 ppm.; Phosphorus -- 0 ppm., 5 ppm., 10 ppm. and 20 ppm.; Potassium -- 0 ppm., 15 ppm., 30 ppm., 60 ppm. and 100 ppm.

Every possible combination of these three nutrients and of the levels as stated above was made so that there were 100 different treatments. Therefore, each plant was grown at a different nutrient level, with a total of 20 plants at each level of nitrate, a total of 25 plants at each level of phosphorus, and, finally, a total of 20 plants at each level of potassium.

Table 2 shows the treatment numbers and parts per million of each nutrient as established in each pot.

Source of Nutrients

Sodium nitrate ($NaNO_3$) and ammonium nitrate were used as carriers of nitrogen, and monocalcium phosphate $CaH_4(PO_4)_2$ was the source of phosphorus, with potassium sulphate (K_2SO_4) supplying the potassium. All of the above compounds were chemically pure. Ammonium nitrate was used to supply half of the nitrogen at each level in an attempt to alleviate the possibility of sodium toxicity in the pots requiring high levels of nitrogen.

Method of Preparing Stock Solutions

Stock solutions for each nitrogen level were prepared as shown below for the level of 25 ppm.

As indicated previously by the fixation tests, .04 grams of $NaNO_3$ was required to raise the level of NO_3 in

125 grams of soil to 25 ppm. Table 1. Using that rate of $NaNO_3$ to soil, .464 grams was required to raise 1450 grams of soil to 25 ppm. of NO_3.

One-half of the nitrogen was supplied as $NaNO_3$ and the other half as NH_4NO_3. Thus each pot maintained at 25 ppm. of nitrate received, .232 gram of $NaNO_3$ and the equivalent of that quantity of $NaNO_3$ as NH_4NO_3 (.109 gram). Stock solutions of each of these salts were made up in such concentrations as to contain the amount of the salt necessary for one pot in 10 ml. of distilled water. Applications were then made in solution.

Stock solutions for each potassium level were prepared as shown below for the level of 15 ppm.

As the fixation tests indicated, .020 grams of K_2SO_4 was required to raise the level of potassium in 125 grams of soil to 15 ppm. Using this ratio of K_2SO_4 to soil, .232 grams was required for the 1450 grams of soil used in each pot.

For 15 and 30 ppm. of K_2O, stock solutions were made up containing the required amount of K_2SO_4 for each pot in 10 ml. of distilled water, but for the levels of 60 and 100 ppm. of K_2O, it was necessary to use fifty ml. of water to completely dissolve the necessary amount of K_2SO_4 for each pot.

Phosphorus was added to the pots in the dry form of monocalcium phosphate ($CaH_4\ (PO_4)_2$). The amount was determined as given below for the 5 ppm. level.

As indicated by the fixation test, .10 gram of $CaH_4(PO_4)_2$ was required to raise the level of 125 grams of soil to 5 ppm. Using that ratio of $CaH_4(PO_4)_2$ to soil, 1.16 grams was required for the 1450 grams of soil used in each pot.

Table 3, shows the amount of nutrient carrier required in 1450 grams of soil to bring the level of each nutrient up to the total parts per million desired for the treatments used in this investigation.

Cultural Practices

Half-mature plants: Two weeks prior to repotting, one-hundred twenty-five half-mature plants of Cyclamen persica were received from Vogts Greenhouses, Sturgis, Michigan. The plants were in very vigorous and healthy growth, having dark green foliage with the typical cyclamen leaf pattern, averaging approximately 10 mature leaves to the plant. The pattern of leaf coloration was observed closely because it was thought that various nutrient levels might change or influence the subsequent pattern on new leaves.

On July 12-15, 1948, the plants were shifted from $3\frac{1}{2}$" pots to the regular cyclamen pots in soil which had received the necessary nutrients for that particular level combination. Before repotting, the ball of soil in which the plant was growing was placed in a pail of water and all of the soil carefully and gently washed off. Because of the brittle nature of cyclamen roots this had to be done with great care. The new soil, after partial air-drying, was carefully worked among the roots. Each pot was thoroughly watered and placed in a bench with a one-inch layer of gravel. This gravel was watered daily even when the plants did not require watering.

In order to decrease the effect from the shock of removing the soil from the roots at this age and time of year, a cheese cloth shade was constructed and placed over the bench. This reduced the intensity of the sun during the summer months. To further aid in reducing the temperature and sun intensity, a mud shade was put on the greenhouse glass and the walks were wet-down twice daily.

In September, October and November, the temperature was held between 50° and 55° F. From the latter part of November to the end of the experiment, the plants were moved to another greenhouse in which the temperature was 65° to 70° F.

No disease or insect injury was in evidence. However, as a preventive measure, the plants were twice sprayed with Parathion 25% at the rate of 1 tsp. per gallon of water.

Spot-watering was practiced in order to keep the pots at as uniform a moisture content as possible. It was noticed that the soil of the higher nutrient levels dried out considerably slower than that of the lower levels.

Periodic soil samples were taken approximately every two weeks, and tested by the Spurway method, to get the present level and to determine whether the nutrients needed to be replenished.

This part of the experiment was terminated January 6, 1949, at which time the number of flowers per plant; the length of peduncle; and the weights of the whole plant, the top, and lower parts consisting of the hypocotyl and roots were taken (Table 4 and 5).

Seedlings: In order to get a more complete picture of the response of cyclamen to various nutrient levels, it was decided to grow them in the seedling stage at the same nutrient levels at which the mature plants were grown.

On July 20, 1948, seeds from some "selfed" varieties in the Michigan State College greenhouses were planted. The seedlings were allowed to grow until two to three leaves were formed before transplanting. On October 24, 1948, the seedlings were lifted and potted into 2½" pots containing the same type of soil as was used for the larger plants and with the same combinations of nutrient levels.

These seedlings were grown at a night temperature of 48° to 55° F., and the day temperature of less than 65° F.

Periodic soil tests were made and sufficient nutrients added as their need was indicated by test results.

On March 24, 1949, the fresh and oven-dry weights were taken of the tops and hypocotyl and roots, which are recorded in table 5.

The number of leaves and the average leaf size was recorded at the beginning of the investigation and also at the end.

Table 1. Nutrient Fixation Capacity of Oshtemo

Sandy Soil

Treatment	Nutrient	Carrier	Amount of Carrier (gm.)	Solution	Level Obtained (ppm.)
1	Nitrate	$NaNO_3$	0	0	2*
2	"	"	.01	0.1	5
3	"	"	.02	0.2	10
4	"	"	.03	0.3	15
5	"	"	.04	0.4	25
6	"	"	.05	0.5	35
7	"	"	.06	0.6	50
8	"	"	.08	0.8	50*
9	"	"	.1	1.0	75
10	"	"	.2	2.0	100*
11	"	"	.5	5.0	200*
12	"	"	1.0	10.0	500
1	Phosphorus	$(CaH_4(PO_4)_2$	0	0	0*
2	"	"	.02	0	.5
3	"	"	.03	0	1.0
4	"	"	.04	0	1.5
5	"	"	.05	0	2.5
6	"	"	.06	0	3.5
7	"	"	.08	0	4.0
8	"	"	.10	0	5.0*
9	"	"	.15	0	10.0
10	"	"	.20	0	10.0*

Table 1. (Continued)

Treatment	Nutrient	Carrier	Amount of Carrier (gm.)	Solution (ml.)	Level Obtained (ppm.)
11	Phosphorus	$CaH_4(PO_4)_2$	.25	0	15.0
12	"	"	.30	0	20.0
1	Potassium	K_2SO_4	0	0	2*
2	"	"	.02	0.4	15*
3	"	"	.035	0.7	20
4	"	"	.05	1.0	30*
5	"	"	.1	2.0	40
6	"	"	.15	3.0	60*
7	"	"	.2	4.0	80
8	"	"	.25	5.0	100*
9	"	"	.30	6.0	120
10	"	"	.4	8.0	140
11	"	"	.5	10.0	175
12	"	"	1.0	20.0	240

*Levels selected for use in the experiment.

Table 2. Nutrient Levels Maintained (P.P.M.)

Treatment	NO_3	P	K
1.	0	0	0
2.	0	0	15
3.	0	0	30
4.	0	0	60
5.	0	0	100
6.	0	5	0
7.	0	5	15
8.	0	5	30
9.	0	5	60
10.	0	5	100
11.	0	10	0
12.	0	10	15
13.	0	10	30
14.	0	10	60
15.	0	10	100
16.	0	20	0
17.	0	20	15
18.	0	20	30
19.	0	20	60
20.	0	20	100
21.	25	0	0
22.	25	0	15
23.	25	0	30
24.	25	0	60
25.	25	0	100

Table 2. (continued) Nutrient Levels Maintained (P.P.M.)

Treatment	NO_3	P	K
26.	25	5	0
27.	25	5	15
28.	25	5	30
29.	25	5	60
30.	25	5	100
31.	25	10	0
32.	25	10	15
33.	25	10	30
34.	25	10	60
35.	25	10	100
36.	25	20	0
37.	25	20	15
38.	25	20	30
39.	25	20	60
40.	25	20	100
41.	50	0	0
42.	50	0	15
43.	50	0	30
44.	50	0	60
45.	50	0	100
46.	50	5	0
47.	50	5	15
48.	50	5	30
49.	50	5	60
50.	50	5	100

Table 2 (continued) Nutrient Levels Maintained (PPM.)

Treatment	NO_3	P	K
51.	50	10	0
52.	50	10	15
53.	50	10	30
54.	50	10	60
55.	50	10	100
56.	50	20	0
57.	50	20	15
58.	50	20	30
59.	50	20	60
60.	50	20	100
61.	100	0	0
62.	100	0	15
63.	100	0	30
64.	100	0	60
65.	100	0	100
66.	100	5	0
67.	100	5	15
68.	100	5	30
69.	100	5	60
70.	100	5	100
71.	100	10	0
72.	100	10	15
73.	100	10	30
74.	100	10	60
75.	100	10	100

Table 2 (continued) Nutrient Levels Maintained (PPM.)

Treatment	NO_3	P	K
76.	100	20	0
77.	100	20	15
78.	100	20	30
79.	100	20	60
80.	100	20	100
81.	200	0	0
82.	200	0	15
83.	200	0	30
84.	200	0	60
85.	200	0	100
86.	200	5	0
87.	200	5	15
88.	200	5	30
89.	200	5	60
90.	200	5	100
91.	200	10	0
92.	200	10	15
93.	200	10	30
94.	200	10	60
95.	200	10	100
96.	200	20	0
97.	200	20	15
98.	200	20	30
99.	200	20	60
100.	200	20	100

Table 3. Amount of Nutrient Carriers Required For Desired Levels.

Nutrient	Nutrient Carrier	Amount of soil (grams)	PPM. of each nutrient	Total PPM.	Amount of carrier (grams)
NO_3	$NaNO_3$	1450	12.5		.232
NO_3	NH_4NO_3	1450	12.5	25	.109
NO_3	$NaNO_3$	1450	25.0		.464
NO_3	NH_4NO_3	1450	25.0	50	.218
NO_3	$NaNO_3$	1450	50.0		1.16
NO_3	NH_4NO_3	1450	50.0	100	.54
NO_3	$NaNO_3$	1450	100.0		2.9
NO_3	NH_4NO_3	1450	100.0	200	1.3
P	$CaH_4(PO_4)_2$	1450	5	5	1.16
P	$CaH_4(PO_4)_2$	1450	10	10	2.32
P	$CaH_4(PO_4)_2$	1450	20	20	3.48
K	K_2SO_4	1450	15	15	.232
K	K_2SO_4	1450	30	30	.58
K	K_2SO_4	1450	60	60	1.74
K	K_2SO_4	1450	100	100	2.9

RESULTS

Fixation Capacity of Oshtemo Soil

The results of the tests to determine the fixing capacity of Oshtemo sandy soil for nitrate, phosphorus and potassium are shown by the data presented in table 1. The graphs shown as figures 1, 2 and 3 were constructed from these data. By making use of these graphs it is possible to determine the quantity of each fertilizer necessary to raise the nutrient content of any certain quantity of Oshtemo soil to any desired level in parts per million.

Effect of Nutrients on Growth

On January 6, 1949, 177 days after repotting, the mature cyclamen plants were removed from the pots, washed clear of soil and weighed. The data were recorded as fresh and dry weights of tops and fresh and dry weights of hypocotyl plus roots. These data are recorded in table 4.

The same data were obtained for the seedlings on March 26, 1949, 151 days after repotting and are recorded in table 5.

Response to Nitrogen

Two weeks after the plants had been repotted a visible difference in response to the various levels of nutrient concentration was noted. Those plants at 25 ppm. and 50 ppm. of nitrates seemed to withstand the shift better than those growing at 100 and 200 ppm. of nitrates. Dying of the top parts of the plants was most severe at 200 ppm. of nitrates and 100 ppm. of potassium. Twenty days after repotting, potassium toxicity, which was shown by a general browning of the leaves from the outer edge inward, was most evident on plants grown at 100 ppm. of potassium and low nitrogen (0 ppm). This was less evident as the level of nitrogen was increased.

Effect of Nitrogen on Growth of Tops

The fresh weight of the tops of mature plants at 25 ppm. of nitrates, a total of twenty plants, was 764.4 grams, a higher figure than that reached by the plants at any of the other nitrate levels (see table 6). The fresh weight of all tops at 0 ppm. of nitrate was 431.4 grams, a difference of 333 grams which an F value of 6.24 showed to be significant. At the 5 per cent point the F needed to be 4.04 for statistical significance; at the 1 per cent point it needed to be 7.19. The response curve of mature cyclamen to nitrate expressed by the fresh weight of the tops, as seen in figure 6, was nearly the same as that for the number of flowers. The correlation of the curves for dry weight of tops and flowering was not as great as that of fresh weight of tops and flowering. There was no statistical difference between the fresh weight of the tops at 50 ppm. and 100 ppm. of nitrate. There was a sudden drop in fresh weight, however, at 200 ppm. of nitrate, which showed the toxicity of 200 ppm. of nitrate. The statistical break down, as presented in table 6, shows that growth of the tops at 25, 50 and 100 ppm. of nitrate was significantly better than at 0 ppm. of nitrate. It also shows that 200 ppm. of nitrate has a greater depressing effect upon growth than 0 ppm. of nitrate.

The differences expressed in the dry weight of the tops (table 7 and figure 7) showed that the same things were true as stated for the fresh weight of tops, except that there were no significant differences between 25, 50 and 100 ppm. of nitrate. That 0 ppm. and 200 ppm. of nitrate had a retarding effect on growth was also shown by the dry weight of the tops.

Seedlings: The seedlings displayed a little different response to nitrates than did the mature plants. In the seedlings, the response curve to nitrate expressed by the fresh weight of tops showed that 50 ppm. of nitrate produced the greatest weight (figure 4), as compared to 25 ppm. of nitrate in the case of the mature plants. Also there was a significant increase in fresh weight of tops from 0 ppm. to 50 ppm. of nitrate and then a straight line decrease at 100 and 200 ppm. of nitrate. Level N^1

compared with N^2, N^3 and N^4 showed significance at 5% point (table 8) which was also true with the mature plants. However, N^2 compared with N^3 and N^4 showed a highly significant difference. This was not true in the mature plants when fresh and dry weight of tops were used as a measurement of growth.

The dry weight of the tops of the seedlings at 50 ppm. of nitrate was significantly greater than that at 0, 25, 100 and 200 ppm. of nitrate. There was a significant increase between 0 ppm. and 25 ppm. of nitrate and between 25 ppm. and 50 ppm. of nitrate, but at 100 ppm. of nitrate there was a significant drop in weight and a highly significant drop at 200 ppm. The toxicity of 200 ppm. of nitrate is quite evident in the seedlings as well as in the mature cyclamen plants. The seedlings differed from the mature plants in that the mature plants showed no significant difference in dry weight of tops between 25, 50 and 100 ppm. of nitrate while the seedlings showed a significant increase in dry weight of tops from 0 to 25 to 50 ppm. of nitrate while the drop began at 100 ppm. of nitrate instead of at 200 ppm. (table 9 and figure 5).

Effect of Nitrogen on Hypocotyl plus Root

It was observed that the best root development took place in the soils of low nitrate levels. There were many dead roots in the pots maintained at high nitrate levels. This may be the manner in which the very high nitrate levels limited plant growth. The increasing of phosphorus had a tendency to temper the detrimental effects of the high nitrogen on root development. Figure 7 shows the interaction of different levels of nitrates and phosphorus upon the hypocotyl and roots. Figure 4 shows the response curve of the hypocotyl plus roots to various levels of nitrates. As the levels of nitrate were increased, the fresh weight of the lower parts of the plant decreased. There was a negatively significant difference between all the nitrate levels in that they decreased the fresh weight of the hypocotyl plus roots. (see table 10).

Effect of Nitrogen on Flowering

Figure 6 shows the response curve of the effect of various levels of nitrate nitrogen upon the production of flowers. The curve shows two peaks, the higher one at 25 ppm. and the next at 100 ppm. At 25 ppm. of nitrates, 196 blossoms were produced and at 200 ppm., 42 blossoms. The difference is highly significant. Table 110 shows further comparisons. There was a significant drop in production from 100 ppm. to 200 ppm. of nitrate. It seems that cyclamen respond best to comparatively low levels of nitrate. The increase from 122 blossoms at 0 ppm. level of nitrate to 195 blossoms at 25 ppm. is greater than is necessary for significance at 1%. In general any amount over 25 ppm. of nitrates has a depressing effect on the production of flowers. Plate 2 pictures the effect of various levels of nitrate on plant growth and flowering when phosphorus and potassium are at their optimum.

In computing the number of flowers, those buds which were sufficiently developed, and would probably have opened if allowed to remain longer, were counted as blossoms. However, an examination of table 12 will reveal that the percentage of unopened blossoms as well as that of fewer blossoms was highest for the higher levels of nitrate and potassium.

Response to Potassium

The effect of potassium applications upon mature cyclamen did not prove to be significant when fresh weight of tops was used as a measurement of growth. As shown by the summations in Table 6, the plants which did not receive potassium yielded slightly more than did those which were grown at the 15 ppm. level. However, the difference was not significant. The toxicity level of potassium was reached at 60 and 100 ppm.

The statistical analysis of the effect of potassium levels upon the dry weight of the tops of mature cyclamen revealed that 15 ppm. of potassium produced the greatest weight. The difference between 0 ppm. and 15 ppm. of potassium was significant. The toxicity of 100 ppm. of K_2O was shown by the sudden drop when K^3 was compared with K^4. There was no significant difference between dry weight of tops when grown at 30 and 60 ppm. (Table 7).

Seedlings: The fresh weight of the tops of seedlings also showed no significant response to applications of potassium but unlike the mature plants the maximum fresh weight of tops was reached at 30 rather than at 0 ppm. of potassium. However, there was very little difference between the effects of 15 and 30 ppm. of potassium. The best response then seemed to come from 15 and 30 ppm. of potassium.

Where the nitrate was low, the increase in potassium resulted in decreased growth, which began to be quite noticeable at 30 ppm. of potassium, but where the nitrate was raised from 0 ppm. to 100 ppm., the ill effects appeared mainly at 60-100 ppm. of potassium (see plates 3 and 5).

Potassium caused significant differences at the 5% point in the dry weight of seedling tops. A breakdown of this showed that 30 ppm. of potassium caused results which were significantly different from those caused by the 60 and 100 ppm. The differences caused by the K^1 and K^2 levels of potassium were statistically significant (see table 9). These differences are clearly shown by the seedlings shown in plate 7.

Effect of Potassium on Flowering

The greatest number of flowers was produced at 15 ppm. of potassium. The number produced at this level was significantly greater than that produced at the 30, 60 and 100 ppm. levels. The difference was significant at the 5% point. Table 11 and plate 5 illustrate this fact. It is interesting to note the correlation between the dry weight of the tops and flowering.

Effect of Potassium Upon Hypocotyl and Roots

The reducing effect on the fresh weight of the hypocotyl and roots caused by potassium was remarkable. On the plants not treated with potassium the hypocotyl and roots were larger than on those which received this nutrient. 15 ppm. of potassium reduced the fresh weight over that at 0 ppm. by 49%. Levels 30 and 60 ppm. of potassium had about the same reducing effect, with another sudden drop at 100 ppm. of K_2O.

There was a statistically significant interaction between nitrate and potassium levels upon the fresh weight of seedling tops. The highest was reached at a combination of 30 ppm. of K_2O and 100 ppm. of nitrate nitrogen. (Figure 13). Dry weight of seedling tops did not show this to be significant.

Response to Phosphorus

Phosphorus had no apparently significant effect upon the total fresh or dry weight, the number of flowers, the fresh and dry weight of tops, or the fresh and dry weights of hypocotyl plus roots in the mature plants.

The time of flowering was hastened by increasing the phosphorus when the nitrate level was low. This is clearly shown in plate 4, in which the potassium was maintained at 15 ppm; nitrate 0 ppm. and phosphorus increased from 0 to 20 ppm.

The number of pots showing blossoms at certain intervals of time, based on different levels of phosphorus, as recorded in table 16, showed further the effect of high phosphorus on early flowering.

There was a significant interaction between nitrate and phosphorus levels which affected the fresh weight of the mature plant tops (Figure 8). At the low nitrate level, the fresh weight of the tops decreased as the phosphorus was increased. At the highest level of phosphorus, the maximum fresh weight of mature plants was reached in combination with 25 ppm. of nitrate. However, this was not statistically significant. The above weight was also the highest for any of the NP level combinations. The growth of the top did not increase directly when both nitrate and phosphorus levels were increased, but there was an interaction which varied with different concentrations of both. At 50 ppm.

of nitrates, the best growth of the tops was attained in combination with 0 ppm. of phosphorus. The maximum growth of the tops came about at the 5 ppm. of phosphorus level and decreased with 100 and 200 ppm. of nitrate. The maximum dry weight of the tops for all combinations of NP was reached at 20 ppm. of phosphorus when in combination with 100 ppm. of nitrate.

The response of the hypocotyl plus roots to NP levels is shown in figure 7. The low levels of nitrogen combined with increasing levels of phosphorus gave the highest weights. At 20 ppm. of phosphorus, increments of nitrates reduced decidedly the fresh weight of the hypocotyl plus roots.

Table 4. Fresh and Dry Weight of Tops and Hypocotyls plus Roots.of the mature plants.

	Fresh Weight (grams)			Dry weight (grams		
Treatment	Top	Hypocotyl and Roots	Total	Top	Hypocotyl and Roots	Total
1	33.7	26.3	60.0	3.8	6.8	10.6
2	39.0	49.0	88.0	4.1	9.8	13.9
3	29.5	29.0	58.5	3.3	5.5	8.8
4	5.0	9.0	14.0	3.0	1.7	4.7
5	11.5	23.0	34.5	3.4	4.3	7.7
6	43.0	48.5	91.5	5.3	7.5	12.8
7	22.0	30.0	52.0	2.9	7.8	10.7
8	19.0	20.5	39.5	3.7	4.3	8.0
9	39.0	35.0	74.0	3.6	6.0	9.6
10	5.9	14.1	20.0	2.9	2.8	5.7
11	27.5	35.0	62.5	4.0	5.2	9.2
12	7.5	16.5	24.0	2.7	2.8	5.5
13	18.0	15.5	33.5	3.0	2.9	5.9
14	29.0	32.0	61.0	4.7	6.5	11.2
15	28.0	30.5	54.5	3.1	6.5	9.6
16	18.3	24.0	42.3	3.0	4.0	7.0
17	21.0	31.	52.0	4.2	5.0	9.2
18	16.0	38.5	54.5	2.6	9.7	13.3
19	7.5	16.0	23.5	2.5	3.0	5.5
20	11.0	28.4	39.4	2.4	5.2	7.6
21	33.5	21.8	55.3	5.6	5.9	11.5
22	6.5	12.5	19.0	3.8	2.4	6.2
23	5.0	17.1	21.1	2.3	3.4	5.7

Table 4. (continued)

	Fresh Weight (grams)			Dry Weight (grams)		
Treatment	Top	Bottom	Total	Top	Bottom	Total
24	3.5	18.5	22.0	1.5	3.3	4.8
25	1.5	18.7	26.2	2.8	3.2	6.0
26	33.0	14.0	47.0	5.4	2.0	7.4
27	37.0	25.0	62.0	5.8	4.2	10.0
28	83.5	37.5	121.0	7.8	9.7	18.6
29	25.0	18.0	43.0	5.0	2.9	7.9
30	18.5	24.0	42.5	4.2	5.0	9.2
31	57.5	26.0	83.5	1.9	4.3	6.2
32	68.3	21.7	90.0	7.4	3.6	12.0
33	62.5	26.0	88.5	6.1	5.7	11.8
34	4.0	10.0	14.0	2.6	2.3	4.9
35	16.5	12.5	29.0	3.7	2.0	5.7
36	33.0	12.0	45.0	4.0	2.0	6.0
37	89.1	45.4	134.5	9.1	8.2	17.3
38	110.0	36.5	146.5	11.5	7.1	18.6
39	23.5	12.5	35.0	4.5	2.2	6.7
40	47.0	35.0	82.0	5.8	8.1	13.9
41	77.5	40.0	117.5	7.0	8.6	15.6
42	54.5	26.5	37.5	6.3	10.0	16.3
43	17.0	20.5	37.5	3.2	4.5	7.7
44	15.0	28.0	43.0	5.0	5.5	10.5
45	82.0	58.0	140.0	8.3	13.6	22.1
46	20.0	16.5	36.5	4.4	3.1	7.5

Table 4. (continued)

Treatment	Top	Bottom	Total	Top	Bottom	Total
47	58.0	28.0	86.0	6.5	6.0	12.5
48	10.0	20.0	30.0	2.8	4.2	7.0
49	3.0	8.0	11.0	1.9	1.5	3.4
50	3.0	15.0	18.0	2.1	4.5	6.6
51	78.0	43.0	121.0	7.3	10.0	17.3
52	10.0	12.0	22.0	2.7	2.5	5.2
53	12.0	15.0	27.0	4.0	2.2	6.2
54	23.2	30.3	53.5	4.1	7.6	11.7
55	69.0	44.0	113.0	9.5	5.0	14.5
56	1.5	3.6	5.1	1.1	0.9	2.0
57	22.5	13.0	35.5	3.7	3.0	6.7
58	27.0	15.0	42.0	5.6	2.1	7.7
59	13.4	15.1	28.5	4.2	3.3	7.5
60	36.0	34.0	70.0	7.0	6.5	13.5
61	104.5	29.0	133.5	10.0	4.0	14.0
62	53.5	29.5	83.0	6.0	5.0	11.0
63	12.0	26.0	38.0	4.0	5.5	9.5
64	10.0	19.5	29.5	2.8	3.2	6.0
65	1.5	3.6	5.1	1.1	0.9	2.0
66	23.5	30.5	54.0	6	5.7	11.7
67	82.5	29.5	112.0	8.8	4.5	13.3
68	90.0	28.3	118.3	8.9	8.5	17.4
69	70.5	27.5	97.0	8.3	5.6	13.9
70	3.5	3.0	6.5	2.7	1.0	3.7

Table 4 (continued)

	Fresh Weight (grams)			Dry Weight (grams)		
Treatment	Top	Bottom	Total	Top	Bottom	Total
71	22.5	25	47.5	3.7	5.5	9.2
72	30.5	29.0	59.5	5.7	9.5	15.2
73	14.0	26.0	40.0	3.4	5.5	8.9
74	15.0	42.0	57.0	7.5	10.0	17.5
75	1.5	3.6	5.1	1.1	0.9	2.0
76	23.0	14.5	37.5	4.0	2.5	6.5
77	5.6	20.0	25.6	4.4	3.5	7.9
78	3.0	7.5	10.5	2.0	1.0	3.0
79	60.0	28.0	88.0	5.5	5.5	11.0
80	12.5	31.0	43.5	4.8	6.2	11.0
81	50.6	27.5	78.1	7.5	5.8	12.3
82	2.3	3.7	6.0	2.2	1.0	3.2
83	2.0	5.0	7.0	1.5	1.4	2.9
84	70.0	46.0	116.0	10.7	12.3	21.0
85	1.5	5.0	6.5	1.5	1.5	3.0
86	3.0	5.5	8.5	1.5	1.5	3.0
87	39.0	34.0	73.0	5.0	8.5	13.5
88	5.0	15.0	20.0	2.0	3.0	5.0
89	2.0	7.2	9.2	1.9	1.0	2.9
90	2.2	8.7	10.9	1.6	1.4	3.0
91	8.0	14.1	22.1	2.8	2.5	5.3
92	4.0	26.0	30.0	2.7	11.5	14.2
93	28.0	23.5	51.5	5.5	3.5	9.0

Table 4 (continued)

	Fresh Weight (grams)			Dry Weight (grams)		
Treatment	Top	Bottom	Total	Top	Bottom	Total
94	31.0	24.6	55.6	5.5	4.0	9.5
95	7.1	13.8	20.9	0.8	2.2	3.0
96	6.5	20.0	26.5	2.5	4.0	6.5
97	28.5	23.0	51.5	4.2	4.0	8.2
98	10.0	14.0	24.0	4.0	2.0	6.0
99	4.8	2.5	7.3	2.7	1.2	3.9
100	2.4	8.6	11.0	1.8	2.1	3.9

Table 5. Fresh and Dry Weight of the Top and Hypocotyl plus Roots of The Seedlings (grams)

Pot No.	Fresh Weight: Top	Fresh Weight: Hypocotyl and Roots	Total	Dry Weight: Top	Dry Weight: Hypocotyl and Roots	Total
1	.50	1.50	2.00	.040	.210	.250
2	.75	1.80	2.55	.060	.220	.280
3	.70	1.00	1.70	.070	.150	.220
4	.75	1.30	2.05	.075	.210	.285
5	.90	1.70	2.60	.100	.335	.435
6	1.00	2.50	3.50	.100	.300	.400
7	1.00	3.50	4.50	.080	.520	.600
8	1.40	2.70	4.10	.130	.500	.630
9	2.00	3.30	5.30	.270	.720	.990
10	1.20	1.40	2.60	.100	.280	.380
11	1.10	1.70	2.80	.110	.290	.400
12	1.55	2.65	4.20	.150	.470	.620
13	1.40	2.30	3.70	.195	.400	.595
14	1.40	2.15	3.55	.150	.380	.530
15	1.05	1.60	2.65	.090	.260	.350
16	1.90	4.50	6.40	.090	.890	.980
17	1.25	2.25	3.50	.165	.455	.620
18	2.00	3.00	5.00	.200	.520	.720
19	1.15	3.00	4.15	.100	.440	.540
20	.85	1.90	2.75	.100	.260	.360
21	.60	1.80	2.40	.080	.295	.375
22	.80	2.10	2.90	.080	.320	.400

Table 6. Fresh and Dry Weight of the Top and Hypocotyl plus Roots of the Seedlings (grams) (continued)

Pot No.	Fresh Weight Top	Fresh Weight Hypocotyl and Roots	Total	Dry Weight Top	Dry Weight Hypocotyl and Roots	Total
23	.65	2.00	2.65	.115	.310	.425
24	.70	1.50	2.20	.125	.165	.290
25	.50	1.55	2.05	.100	.175	.275
26	1.70	3.80	5.50	.200	.480	.680
27	1.70	1.70	3.40	.140	.240	.380
28	.85	.40	1.25	.090	.200	.290
29	1.20	2.45	3.65	.120	.380	.500
30	.65	.60	1.25	.065	.100	.165
31	1.50	2.00	3.50	.140	.330	.470
32	1.55	3.35	4.90	.160	.390	.550
33	1.50	1.85	3.35	.160	.260	.420
34	2.20	2.30	4.50	.235	.355	.590
35	2.30	1.65	3.95	.285	.285	.570
36	1.45	3.50	4.95	.130	.480	.610
37	1.60	2.50	4.10	.200	.350	.550
38	2.40	2.40	4.80	.285	.325	.610
39	.75	.75	1.50	.070	.130	.200
40	1.75	2.75	4.50	.175	.380	.555
41	.30	1.00	1.30	.070	.130	.200
42	.90	2.50	3.40	.100	.330	.430
43	1.60	2.80	4.20	.140	.500	.640
44	.50	1.40	1.90	.055	.145	.200

Table 5. (continued) The Fresh and Dry Weight of the Top and Hypocotyl plus Roots of Seedlings (grams).

Pot No.	Fresh Weight Top	Fresh Weight Hypocotyl and Roots	Fresh Weight Total	Dry Weight Top	Dry Weight Hypocotyl and Roots	Dry Weight Total
45	.80	1.60	2.40	.070	.200	.270
46	1.50	2.80	4.30	.120	.310	.430
47	2.50	1.50	4.00	.220	.290	.510
48	1.15	1.80	3.35	.150	.235	.385
49	2.50	3.40	5.90	.250	.540	.790
50	3.65	3.25	6.90	.300	.430	.730
51	2.00	3.00	5.00	.150	.450	.600
52	1.60	.75	2.35	.200	.150	.350
53	.35	.35	.70	.050	.065	.115
54	1.20	1.40	2.60	.150	.200	.350
55	1.65	1.30	2.95	.180	.255	.445
56	1.30	3.20	4.50	.170	.380	.550
57	1.60	1.90	3.50	.120	.260	.380
58	2.15	1.70	3.85	.240	.280	.520
59	2.20	2.00	4.20	.220	.360	.580
60	.60	.20	1.30	.080	.130	.210
61	.20	.80	1.00	.030	.120	.150
62	.45	.20	1.15	.050	.100	.150
63	.40	2.00	2.40	.085	.355	.440
64	1.25	1.90	3.15	.140	.315	.455
65	.50	.80	1.30	.030	.100	.130
66	.40	.30	.70	.060	.070	.130

Table 5.(continued) The Fresh and Dry Weight of the Top and Hypocotyl plus Roots of Seedlings (grams)

	Fresh Weight			Dry Weight		
Pot. No.	Top	Hypocotyl and Roots	Total	Top	Hypocotyl and Roots	Total
67	.75	.75	1.50	.075	.145	.220
68	1.80	2.15	3.95	.170	.410	.580
69	.30	.80	1.10	.070	.120	.190
70	1.30	1.10	2.40	.215	.280	.495
71	.80	2.10	2.90	.095	.225	.320
72	.70	1.00	1.70	.075	.170	.245
73	1.60	1.50	3.10	.215	.285	.500
74	1.20	1.60	2.80	.115	.235	.350
75	.25	.40	.65	.035	.055	.090
76	1.65	2.50	4.15	.240	.440	.680
77	1.50	1.20	2.70	.200	.180	.380
78	4.30	1.35	5.65	.510	.260	.770
79	1.30	.80	2.10	.140	.170	.310
80	1.00	.65	1.65	.130	.180	.210
81	.10	.50	.60	.020	.050	.070
82	1.00	.60	1.60	.110	.105	.215
83	.85	.55	1.40	.105	.100	.205
84	.30	.45	.75	.070	.080	.150
85	.35	.50	.85	.060	.100	.160
86	.85	.45	1.30	.120	.110	.230
87	.20	.80	1.00	.070	.110	.180
88	.20	.60	.80	.130	.130	.260

Table 5. (continued) The Fresh and Dry Weight of the Top and Hypecotyl plus Roots of Seedlings (grams)

Pot No.	Fresh Weight Top	Hypecotyl and Roots	Total	Dry Weight Top	Hypocotyl and Roots	Total
89	.45	.50	.95	.050	.095	.145
90	.20	.70	.90	.070	.120	.190
91	1.25	1.00	2.25	.150	.210	.360
92	.60	.35	.95	.100	.100	.200
93	.70	.60	1.30	.100	.100	.200
94	.40	.60	1.00	.050	.130	.180
95	.30	.40	.70	.030	.050	.080
96	.30	.70	1.00	.020	.070	.090
97	1.10	.50	1.60	.110	.110	.220
98	.20	.50	.70	.060	.080	.140
99	.50	.45	.95	.100	.060	.160
100	.45	.45	.90	.070	.060	.130

Table 6. Analysis of Variance of the Fresh Weight of Tops -- Mature Plants

A. Two-way tables:

	P^0	P^1	P^2	P^3	Σ
N^0	118.7	128.9	110.0	73.8	431.4
N^1	56.0	197.0	208.8	302.6	764.4
N^2	246.0	94.0	192.2	100.4	632.6
N^3	181.5	270.0	83.5	104.1	639.1
N^4	126.4	51.2	78.1	52.2	307.9
Σ	728.6	741.1	672.6	633.1	

	K^0	K^1	K^2	K^3	K^4	Σ
N^0	122.5	89.5	82.5	80.5	56.4	431.4
N^1	157.0	200.9	261.0	56.0	89.5	764.4
N^2	177.0	145.0	66.0	54.6	190.0	632.6
N^3	173.5	172.1	119.0	155.5	19.0	639.1
N^4	68.1	73.8	45.0	107.8	13.2	307.9
Σ	698.1	681.3	573.5	454.4	368.1	

	K^0	K^1	K^2	K^3	K^4	Σ
P^0	299.8	155.8	65.5	103.5	104.0	728.6
P^1	122.5	238.5	207.5	139.5	33.1	741.1
P^2	193.5	120.3	134.5	102.2	122.1	672.6
P^3	82.3	166.7	166.0	109.2	108.9	633.1
Σ	698.1	681.3	573.5	454.4	368.1	

B. Summary of analysis of variance of the fresh weight of tops:

Source	Degree of freedom	Sums of squares	Mean of squares	f
Total	99	69572.75		
N	4	6663.91	1665.98	3.74 (V.S.)
P	3	303.29	101.10	--
K	4	4091.17	1022.80	2.30 (N.S.)
NP	12	14565.85	1213.82	2.73 (V.S.)
NK	16	12686.27	792.89	1.78 (N.S.)
PK	12	9923.62	826.96	1.86 (N.S.)
NPK	48	21338.68	444.55	

Table 6. (continued) Analysis of Variance of the Fresh Weight of Tops -- Mature Plants

C. Breakdown of treatment variance:

N^0 vs $N^1 + N^2 + N^3 + N^4$ (N.S.)
N^1 vs $N^2 + N^3 + N^4$ (S. at 5%)
N^2 vs $N^3 + N^4$ (N.S.)
N^3 vs N^4 (V.S. at 5%)
N^0 vs $N^1 + N^2 + N^3$ (V.S. at 5%)

See figure for the interreaction of NP levels.

Table 7. Analysis of Variance of the Dry Weight of Tops (mature plants)

A. Two-way tables:

	P^0	P^1	P^2	P^3	Σ
N^0	17.6	18.4	17.5	14.7	68.2
N^1	16.0	28.2	21.7	34.9	100.8
N^2	30.0	17.7	27.6	21.6	96.9
N^3	23.9	34.7	21.4	20.7	100.7
N^4	23.4	12.0	17.3	15.2	67.9
Σ	110.9	111.0	105.5	107.1	

	K^0	K^1	K^2	K^3	K^4	Σ
N^0	16.1	13.9	12.6	13.8	11.8	68.2
N^1	16.9	26.1	27.7	13.6	16.5	100.8
N^2	19.8	19.2	15.6	15.2	27.1	96.9
N^3	23.7	24.9	18.3	24.1	9.7	100.7
N^4	14.3	14.1	13.0	20.8	5.7	67.9
Σ	90.8	98.2	87.2	87.5	70.8	

	K^0	K^1	K^2	K^3	K^4	Σ
P^0	33.9	22.4	14.3	23.0	17.3	110.9
P^1	22.6	29.0	25.2	20.7	13.5	111.0
P^2	19.7	21.2	22.0	24.4	18.2	105.5
P^3	14.6	25.6	25.7	19.4	21.8	107.1
Σ	90.8	98.2	87.2	87.5	70.8	

B. Summary of analysis of variance of the dry weight of tops.

Source	Degree of freedom	Sums of squares	Mean of squares	f.	
Total	99	528.31			
N	4	59.72	14.92	4.46	(V.S.)
P	3	.92	---	---	(N.S.)
K	4	20.13	5.03	1.50	(N.S.)
NP	12	98.67	8.22	2.45	(N.S.)
NK	16	114.90	7.18	2.14	(N.S.)
PK	12	73.06	6.09	1.82	(N.S.)
NPK	48	160.91	3.35		

Table 7. (continued) Analysis of Variance of the Dry Weight of tops - mature plants

C. Breakdown of treatment variance

N^0 vs $N^1 \not{-} N^2 \not{-} N^3 \not{-} N^4$ (S. at 5%)
N^1 vs $N^2 \not{-} N^3 \not{-} N^4$ (N.S.)
N^2 vs $N^3 \not{-} N^4$ (N.S.)
N^3 vs N^4 (S.)

Table 8. Analysis of Variance of the Fresh Weight of Tops -- Seedlings

A. Two-way tables:

	P^0	P^1	P^2	P^3	Σ
N^0	3.60	6.60	6.50	7.15	23.85
N^1	3.25	8.10	9.05	7.95	26.35
N^2	4.10	11.70	6.80	7.85	30.45
N^3	2.80	4.55	4.55	9.75	21.65
N^4	2.60	1.90	3.25	2.55	10.30
Σ	16.35	30.85	30.15	35.25	

	K^0	K^1	K^2	K^3	K^4	Σ
N^0	4.50	4.55	5.50	5.30	4.00	23.85
N^1	5.25	5.35	5.40	4.85	5.20	26.35
N^2	5.10	6.60	5.65	6.40	6.70	30.45
N^3	3.05	3.40	8.10	4.05	3.05	21.65
N^4	2.50	2.90	1.95	1.65	1.30	10.30
Σ	20.40	23.10	26.60	22.25	20.25	

	K^0	K^1	K^2	K^3	K^4	Σ
P^0	1.70	3.90	4.20	3.50	3.05	16.35
P^1	5.45	6.15	5.80	6.45	7.00	30.85
P^2	6.65	6.00	5.55	6.40	5.55	30.15
P^3	6.60	7.05	11.05	5.90	4.65	35.25
Σ	20.40	23.10	26.60	22.25	20.25	

B. Summary of analysis of variance of the fresh weight of tops

Source	Degree of freedom	Sums of squares	Mean of squares	f.	
Total	99	55.24			
N	4	8.72	2.18	9.08	(V.V.S.)*
P	3	8.03	2.68	11.16	(V.V.S.)
K	4	1.33	.34	1.41	(N.S.)
NP	12	11.68	.97	4.04	(V.S.)
NK	16	7.38	.46	1.91	(S. at 5%)
PK	12	4.58	.38	1.58	(N.S.)
NPK	48	11.52	.24		

* V.V.S. - Highly significant

Table 8. (Continued) Analysis of Variance of the Fresh Weight of Seedlings

C. Breakdown of treatment variance

N^0 vs $N^1 \neq N^2 \neq N^3 \neq N^4$ (N.S.)
N^1 vs $N^2 \neq N^3 \neq N^4$ (S. at 5%)
N^2 vs $N^3 \neq N^4$ (V.V.S.)
N^3 vs N^4 (V.S.)
N^0 vs $N^1 \neq N^2 \neq N^3$ (N.S.)

P^0 vs $P^1 \neq P^2 \neq P^3$ (V.V.S)
P^1 vs $P^2 \neq P^3$ (N.S.)
P^2 vs P^3 (N.S.)

See figure for a representative of the interreaction response of the plant to NP levels.

Table 9. Analysis of Dry Weight of Tops -- Seedlings

A. Two-way tables:

	P^0	P^1	P^2	P^3	Σ
N^0	.345	.680	.695	.655	2.375
N^1	.500	.615	.980	.860	2.955
N^2	.435	1.040	.730	.830	3.035
N^3	.335	.590	.535	1.220	2.680
N^4	.365	.440	.430	.360	1.595
Σ	1.980	3.365	3.370	3.929	

	K^0	K^1	K^2	K^3	K^4	Σ
N^0	.340	.455	.595	.595	.390	2.375
N^1	.550	.580	.650	.550	.625	2.955
N^2	.510	.640	.580	.675	.630	3.035
N^3	.425	.400	.980	.465	.410	2.680
N^4	.310	.390	.395	.270	.230	1.595
Σ	2.135	2.465	3.200	2.555	2.285	

	K^0	K^1	K^2	K^3	K^4	Σ
P^0	.240	.400	.515	.465	.360	1.980
P^1	.600	.585	.670	.760	.750	3.365
P^2	.645	.685	.720	.700	.620	3.370
P^3	.650	.795	1.295	.630	.555	3.925
Σ	2.135	2.465	3.200	2.555	2.285	

B. Summary of analysis of dry weight of tops:

Source	Degree of freedom	Sums of squares	Mean of squares	f.	
Total	99	.5359			
N	4	.0678	.0170	5.31	(s)
P	3	.0825	.0275	8.59	(V.S.)
K	4	.0335	.0084	2.63	(S. at 5%)
NP	12	.0901	.0075	2.34	(S. at 5%)
NK	16	.0535	.0033	1.03	(N.S.)
PK	12	.0532	.0044	1.37	(N.S.)
NPK	48	.1553	.0032		

Table 9. (continued) Analysis of Dry Weight of Tops - Seedlings

C. Breakdown of treatment of variance:

N^0 vs $N^1 + N^2 + N^3 + N^4$ (N.S.)
N^1 vs $N^2 + N^3 + N^4$ (S. at 5%)
N^2 vs $N^3 + N^4$ (S)

P^0 vs $P^1 + P^2 + P^3$ (V.S.)
P^1 vs $P^2 + P^3$ -(N.S.)
P^2 vs P^3 (N.S.)

K^0 vs $K^1 + K^2 + K^3 + K^4$ (N.S.)
K^1 vs $K^2 + K^3 + K^4$ (N.S.)
K^2 vs $K^3 + K^4$ (S at 5%)
K^3 vs K^4 (N.S.)
K^1 vs K^2 (S. at 5%)

Table10. The Analysis of Variance of the Fresh Weight of the Hypocotyl plus Roots --mature plants

A. Two-way tables:

	P^0	P^1	P^2	P^3	Σ
N^0	7.30	13.40	10.40	14.65	45.75
N^1	8.95	8.95	11.15	11.90	40.95
N^2	9.30	12.75	6.80	9.50	38.35
N^3	6.20	5.10	6.60	6.50	24.40
N^4	2.60	3.05	2.95	2.60	11.20
Σ	34.35	43.25	37.90	45.15	

	K^0	K^1	K^2	K^3	K^4	Σ
N^0	10.20	10.20	9.00	9.75	6.60	45.75
N^1	11.10	9.65	6.65	7.00	6.55	40.95
N^2	10.00	6.65	6.65	8.20	6.85	38.35
N^3	5.70	5.65	7.00	5.10	2.95	24.40
N^4	2.65	2.25	2.25	2.00	2.05	11.20
Σ	39.65	32.40	31.55	32.05	25.00	

	K^0	K^1	K^2	K^3	K^4	Σ
P^0	5.60	7.70	8.35	6.55	6.15	34.35
P^1	9.85	8.25	7.65	10.45	7.05	43.25
P^2	9.80	8.10	6.60	8.05	5.35	37.90
P^3	14.40	8.35	8.95	7.00	6.45	45.15
Σ	39.65	32.40	31.55	32.05	25.00	

B. Summary of analysis of variance of the fresh weight of hypocotyl plus Roots.

Source	Degree of freedom	Sums of Squares	Mean of Squares	f.	
Total	99	95.4733			
N	4	39.9902	10.0000	24.15	(V.V.S.)
P	3	2.9325	.9775	2.36	(N.S.)
K	4	5.3902	1.3475	3.25	(S. at 5%)
NP	12	11.7451	.9788	2.36	(S. at 5%)
NK	16	5.9460	.3716	--	
PK	12	7.5996	.6333	1.52	N.S.
NPK	48	19.8697	.4140		

Table10.(concluded) The Analysis of Variance of the Fresh Weight of the Hypocotyl plus Roots.

C. Breakdown of treatment variance

N^0 vs $N^1 + N^2 + N^3 + N^4$ (V.V.S.)
N^1 vs $N^2 + N^3 + N^4 +$ (V.V.S.)
N^2 vs $N^3 + N^4$ (V.V.S.)
N^3 vs N^4 (S)
N^1 vs N^2 (N.S.)

K^0 vs $K^1 + K^2 + K^3 + K^4$(S)
K^1 vs $K^2 + K^3 + K^4$ (N.S.)
K^2 vs $K^3 + K^4$ (N.S.)
K^3 vs K^4 (N.S.)
K^0 vs $K^1 + K^2 + K^3$ (S)

Table 11 Analysis of Variance of the Number of Flowers Produced.

A. Two-way tables

	P^0	P^1	P^2	P^3	Σ
N^0	22	33	39	28	122
N^1	28	54	58	55	195
N^2	44	26	33	26	129
N^3	32	47	37	21	137
N^4	10	15	9	8	42
Σ	136	175	176	138	

	K^0	K^1	K^2	K^3	K^4	Σ
N^0	39	26	21	23	13	122
N^1	36	53	55	31	20	195
N^2	35	25	13	24	32	129
N^3	25	35	31	34	12	137
N^4	6	12	13	9	2	42
Σ	141	151	133	121	79	

	K^0	K^1	K^2	K^3	K^4	Σ
P^0	38	40	20	18	20	136
P^1	38	39	48	34	16	175
P^2	49	37	31	39	20	176
P^3	16	35	34	30	19	138
Σ	141	151	133	121	79	

B. Summary of analysis of variance of the number of flowers

Source	Degrees of freedom	Sums of squares	Mean of squares	f.	
Total	99	2246.75			
N	4	597.90	149.48	10.20	(V.S.)*
P	3	59.39	19.80	1.35	(N.S.)*
K	4	156.40	39.10	2.66	(S.)
NP	12	199.66	16.64	1.13	(N.S.)
NK	16	337.20	21.08	1.44	(N.S.)
PK	12	191.36	15.95	1.09	(N.S.)
(E.T) NPK	48	704.84	14.68		

C. Breakdown of treatment variance

N^0 vs $N^1 + N^2 + N^3 + N^4$ (N.S)
N^1 vs $N^2 + N^3 + N^4$ (V.S.)
N^2 vs $N^3 + N^4$ (N.S.)
N^3 vs N^4 (V.S.)

K^0 vs $K^1 + K^2 + K^3 + K^4$ (N.S.)
K^1 vs $K^2 + K^3 + K^4$ (S. at 5%)
K^2 vs $K^3 + K^4$ (N.S.)
K^3 vs K^4 (N.S.)

*V.S. Very significant

*N.S. Not significant

Table 12. Number of Flowers Open and In Bud Stage and Average Length of Peduncle.

Treatment	Flowers open	Flowers in bud stage	Average Peduncle (cm)	Treatment	Flowers open	Flowers in bud stage	Average Peduncle (cm.)
1.	4	4	11.5	25.	0	2	5.0
2.	5	3	10.5	26.	3	2	5.5
3.	2	1	10.5	27.	5	3	12.0
4.	2	0	10.0	28.	13	9	14.0
5.	0	1	10.0	29.	6	5	11.0
6.	9	5	9.0	30.	5	3	7.0
7.	4	0	9.0	31.	13	4	7.0
8.	0	4	7.0	32.	11	7	9.5
9.	7	0	8.5	33.	7	4	8.0
10.	1	3	7.0	34.	2	6	6.0
11.	6	6	6.0	35.	1	3	4.5
12.	2	2	5.5	36.	3	5	5.0
13.	2	6	5.5	37.	12	6	13.0
14.	4	6	6.0	38.	10	5	14.0
15.	1	4	7.0	39.	3	5	10.0
16.	0	5	6.5	40.	4	2	8.0
17.	7	3	9.0	41.	6	2	15.5
18.	2	4	7.0	42.	5	4	12.0
19.	4	0	6.0	43.	2	0	8.0
20.	1	2	7.0	44.	5	4	7.0
21.	1	5	9.0	45.	9	7	13.0
22.	5	4	7.0	46.	0	9	5.0
23.	0	7	8	47.	7	3	9.0
24.	0	4	7	48.	2	2	4.0

Table 12.(continued) Number of Flowers Open and In Bud Stage and Average Peduncle Length.

Treat-ment	Flowers open	Flowers in bud stage	Average Length of Peduncle (cm.)	Treat-ment	Flowers open	Flowers in bud stage	Average Length of Peduncle (cm.)
49.	0	2	3.0	72.	7	8	6.0
50.	0	1	6.0	73.	5	3	6.5
51.	10	6	12.0	74.	7	2	15.0
52.	1	0	6.0	75.	0	3	4.0
53.	1	1	7.0	76.	0	1	5.0
54.	2	5	16.0	77.	0	1	5.5
55.	4	3	12.0	78.	0	2	6.0
56.	0	2	5.0	79.	9	2	8.0
57.	1	4	7.5	80.	5	1	7.5
58.	4	1	8.0	81.	0	4	4.0
59.	0	6	5.0	82.	0	3	5.0
60.	3	5	4.5	83.	0	2	4.0
61.	7	5	13.5	84.	0	1	4.0
62.	1	10	7.0	85.	0	0	0.0
63.	0	6	6.0	86.	0	2	8.0
64.	2	0	7.5	87.	3	4	9.0
65.	0	1	4.0	88.	0	3	7.0
66.	4	4	10.0	89.	0	2	6.0
67.	6	4	12.0	90.	0	1	3.0
68.	11	4	13.0	91.	0	0	0.0
69.	8	4	11.0	92.	0	1	3.5
70.	1	1	4.0	93.	0	2	5.4
71.	1	3	5.0	94.	3	2	8.0

Table 12.(continued) Number of Flowers Open and in Bud Stage and Average Length of Peduncle.

Treat-ment	Flowers open	Flowers in bud stage	Average Peduncle Length (cm.)	Treat-ment	Flowers open	Flowers in bud stage	Average Peduncle Length (cm.)
95.	0	1	3.7	98.	0	6	5.2
96.	0	0	0.0	99.	0	1	4.5
97.	0	1	5.0	100.	0	0	0

Table 13. The Number of Pots Producing Flowers at Different Intervals from the Beginning of the Treatment.

Time Interval - Days*	Levels of Phosphorus			
	0 PPM.	5 PPM.	10 PPM.	20 PPM.
102-108	0	0	(0-N 1(60-K	(0-N 2 (15-30 K
109-139	0	(25-N 3 (15-60K	(25-50-N 2(30-100-K	(0-25 N 2 (15-30 K
140-155	(25-50N 2(30-K	(100-N 1 (15-K	(100-N 2(15-K	(25-N 2 (60-K
Total	2	4	5	6

*After December 15, 1948 there was very little difference in the time of blossoming of the remaining pots.

Table14, Average Number and Size of Leaves -- Seedlings

Pot	Number of Leaves		Average Size	
No.	Beginning	End	Beginning	End
1	2	2.5	1.4/1.5	1.7/1.5
2	2	3.	1.0/1.5	1.6/1.6
3	2.5	3.	1.4/1.0	2.0/1.5
4	2.5	4	2.0/1.8	1.5/1.5
5	4	4	2.0/2.0	2.0/2.0
6	2	4	2.0/1.9	2.0/2.0
7	3	4	2.0/2.5	2.3/2.3
8	3	4	2.0/2.0	2.1/2.2
9	3	4	2.2/2.2	3.0/3.0
10	3	3.5	1.4/1.4	1.7/1.7
11	2	4	1.4/1.4	2.2/2.0
12	2	4	2.4/2.5	2.4/2.5
13	3	4	1.6/1.6	2.2/2.2
14	2.5	4	1.3/1.3	2.0/2.5
15	.3	3	2.5/2.5	2.5/2.5
16	3	4.5	2.6/2.9	2.5/2.5
17	3	4	2.0/2.3	2.0/2.3
18	2	4.5	2.6/2.0	2.5/2.0
19	2	3	3.0/2.0	2.5/2.5
20	3	4	1.7/2.0	1.7/1.5
21	2	3	1.4/1.5	1.8/2.0
22	3	2	2.0/2.3	2.0/2.5
23	3	4	1.3/2.0	2.0/2.3

Table 14, (continued) Average Number and Size of Leaves -- Seedlings

Pot No.	Number of Leaves Beginning	End	Average Size * Beginning	End
24	3	3	1.6/1.6	1.9/1.9
25	3	3.5	1.5/1.5	1.7/1.7
26	2	3.5	2.2/2.8	3.5/3.0
27	1.5	4.5	1.9/2.0	2.1/2.2
28	2	2	1.6/1.6	2.3/2.0
29	4	4.5	1.4/1.4	2.0/2.0
30	2	2	1.7/1.7	1.8/2.3
31	3	3.5	1.7/1.5	2.5/2.0
32	3	4	1.5/1.2	2.5/2.0
33	2	3	1.4/1.5	2.5/2.3
34	3	5	1.8/2.0	2.5/2.0
35	4	5.5	2.5/2.8	3.0/2.0
36	2	4	2.0/2.0	2.4/2.5
37	3	4.5	2.0/2.0	2.1/2.3
38	2	4	2.0/2.0	2.5/2.5
39	2	3.5	2.0/14	1.7/1.5
40	3	3.5	2.0/2.0	2.3/2.0
41	2	2	1.7/2.0	--
42	2	2	2.0/1.9	2.5/2.0
43	3	3	1.7/1.7	2.5/2.5
44	2	2	2.5/2.5	1.9/2.0
45	2	3.5	1.7/1.7	1.8/2.0
46	2	2.5	2.2/2.0	3.0/2.5

Table 14 (continued) Average Number and Size of Leaves -- Seedlings

No. of Pot	Number of Leaves Beginning	End	Average Size* Beginning	End
47	2	3.5	1.6/2.2	3.5/3.5
48	2	6	1.6/2.2	1.7/2.0
49	3	5	1.2/1.4	2.0/1.8
50	3	3	2.0/2.0	3.5/3.5
51	2	4	1.9/2.7	2.4/2.0
52	3	4	2.0/1.5	2.1/2.0
53	2	2	2.8/1.5	--
54	2	3	1.5/1.5	2.0/2.0
55	3	3	1.2/1.2	2.9/2.4
56	2	3.5	2.0/2.2	3.0/2.5
57	2	2	2.5/2.0	3.0/2.0
58	2	4	2.5/1.9	2.2/3.0
59	4	7	1.2/2.1	2.3/2.1
60	2	2	2.0/1.5	2.0/2.5
61	3	3	1.8/1.2	--
62	2.5	3	2.2/2.2	--
63	3	3	2.0/2.2	--
64	3	2	3.0/2.0	3.3/3.0
65	2	1	1.5/2.0	1.9/2.0
66	2.5	3	1.2/1.2	1.6/1.6
67	3	3	1.2/1.4	1.7/2.0
68	3	5	2.0/2.2	2.3/2.5
69	2	2	1.7/1.9	2.0/2.0

Table 14.(continued) Average Number and Size of Leaves -- Seedlings

No. of Pots	Number of Leaves Beginning	End	Average Size* Beginning	End
70	3	4	2.2/2.2	2.5/2.2
71	2	1	1.5/1.5	3.0/3.0
72	2	3	1.5/1.5	1.7/1.8
73	4	4	2.0/2.0	1.6/3.0
74	3	3	1.5/1.5	2.4/2.4
75	2	2	1.0/1.0	--
76	4	4	1.9/1.9	2.8/3.0
77	3	7	1.9/1.9	1.5/1.9
78	3	7.5	1.5/1.5	2.0/2.6
79	3	5.5	1.5/1.9	1.7/2.1
80	1.5	3	1.5/1.4	1.7/2.0
81	2.5	0	2.0/1.7	--
82	2	3	2.0/1.7	2.5/2.0
83	2	4	1.6/1.6	1.9/2.0
84	2.5	3	2.2/2.0	2.3/2.5
85	3.5	4	1.4/1.4	1.4/1.4
86	3.5	3.5	2.0/1.5	2.0/1.5
87	3	3	1.0/1.5	--
88	3	3	2.5/2.5	--
89	2	2.5	1.0/1.0	1.5/1.9
90	2	2	1.5/1.5	2.0/2.0
91	3.5	3	1.8/2.0	2.3/2.6
92	2	3.5	1.2/1.5	1.8/1.7

Table 14.(continued) Average Number and Size of Leaves -- Seedlings

No. of Pots	Number of Leaves Beginning	End	Average Size* Beginning	End
93	2.5	3.5	1.5/1.5	1.9/1.5
94	2.5	2.5	1.2/1.2	1.5/1.3
95	2.5	1.5	1.2/1.2	1.5/1.5
96	1.5	3	1.9/1.9	1.3/1.5
97	3	4	1.6/1.7	2.0/2.5
98	2	2	1.8/1.8	--
99	2.5	3	2.5/2.2	--
100	3	3	1.5/1.5	2.0/2.0

*First number represents length of leaf and the second number width of leaf.

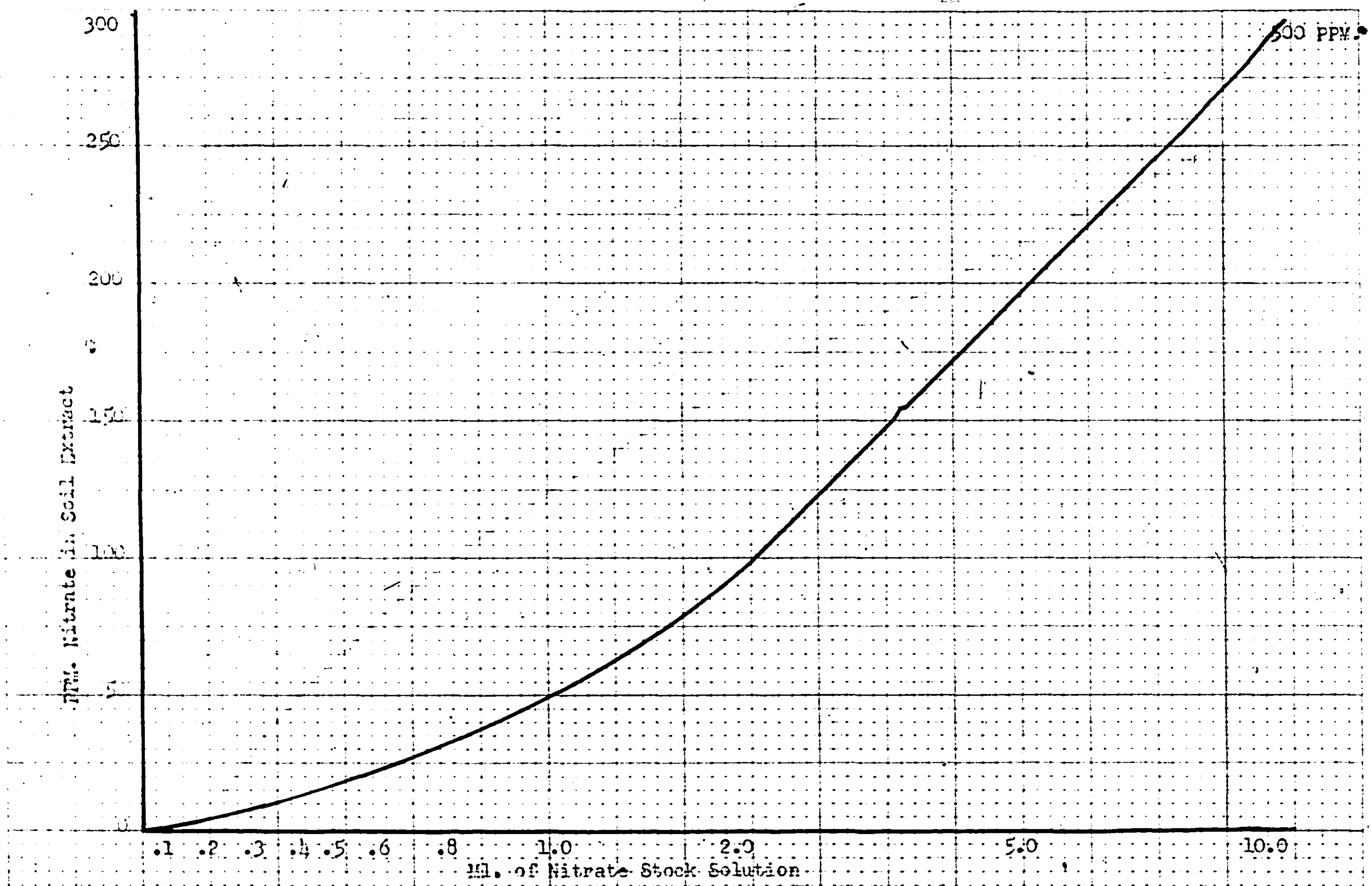


Fig. 1. Nitrate Fixing Capacity of Oshtemo Soil

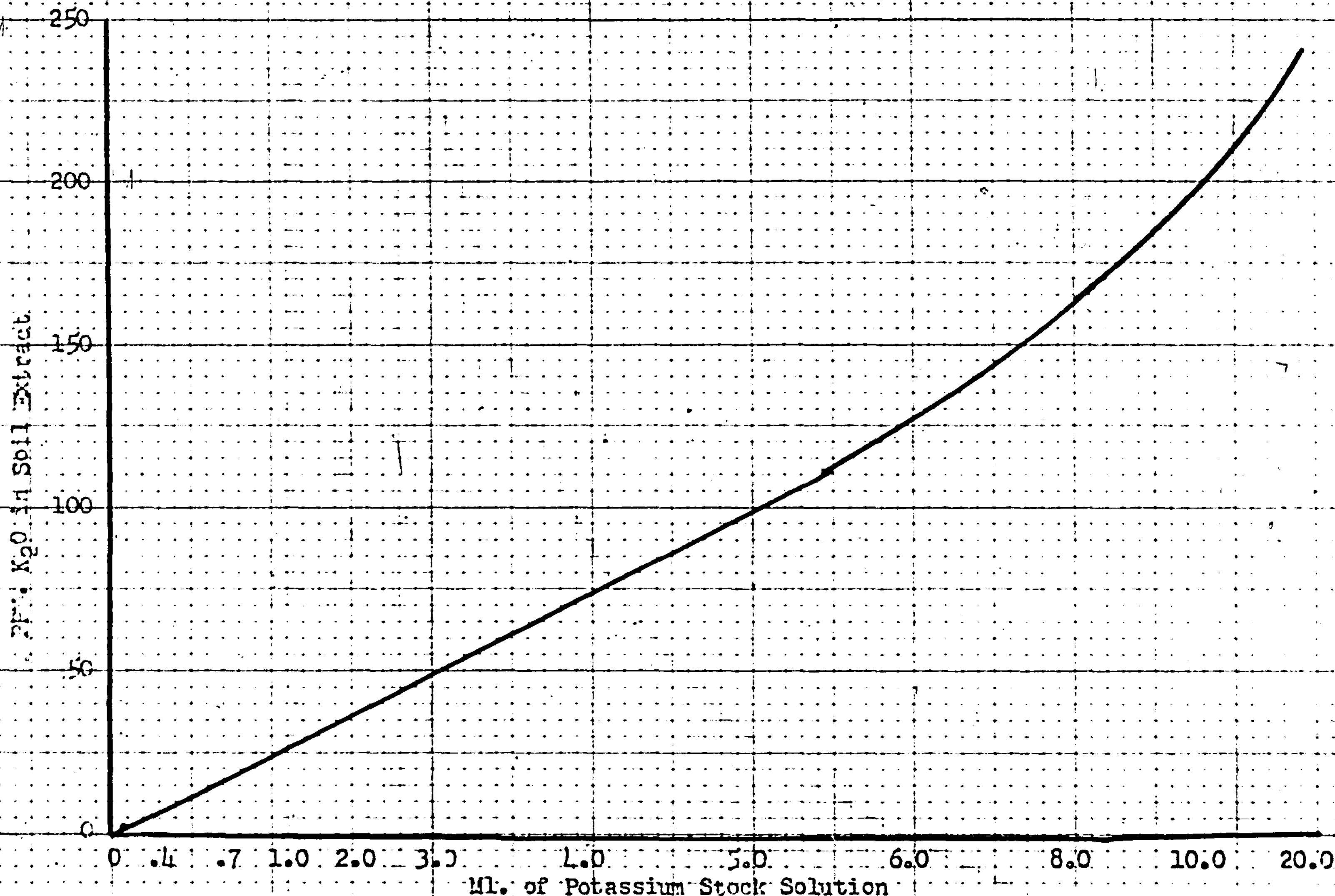


Fig. 2. Potassium Fixation Capacity of Oshtemo Soil

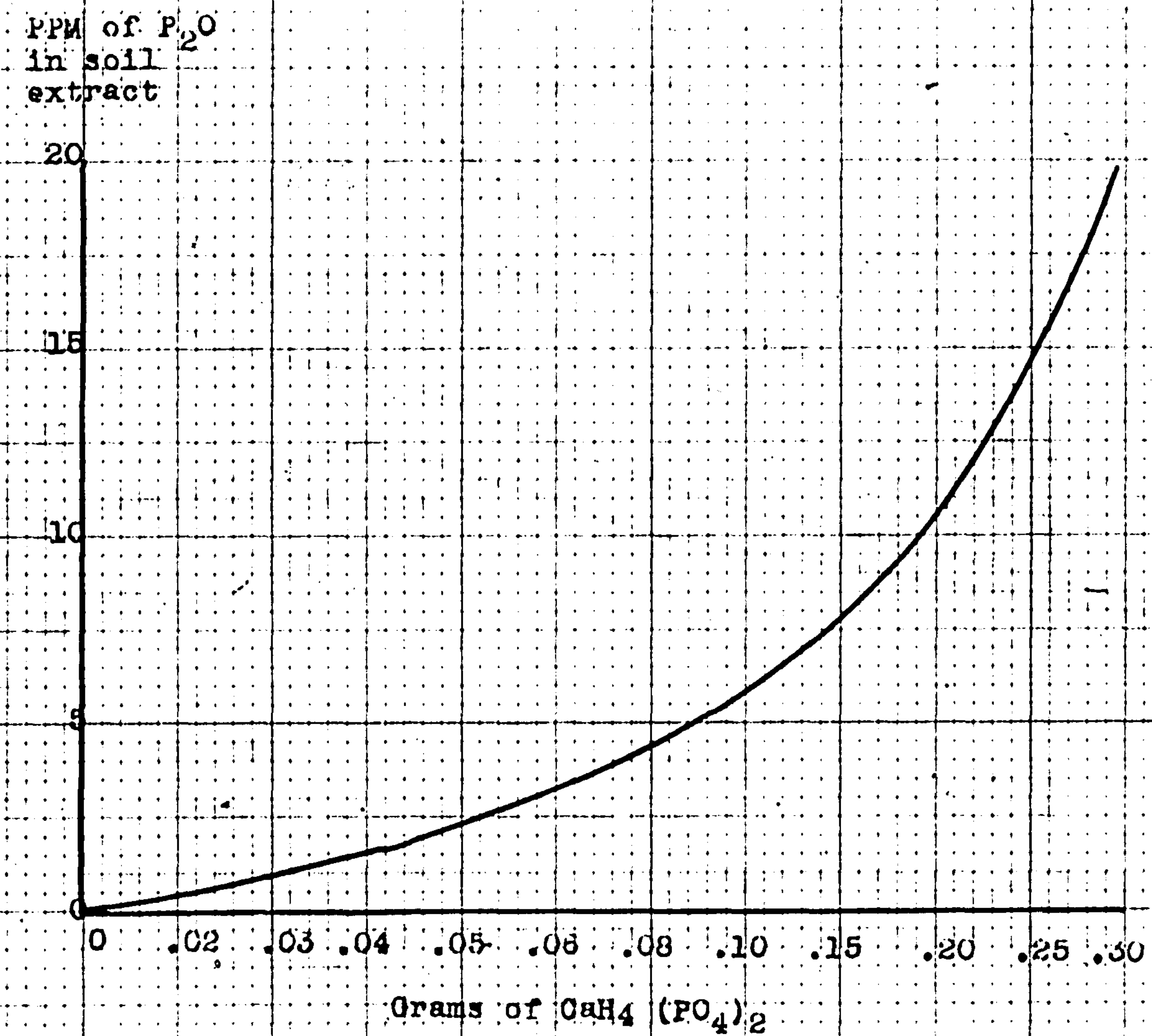


Figure 3. Phosphorus fixation capacity of Oshtemo Soil

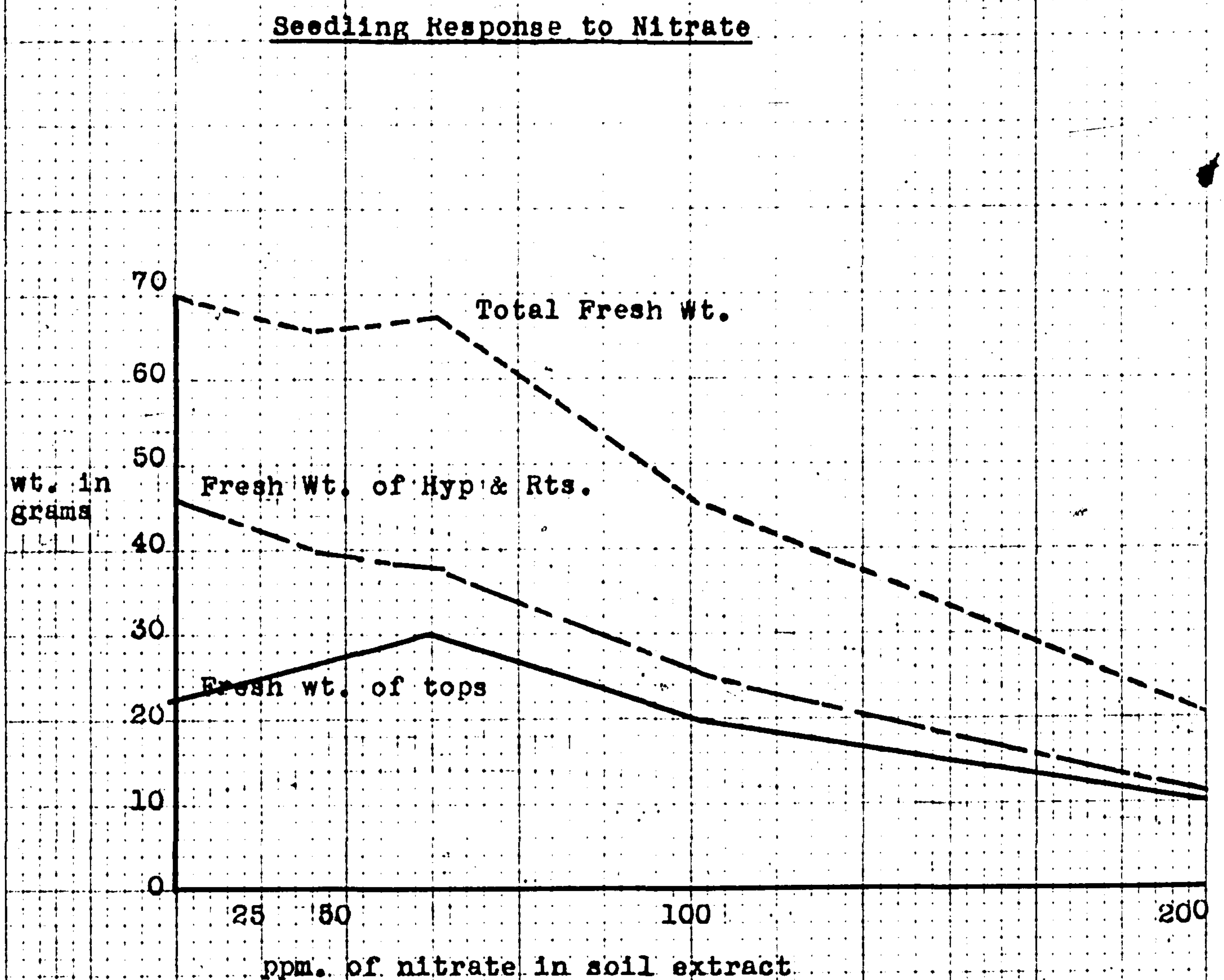


Figure 4. Response curve of seedlings to various levels of nitrate expressed by; total fresh wt, fresh wt. of hypocotyl plus roots, and fresh wt. of tops.

Seedling Response to Nitrate

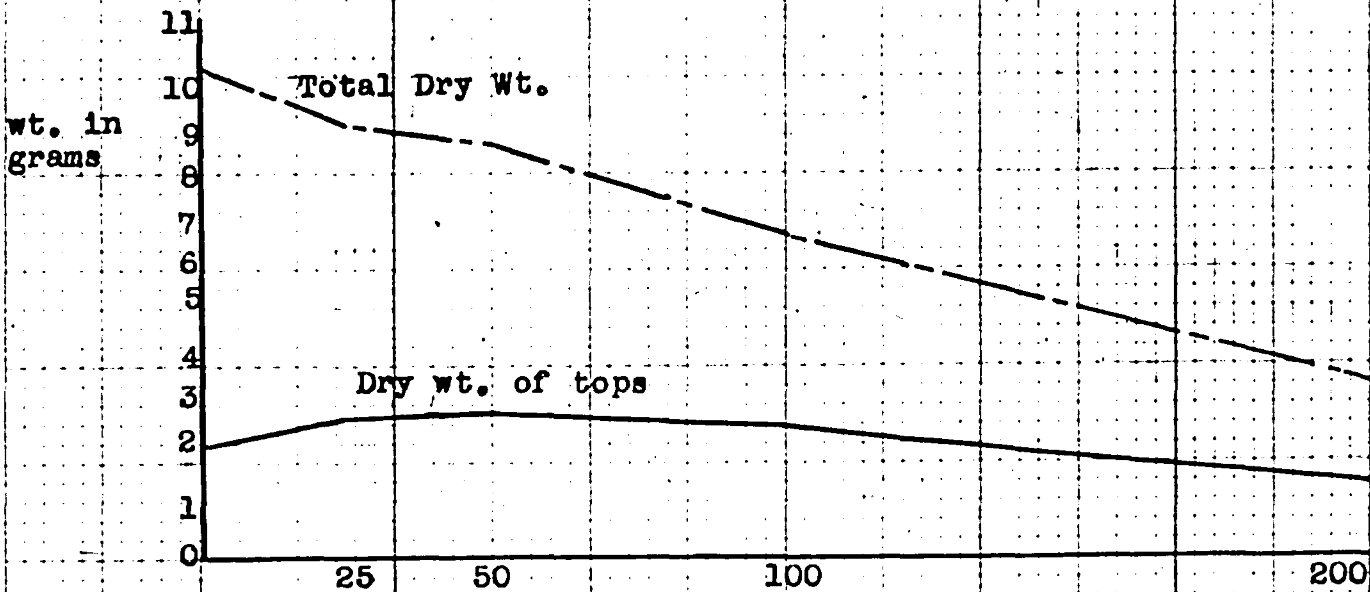


Figure 5. Response curve of seedlings to various levels of nitrate, expressed by total dry weight and dry weight of tops.

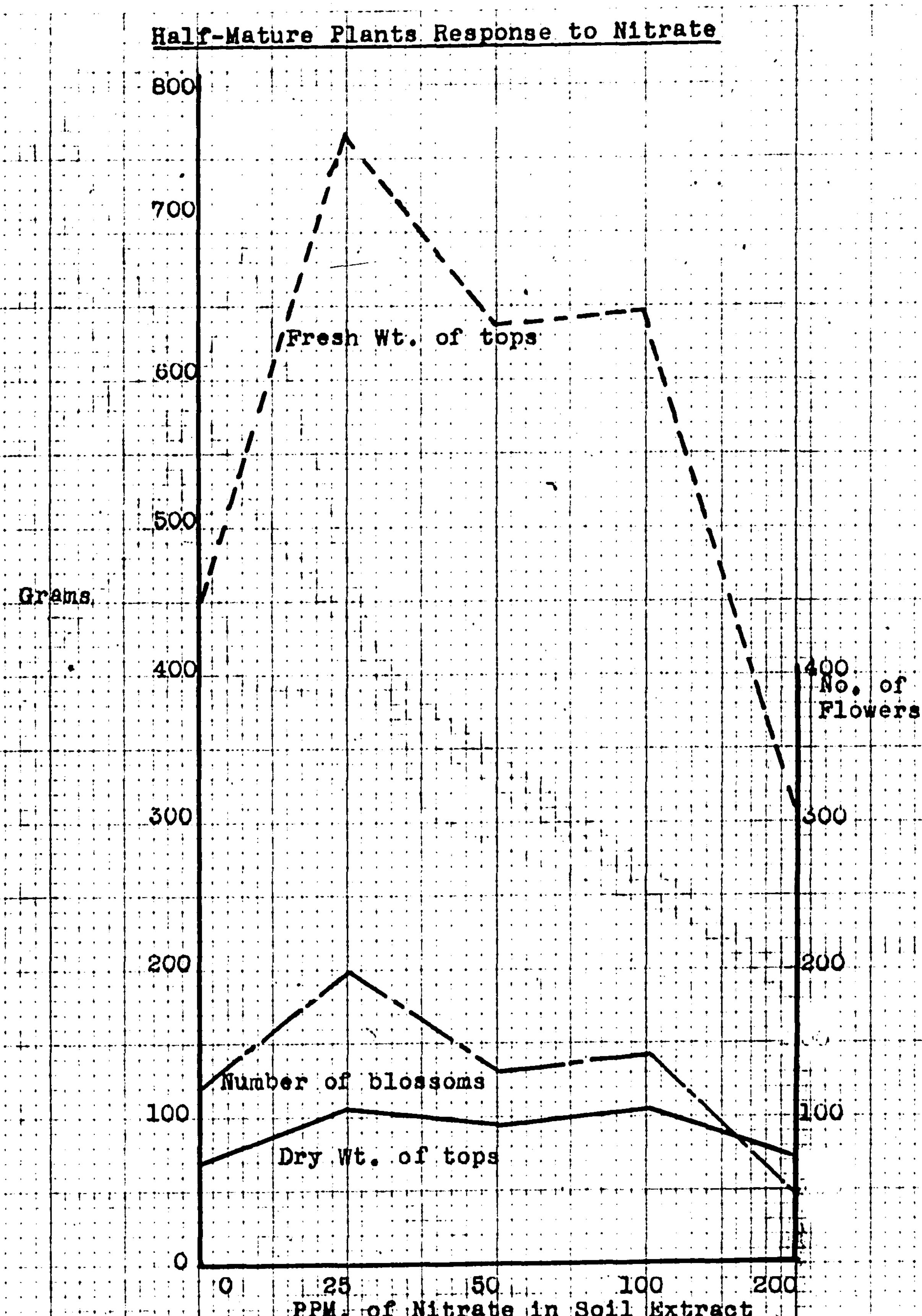
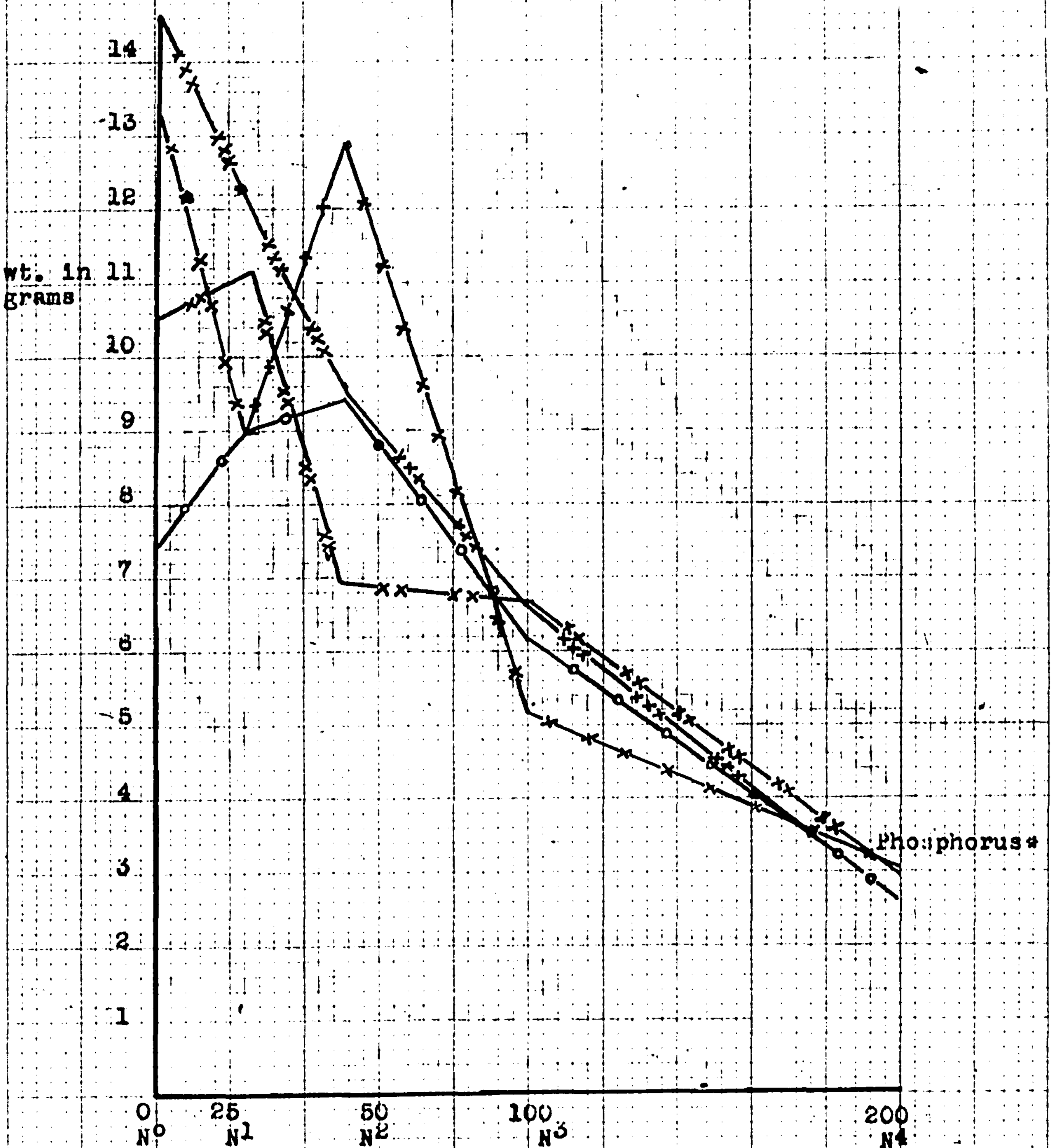


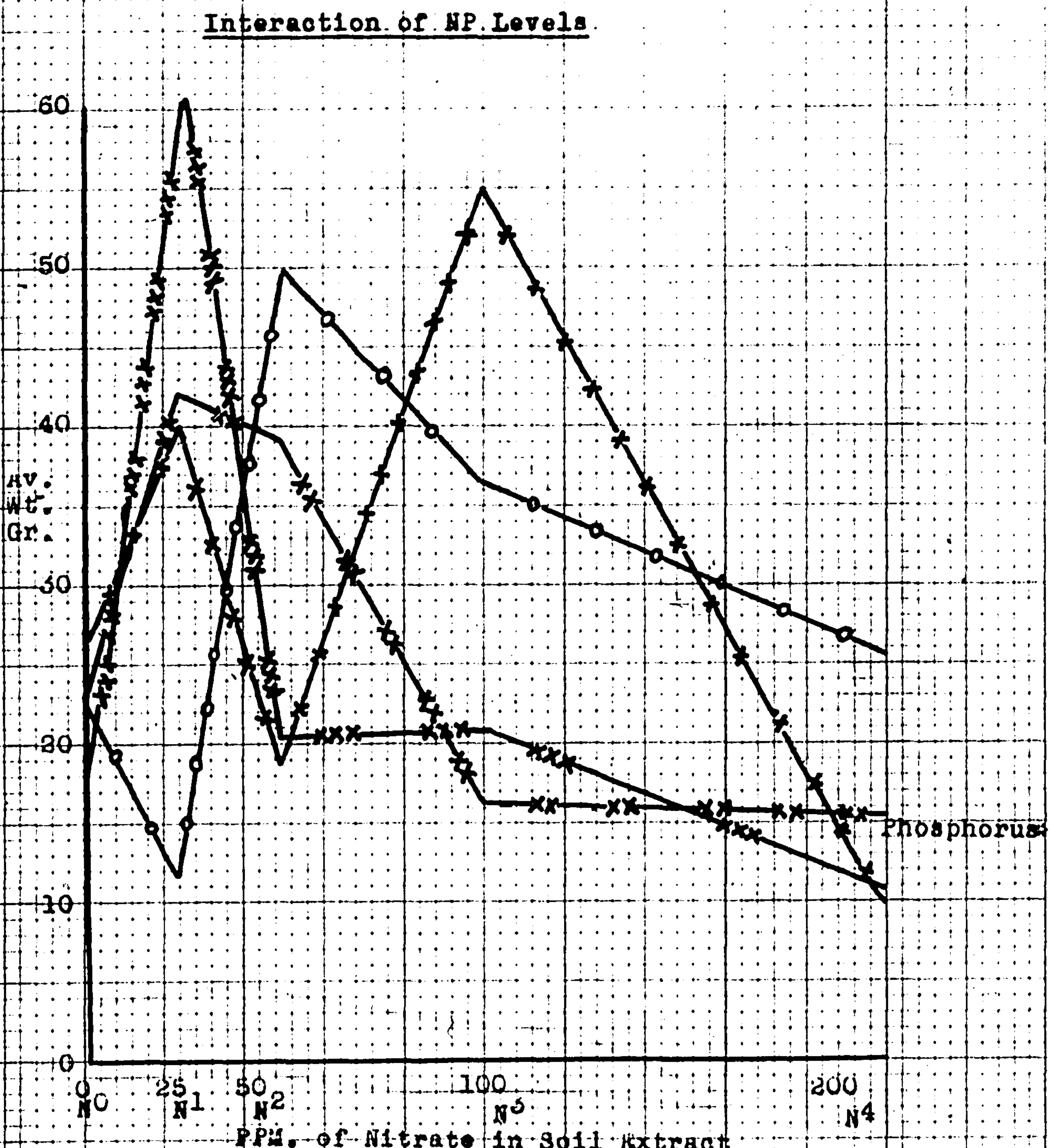
Fig. 6. Response Curve of Half Mature Plants to diff. levels of nitrate expressed in flower production

Interaction of Nitrate and Phosphorus Levels



*P^0---o--- = 0 ppm. of phosphorus
P^1---x--- = 5 ppm. of phosphorus
P^2---xx-- =10 ppm. of phosphorus
P^3---xxx- =20 ppm. of phosphorus

Fig. 7. The Response Curve of the Seedling to Interaction of NP Levels as expressed in Fresh Wt. of the Hypocotyl plus Roots.



P^0 --0-- = 0 ppm. of P_2O_5
P^1 --x-- = 5 ppm. of "
P^2 --xx- =10 " " "
P^3 -xxx- =20 " " "

Figure 8. Response Curve of the Interaction of NP Levels as expressed in Fresh Weight of Tops of mature cyclamen plants.

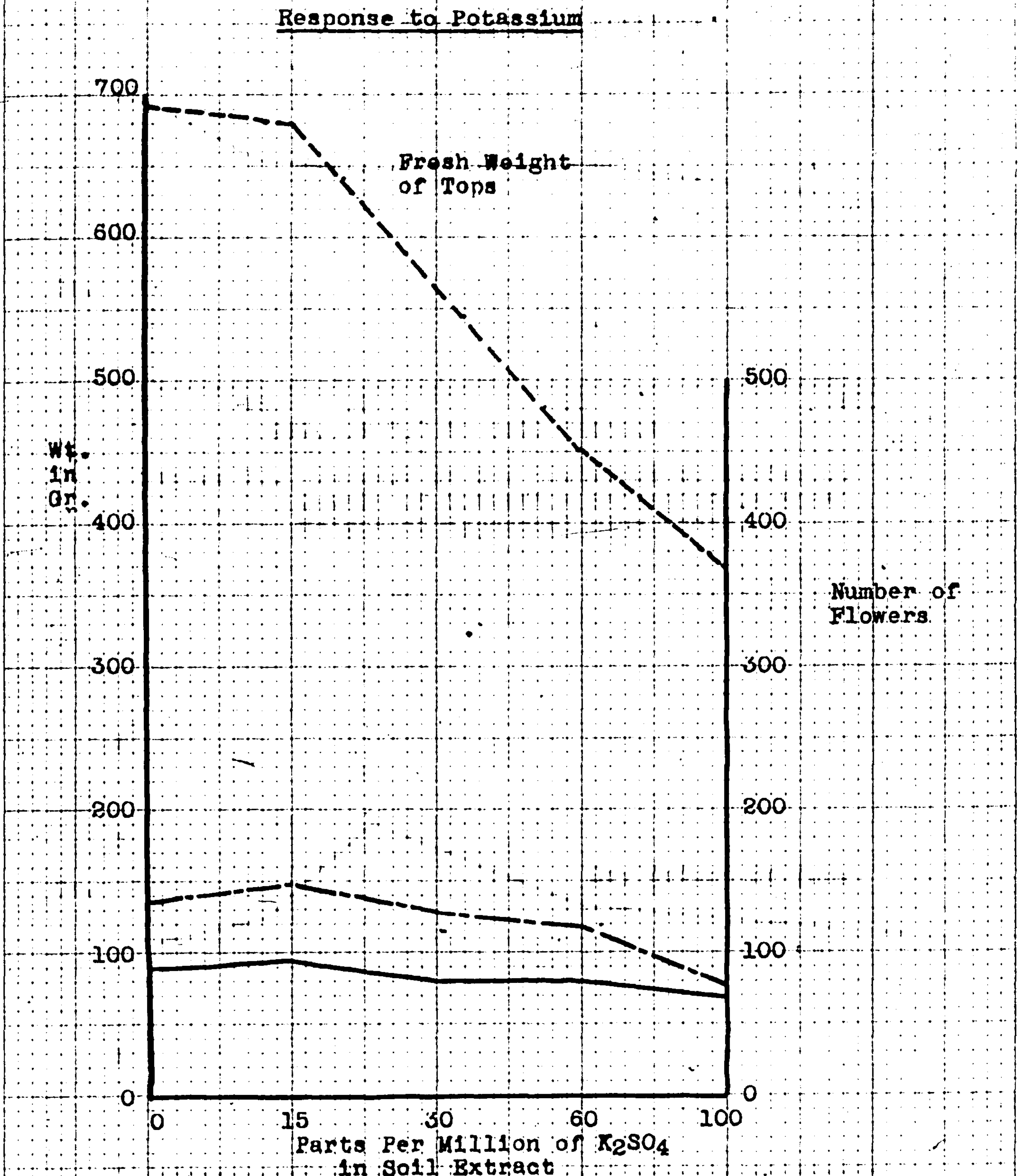


Figure 9. Response curve of mature cyclamen plants to different levels of potassium expressed as flower production, fresh and dry weight of tops.

Response to Potassium

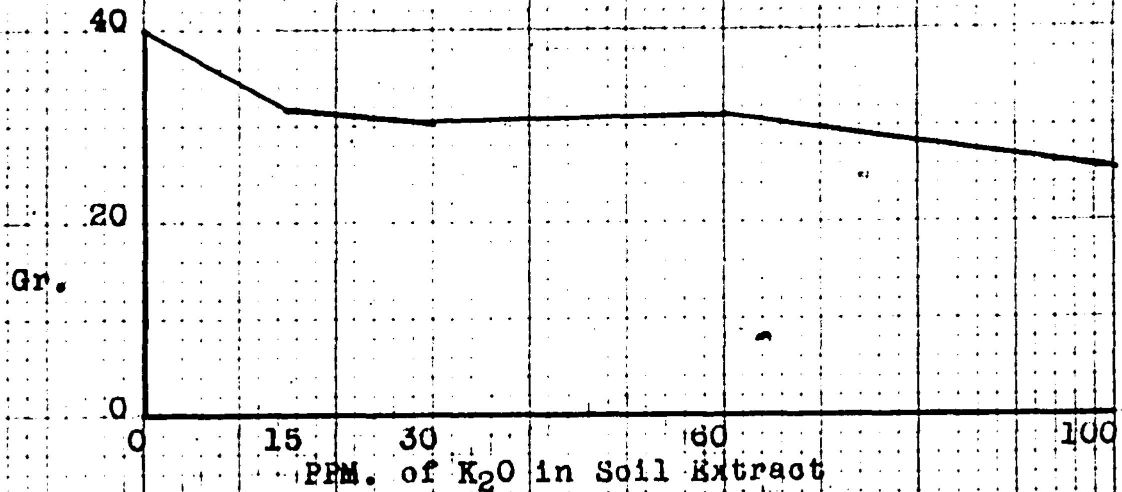


Figure 10. Response of the Seedlings to different Levels of Potassium Expressed by Fresh Weight of Hypocotyl plus Roots.

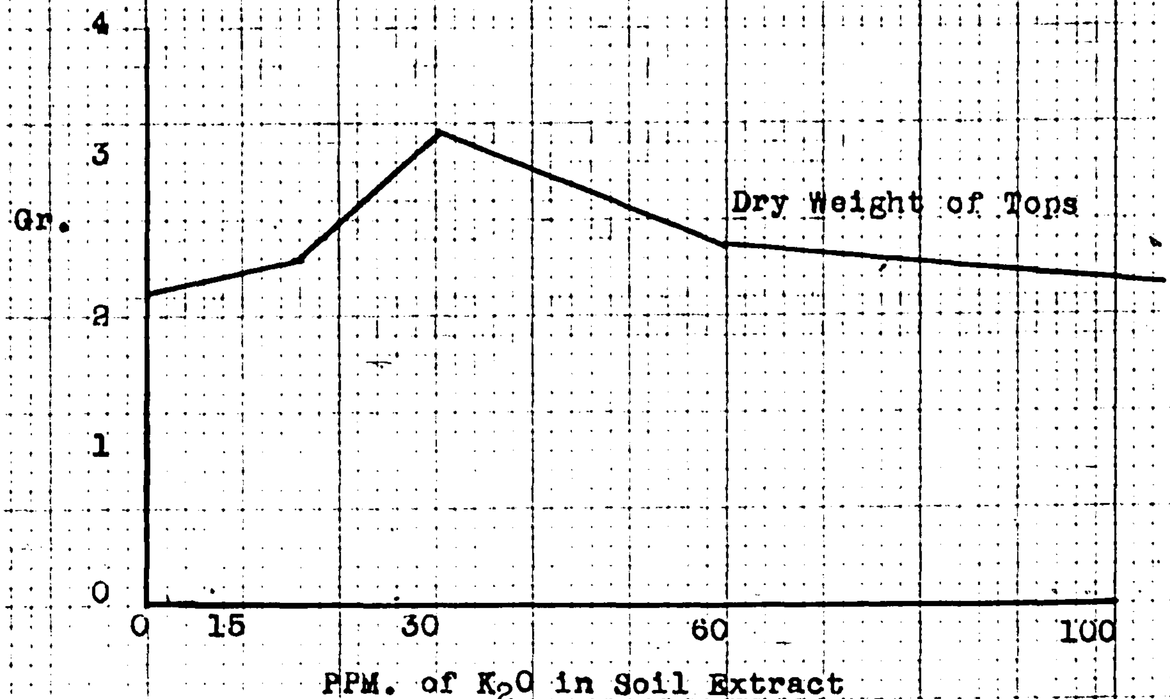


Figure 11. Response curve of the Seedlings to different levels of potassium expressed by the Dry Weight of Tops.

Interaction of NP levels upon Cyclamen Seedings

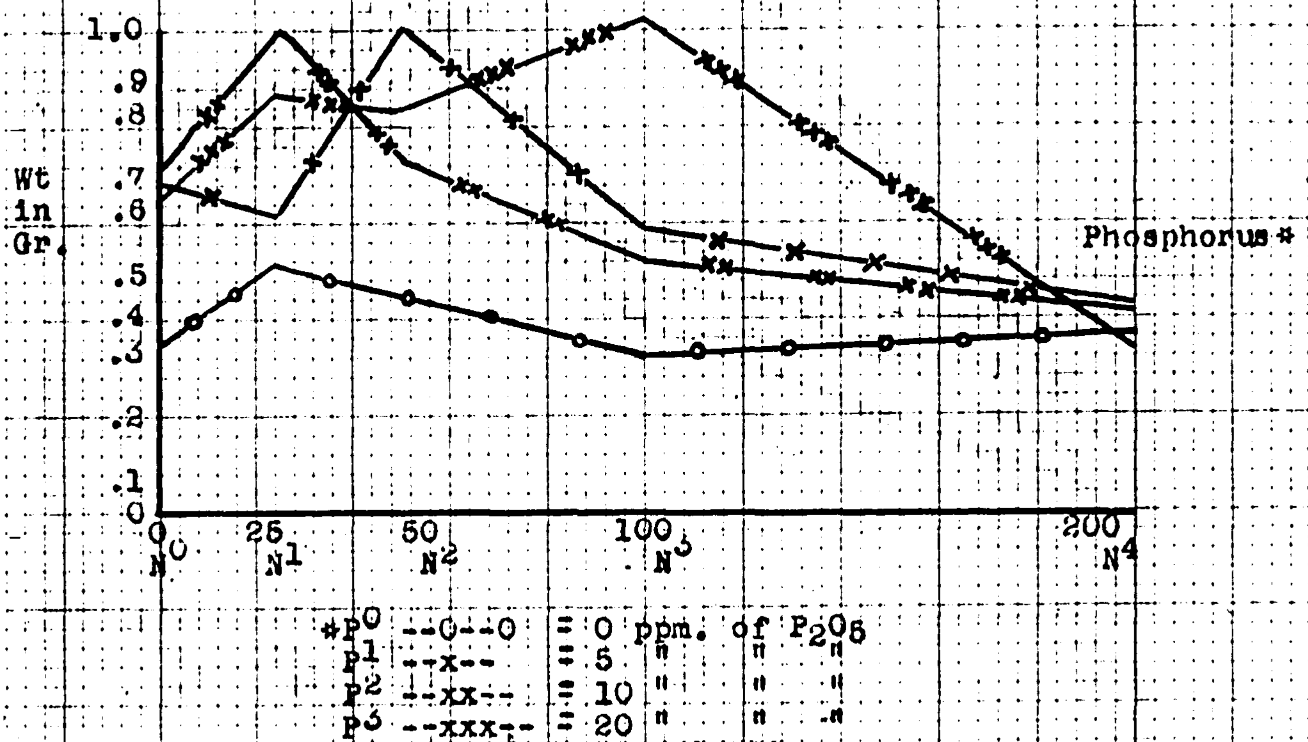
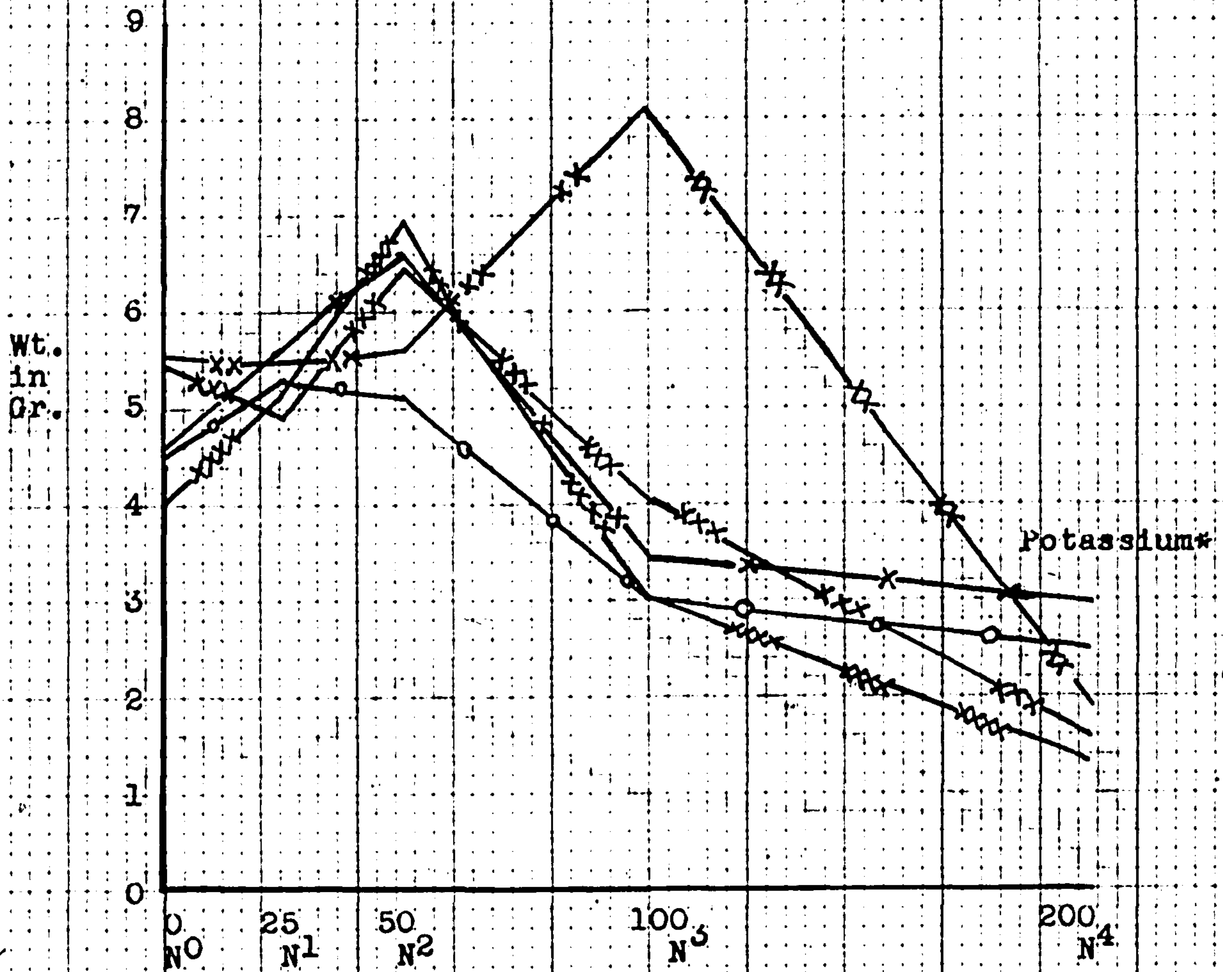


Figure 12. Interaction of NP levels upon Cyclamen Seedlings as expressed by the dry weight of tops.

Interaction of NK Levels Upon Cyclamen Seedlings



PPM. NO_3 in Soil Extract

K^0 ---0---0 = 0 ppm. of K_2O
K^1 ---x---x = 15 " " "
K^2 * xx -xx = 30 " " "
K^3 -xxx-xxx = 60 " " "
K^4-xxxx-xxxx= 100 " " "

Figure 13. The Response Curve of the Interaction of NK Levels upon Cyclamen Seedlings as expressed by fresh weight of top.

Interaction of NP Levels Upon Cyclamen Seedlings

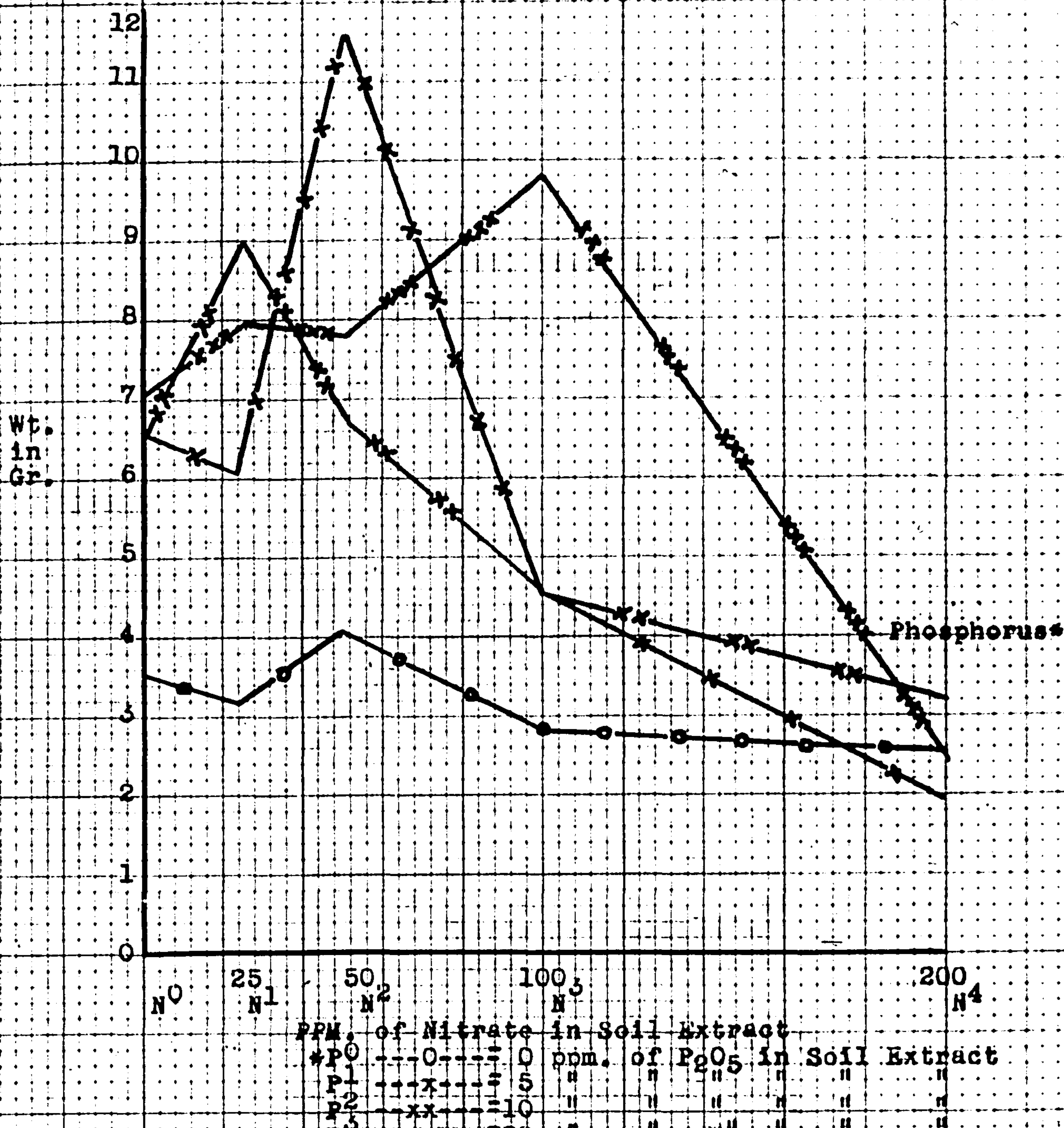


Fig. 14. Response curve of cyclamen seedlings to the interaction of NP levels as expressed by the fresh weight of tops.

Response to Phosphorus

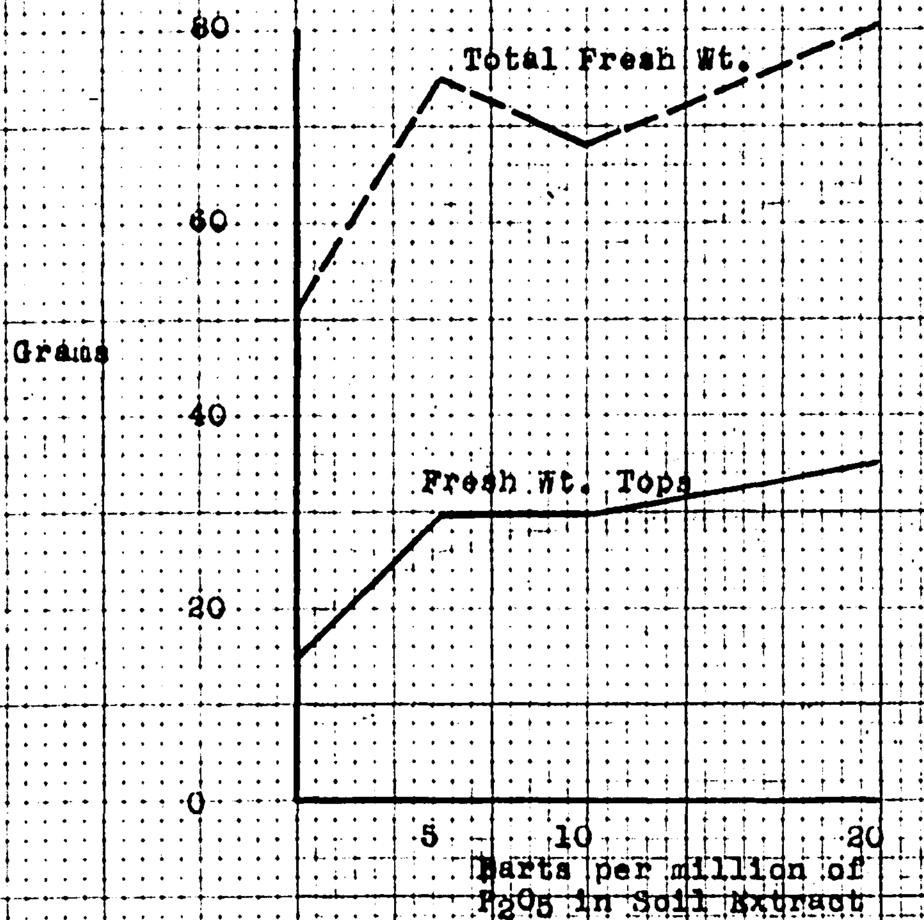


Fig. 15. Response Curve of mature cyclamen plants to various levels of Phosphorus expressed as total fresh weight and fresh weight of tops.

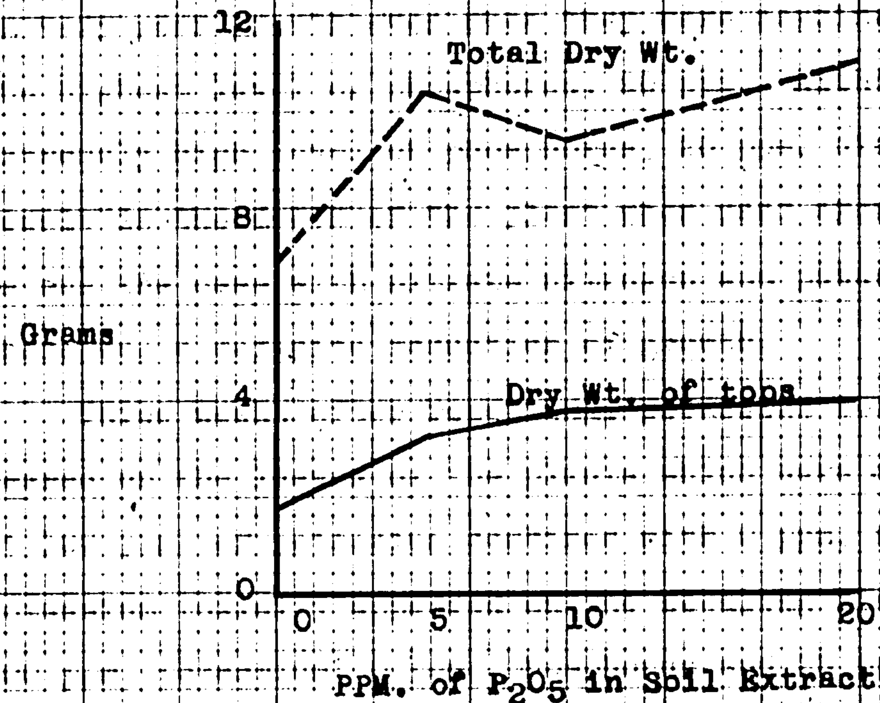


Figure 16. Response curve of mature cyclamen plants to various levels of phosphorus expressed as total dry weight and dry weight of tops.

DISCUSSION

In this experiment, there were several outstanding responses of the half-mature cyclamen to the various levels of nutrients used. The plants did not thrive when given 200 ppm. of nitrate nor under 100 ppm. of potassium. A combination of these two levels resulted in very poor growth even when they were combined with the highest level of phosphorus, 20 ppm. Although the extremely high level of phosphorus, 20 ppm. did not result in the death of the plant when used alone, -- as was the case with nitrate nitrogen and potassium -- there was a definite reduction of growth.

Three weeks after repotting, potassium toxicity appeared on the leaves of the plants which were maintained at 100 ppm. of potassium combined with 0 ppm. nitrate. Potassium toxicity appeared on the seedling plants at 100 ppm. potassium, 0 ppm. phosphorus and 25 ppm. nitrate nitrogen. High levels of potassium used in conjunction with low levels of nitrogen and phosphorus resulted in injury which was symptomatic of potassium toxicity.

The level of nitrate nitrogen which seemed to give the best results in the dry weight of tops was 25 ppm. The dry weight of the tops at 25 ppm. was significantly greater than that at 0 ppm. of nitrate, but the yields obtained as a result of nitrate levels of 50 and 100 ppm. were not significantly greater than those obtained at 25 ppm. Therefore, where plants with many large blossoms, average size foliage and good balance are desired, 25 ppm. will give the best results. However, if a large plant with fewer blossoms is desired, 50 or 100 ppm. would be best.

The greatest number of blossoms was produced at a concentration of 25 ppm. of nitrate and 30 ppm. potassium. The number of blossoms produced at 25 ppm. was significantly greater than that produced at 50 and 100 ppm. nitrate. At 0 ppm. nitrate the number of blossoms decreased as the concentration of potassium increased; but at 25 ppm. of nitrate, the number of blossoms increased as the potassium was increased until the maximum was reached at 30 ppm., and then decreased with further increases in potassium. This was also true with the fresh weight of the tops. There was a close correlation between the number of blossoms produced and the fresh weight of the tops.

Phosphorus as a whole did not cause statistically significant differences in the growth of the mature plants. The greatest number of flowers was produced at 10 ppm. phosphorus, but only one more flower was produced at this level than at 5 ppm. Therefore, 5 ppm. of phosphorus was as effective as any other level and decidedly better than 0 ppm.

In the seedling growth, however, phosphorus effects were highly significant, for most of the factors used as a measurement of growth. It caused significant increases in the total dry and fresh weights and in the dry and fresh weights of tops. The only relationship in the seedlings wherein phosphorus did not produce statistically significant differences was in the dry and fresh weights of the hypocotyl and roots. 5 ppm. of phosphorus affected the same amount of growth statistically as did 10 ppm. and 20 ppm. although both produced slightly more growth than did the 5 ppm.

The ability of high phosphorus to encourage early flowering when combined with 15 ppm. of potassium and 0 ppm. of nitrate was demonstrated clearly by the results shown in Plate 4. This tendency was not sustained when the nitrate level was increased.

The interaction of NP levels upon the fresh weight of the seedling tops is shown in Figure 14. The maximum growth at 0 ppm. of nitrate was obtained when combined with 20 ppm. of phosphorus; at 25 ppm. of nitrate, with 10 ppm. of phosphorus; at 50 ppm., with 5 ppm. of phosphorus; and at 100 ppm. with 20 ppm. of phosphorus. From 0 ppm. up to 50 ppm. of nitrate, maximum growth of the tops was attained by decreasing the phosphorus from 20 ppm. down to 5 ppm. as the nitrate was increased. In other words, in order to get good growth of seedlings at low nitraté level, the phosphorus must be high, and the phosphorus must be diminished as the nitrate is increased until 100 ppm. of nitrate is reached.

When the potassium levels were increased, a decrease in the fresh and dry weights of the hypocotyl and roots resulted. Each level produced a significant decrease over the other. The best root system was produced at the lower levels of potassium and nitrogen.

In the statistical analysis of the dry weight of the seedling tops, potassium proved significant at the 5% point. In a breakdown of this significance, 30 ppm. of potassium showed up the best. The dry weight of the tops at 30 ppm. of potassium was significantly greater than that at 60 ppm. and at 15 ppm.

Study of Germination and Hypocotyl Development

To determine the influence of light and temperature on the germination of cyclamen seed, and to study the development of the hypocotyl, the following experiment was undertaken.

Plan of Procedure

400 cyclamen seeds were divided into 8 lots of 50 seeds each. A total of 100 seeds for each treatment was germinated under the following conditions:

80°F. -- in darkness
60°F. -- in darkness
60°F. -- in continuous light
40°F. -- in darkness

50 seeds were placed in a petri dish on sterilized blotting paper. The paper was ruled in squares to locate each seed. These dishes were placed in 40° and 60° F. Refrigerator rooms and in an 80° F. oven on January 19, 1949.

To reduce the fungus growth, the seeds were placed in a jar and shaken until thoroughly covered with "Arasan" (tetramethylthiuram disulfide - 50% inert ingredients - 50%).

After six days it was observed that fungus growth, if allowed to continue, was sufficient to alter normal germination. All seeds were then soaked for 3-4 minutes in an aqueous solution of bichloride of mercury, (1 gm. per liter) and thoroughly washed with water.

The seeds were observed daily and moistened with distilled water when necessary.

Hypocotyl Development: A hundred of these seeds were planted in a regular seed pan and placed in a warm greenhouse. At different stages of germination three or four were removed and studied under low magnification. Drawings were made and photographs taken to record definite stages of germination. Some embryos were excised before germination to identify the stage at which the swelling of the hypocotyl was evident.

Observations

There was no germination of seeds at 80° F. More fungus and bacterial growth appeared in the petri dishes at 80° F. than in those at 40° and 60° F.

After 91 days, only two per cent (2%) had germinated at 40° F. The experiment was terminated April 12, 1949.

The germination data at 60° F. under continuous light are presented in table 17. The average number of days for germination was computed as 67.9, or 26.2 days longer than that required for germination at 60° F. in darkness. The percentage of seeds which germinated under continuous light was 65%, while that of the seeds in darkness was only 54%.

The seeds at 60° F. in darkness began the germination within 27 days and continued for 47 days (table 18). The average number of days for emergence was 41.7. The accumulative germination for both light and dark conditions, at 5 day intervals, is graphically presented in figures 17 and 18.

Hypocotyl Development: The excised embryo showed that swelling was not present in the dormant embryo (see plate 16), but was in evidence just before the radicle emerged from the seed coat. Plate 17 was prepared just as the radicle appeared as a bulging point beneath the seed coat and shows clearly the beginning of the formation of the tuberous-like structure. When the radicle had completely emerged from the endosperm and seed coat, as shown in plate 18, the swelling was quite visible to the naked eye.

There was very little elongation of the primary root radicle. It seemed to remain as a knob or plate at the base of the swelling from which the secondary roots arose. The hypocotyl swelling was well established before any secondary roots appeared. This is shown in the two seeds at the extreme right of plate 18.

Discussion

The germination of cyclamen seeds under the conditions of this experiment required an average of 41.7 days in darkness at 60° F. Laurie and Kiplinger (10) stated that from 4 to 5 weeks at a temperature of 55°-60° F. was required for germination. Most writers have recommended that the seeds be planted in August. The fact that this experiment was conducted between January and April may possibly account for this disagreement in time of germination.

The seeds placed at 80° F. did not germinate at all, and only two per cent (2%) of those at 40° F. It is therefore concluded that 80° F. is too high a temperature for germination, while 40° F. is too low. The optimum temperature for germination under the conditions of this experiment must fall between 40 and 80° F.

Yet, 26.2 more days were required for the seeds to germinate at 60° F. in continuous light than for those at the same temperature in darkness. Apparently, then, cyclamen seeds are sensitive to light. This may be due to the retarding effect light has upon the formation of certain enzymes which take part in germination.

Although germination was faster in darkness than in light, the percentage of seeds which germinated under light was greater than that of those in darkness, the percentages being 65 and 54 respectively. Too much emphasis should not be placed upon this, however, because the total number of seeds in each test was never more than one hundred.

The swollen basal portion of the cyclamen developed very early, sometimes even before the radicle had completely emerged from the seed coat. The primary root continued to grow for .1 to .28 cm. long before secondary roots appeared at the base of this swollen structure. The primary root never gave rise to secondary roots and soon died.

From all indications, this enlarged portion (confusedly termed the hypocotyl, corm, or bulb by various writers) included the transition region, hypocotyl and part of the roots. In its composition, it is similar to that of the beet, in that the beet "root" consists of root, transition region and several internodes of stem. It differs, however, in that the stem never develops in the cyclamen. It differs from the gladiolus corm in that the leaf bases do not surround the swollen structure but arise from the very top of it.

After excising, it was possible to locate only one developed cotyledon. This cotyledon apparently remains in the seed coat and is an absorbing organ throughout germination and early seedling growth. In the early seedling the first leaf appeared. Gressner (7) believed that this was the second cotyledon that had remained undeveloped in the resting embryo and later became the first leaf of the young plant. Woodcock (18) in studies with the embryo noted also that there was only one developed cotyledon which made the radicle end look as large as the cotyledon end (plate 17).

No true stem developed, and the roots arose from the base of the swollen area which must be made up of the hypocotyl, having two parts (see plate 19): a transition zone "B"; a swollen portion "C", which constituted the majority of this area. Since the radicle "A" did not develop, the secondary root which arose from the transition zone were considered adventitious. It would therefore appear that the tuber-like portion of the cyclamen plant may be considered to have been formed from the hypocotyl.

Table 17. Germination of Cyclamen Seeds - 60% Continuous Light

Days to Emergence	Total Seeds Germinated
35	2
40	3
45	11
50	12
55	14
60	16
65	19
70	25
75	40
80	58
85	65

Table 18. Germination of Cyclamen Seeds - 60% Darkness

Days to Emergence	Total Seeds Germinated
30	4
35	23
40	26
45	35
50	47
55	49
60	49
65	52
70	52
75	54

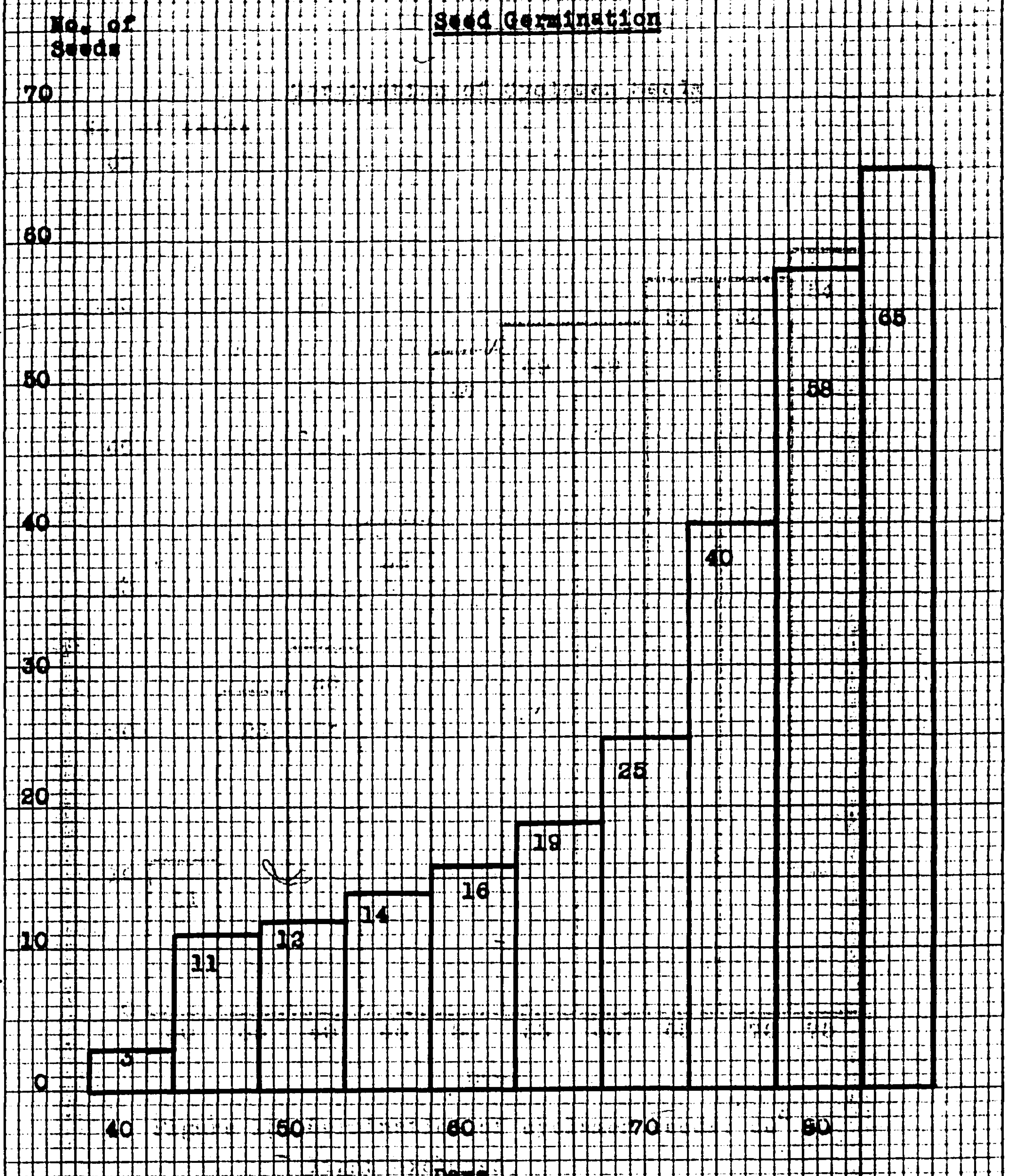


Fig. 14. Germination of cyclamen seed: 60°F. under continuous light.

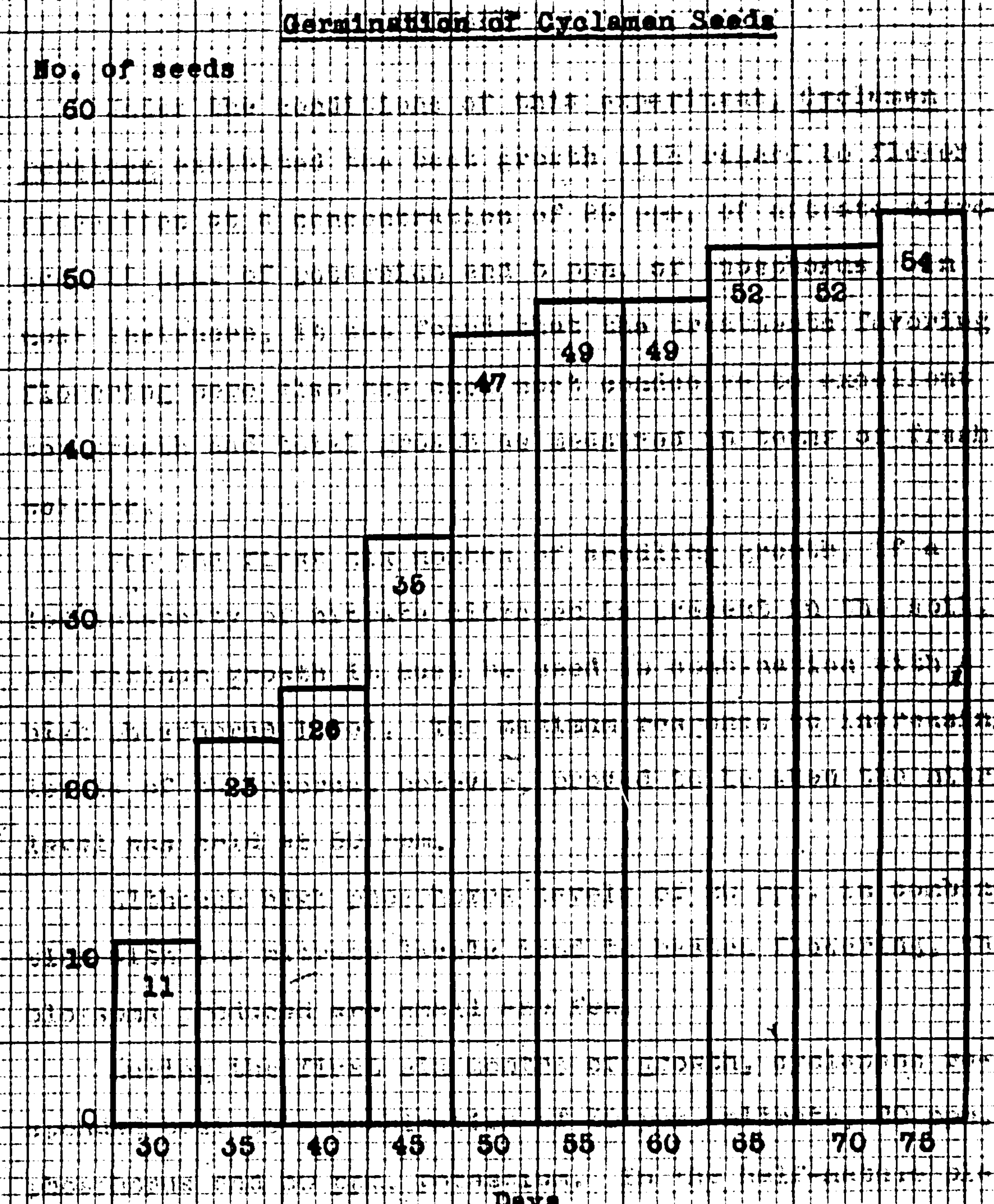


Figure 15. Germination of cyclamen seeds; 60° F. light excluded.

SUMMARY

Under the conditions of this experiment, *Cyclamen persicum* exhibited the best growth with regard to flower production at a concentration of 25 ppm. of nitrate nitrogen, 15 ppm. of potassium and 5 ppm. of phosphorus. In most instances, it was found that the treatments favoring flowering were also the ones most conducive to excellent top growth and total growth as measured in terms of fresh weights.

For the first six months of seedling growth, if a low intensity of nitrate nitrogen is present in the soil, for maximum growth it must be used in combination with a high phosphorus level. The maximum response to increasing levels of phosphorus, however, proved to be when the nitrate level was held at 50 ppm.

Although high phosphorus levels of 20 ppm. in combination with low nitrate levels tend to hasten flowering, the blossoms produced are small and few.

During the first six months of growth, cyclamens responded best to a combination of 50 ppm. nitrate, 20 ppm. phosphorus and 30 ppm. potassium. In the half-mature plants, approximately the last six months of growth, the best response came from a lower balance of intensity: 25 ppm. nitrate, 5 ppm. phosphorus and 15 ppm. potassium.

The fact that 26.2 more days were required to germinate cyclamen seeds in continuous light than was required for germination in darkness shows that they are light sensitive. Continuous light retards but does not inhibit germination.

60° F. is the most favorable temperature for germination of cyclamen seeds.

The tuberous-like base of the cyclamen develops at a very early stage in the germination process. It is well established before the primary root branches and becomes extended. The observation of this tuberous development seems to indicate that it consisted of a hypocotyl, in two parts with a root system which originated adventitiously from the transition zone of the hypocotyl. The swollen basal portion was made up mainly of hypocotyl tissue and may correctly be called the hypocotyl.

Plate 1. Ideal Plant - Grown For 177 days at 25 ppm. Nitrate, 5 ppm. of phosphorus and 30 ppm. of Potassium. Note balance, symmetry and proportion of flowers and foliage.

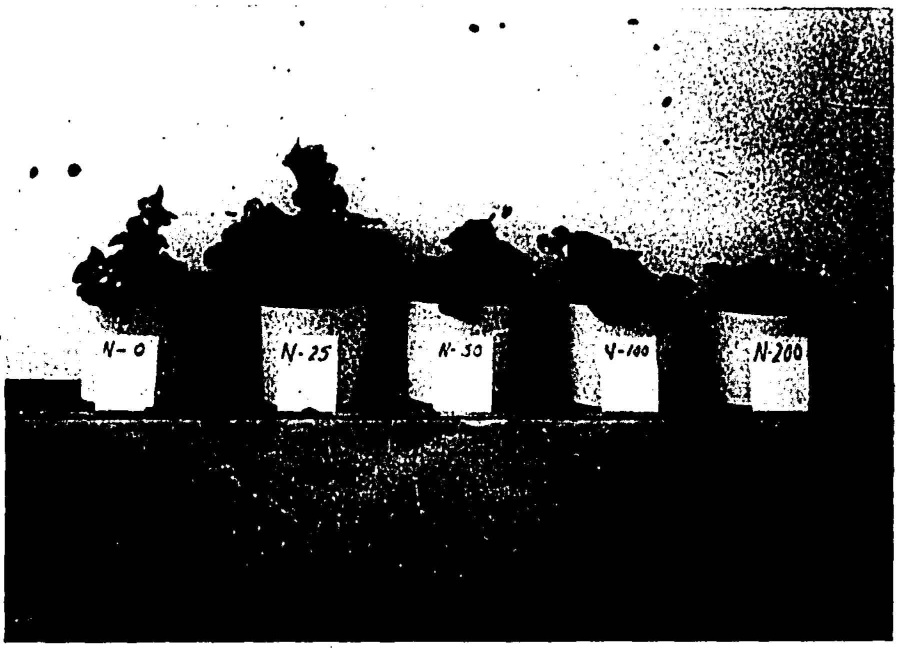


Plate 2. Response of Cyclamen 160 days after repotting to 0, 25, 50, 100 and 200 ppm. of nitrate when grown at 5 ppm. phosphorus and medium potassium.

Plate 3. Response of Cyclamen to 0, 15, 30, 60, and 100 ppm. of Potassium when grown at 0 ppm. of phosphorus and nitrates. Note, potassium, as low as 30 ppm. decreases growth when nitrogen is low.

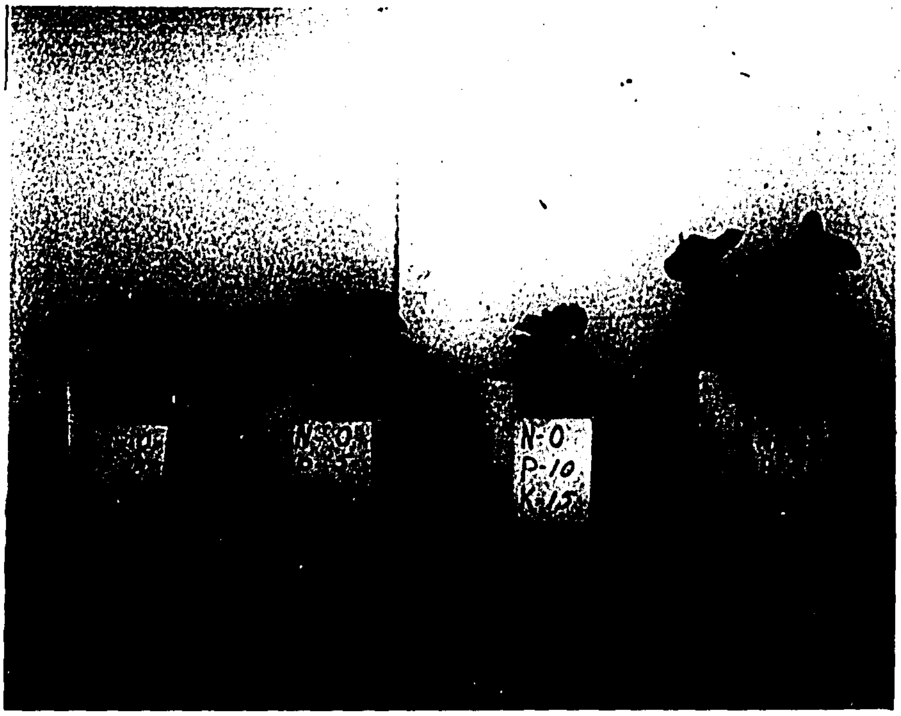


Plate 4. Response of Cyclamen to 0, 5, 10, and 20 ppm. of phosphorus when grown at 0 ppm. nitrate and 15 ppm. potassium for 160 days. Compare with first four pots in plate 6.

Plate 5. The effect of 0, 15, 30, 60 and 100 ppm. upon cyclamen when grown at 25 ppm. nitrate and 0 ppm. potassium. Compare with plate 3 in which the nitrate and phosphorus has been raised one level each.

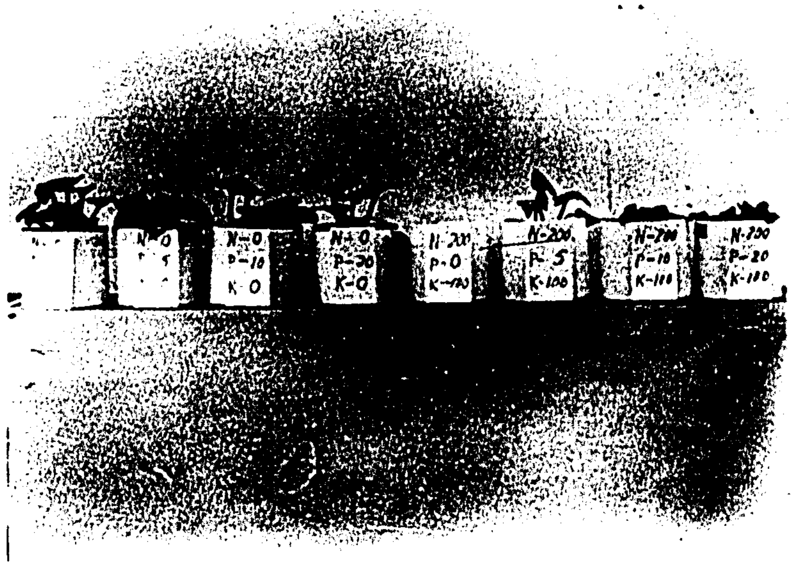


Plate 6. A comparison between the response of cyclamen to 0, 5, 10 and 20 ppm. of phosphorus when the nitrate was changed from 0 to 200 ppm. and the potassium changed from 0 to 100 ppm. Note that damage is not done by increasing the phosphorus but by the high salt concentration of either nitrate or potassium or both. Increasing phosphorus tends to decrease the injurious effect. Increasing "P" alone, however, showed slight damage.

Plate 7. Response of cyclamen to 0, 15, 30, 60, and 100 ppm. potassium when grown at 100 ppm. nitrate, 20 ppm. phosphorus and also at 0 ppm. nitrate, 20 ppm. phosphorus for 149 days. Left to right: upper row:

N - 100 ppm.
P - 20 ppm.
K - Increasing by 0, 15, 30, 60, and 100 ppm.

Lower row:

N - 0 ppm.
P -20 ppm.
K - Increasing by 0, 15, 30, 60 and 100 ppm.

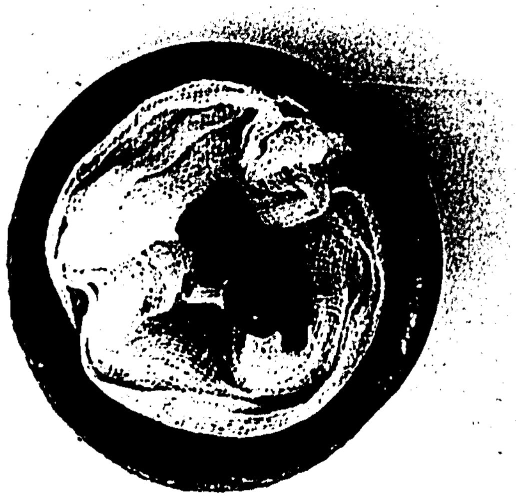


Plate 8. Cyclamen showing potassium toxicity 149 days after repotting when grown at 25 ppm. nitrate, 0 ppm. phosphorus and 100 ppm. potassium. This "K" toxicity disappeared as the phosphorus was increased.

Plate 9. Response of cyclamen 160 days after repotting to 0,25,50,100,and 200 ppm. of nitrate when grown at 0 ppm. potassium and 10 ppm. phosphorus. Compare with plate 11 and plate 2.

Plate 10. The response of cyclamen seedlings, 149 days after repotting to 0,5,10 and 20 ppm. phosphorus when grown at 100 ppm. nitrate, 30 ppm. potassium and 0 ppm. nitrate, 30 ppm. potassium. Left to right: upper row

N - 100 ppm.
K - 30 ppm.
P - 0,5,10,20 ppm.

Lower row:

N - 0 ppm.
K - 30 ppm.
P - 0,5,10,20 ppm.

Note: 100 ppm. nitrate was injurious when no phosphorus was applied although potassium level is at an optimum.

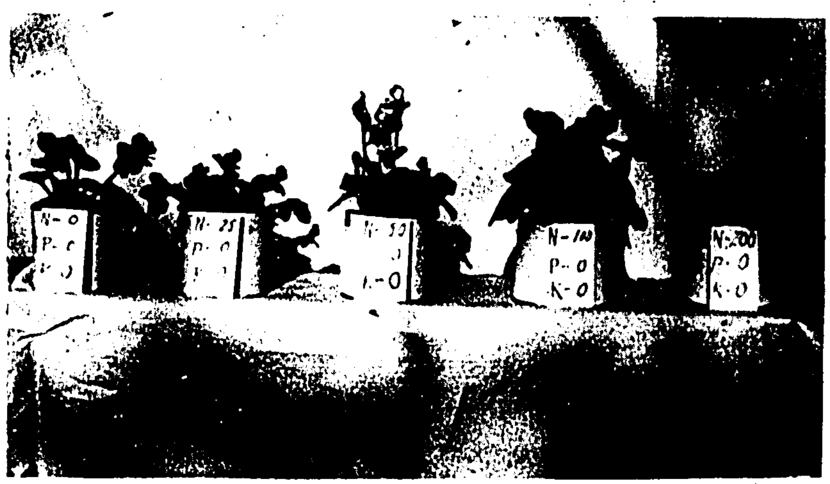


Plate 11. Response of cyclamen to 0,25,50, 100 and 200 ppm. nitrate when grown at 0 ppm. of potassium and phosphorus for 160 days. Compare with plate nine.

Plate 12. Response of cyclamen seedlings to 0, 25,50,100 and 200 ppm. nitrate when grown at 20 ppm. phosphorus, 30 ppm. potassium and 0 ppm. phosphorus, 0 ppm. potassium for 149 days. Left to right: upper row

P - 20 ppm.
K - 30 ppm.
N - 0, 25, 50, 100 and 200 ppm.

Lower row:

P - 0 ppm.
K - 0 ppm.
N - 0,25,50,100,200 ppm.

Note: High nitrate did not become injurious until at the 200 ppm. level when "P" and "K" are at optimum levels. Compare with plate 13.

Plate 13. Response of cyclamen seedlings to 0, 25, 50, 100, 200 ppm. nitrate when grown at 20 ppm. phosphorus, 0 ppm. potassium and 0 ppm. phosphorus and potassium for 149 days. Compare upper row above with upper row of plate 12 to see importance of NK interaction. Left to right: upper row

P - 20 ppm.
K - 0 ppm.
N - 0, 25, 50, 100 and 200

Lower row:

P - 0 ppm.
K - 0 ppm.
N - 0, 25, 50, 100 and 200.

Plate 14. Response of cyclamen to comparatively extremely unbalanced nutrients.

Left	Right
N - 0	N - 25
P -10	P - 10
K -30	K - 30

Plate 15. Response of cyclamen to comparatively closely balanced nutrients.

Left	Right
25 ppm nitrate	50 ppm nitrate
5 ppm phosphorus	10 ppm phosphorus
30 ppm potassium	0 ppm potassium

Plate 16 . Stages in germination of cyclamen seed. Reading from left to right; first two seeds show a typical seed before and after intake of moisture. Third and fourth seeds show the beginning of the hypocotyl swelling. Fifth and sixth seeds show the complete development of the hypocotyl swelling. The seventh seed shows the beginning of the secondary root formation and the undeveloped primary root radicle.

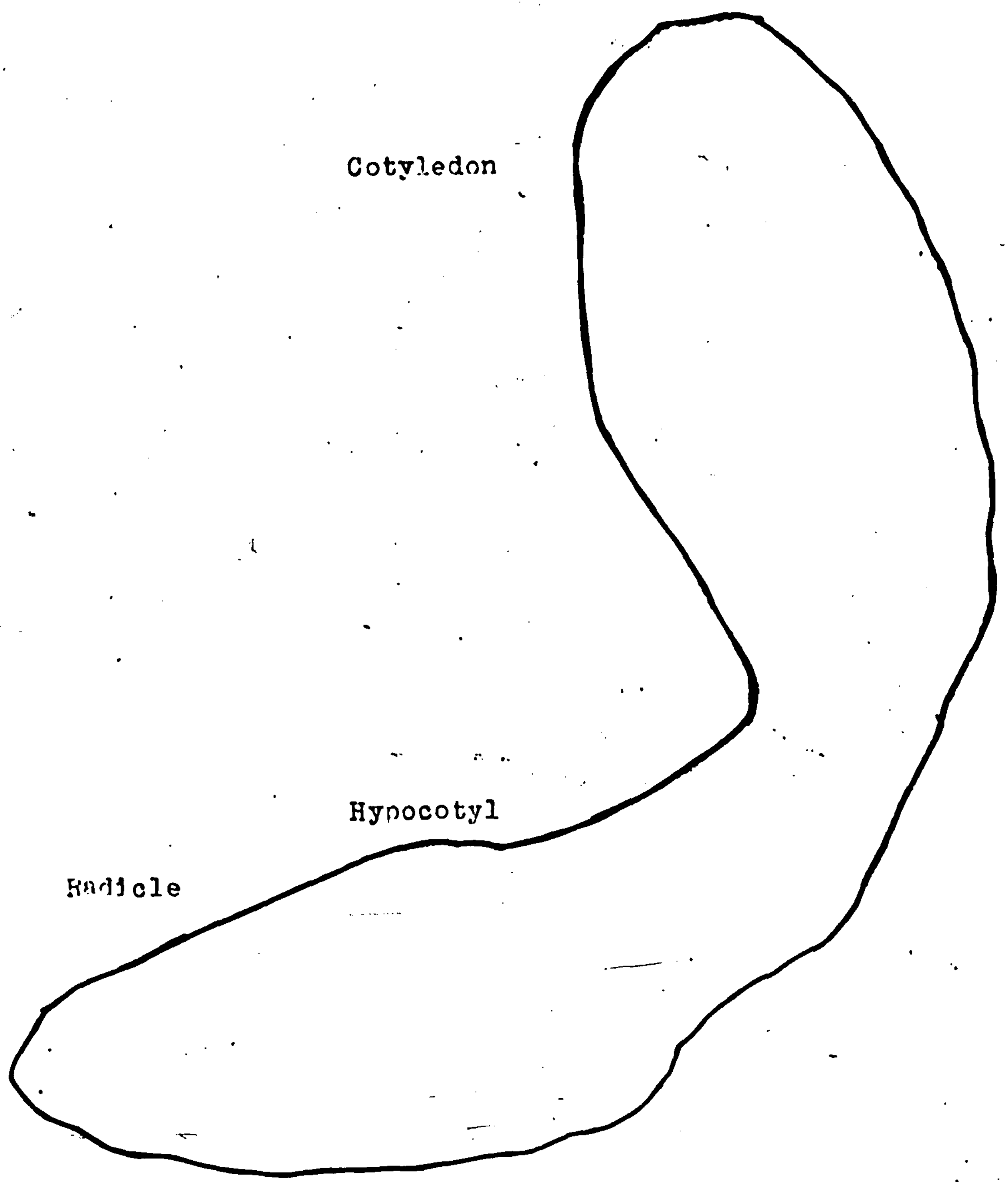


Plate 17. Excised cyclamen embryo showing the dormant radicle, hypocotyl and cotyledon. No hypocotyl swelling is evident.

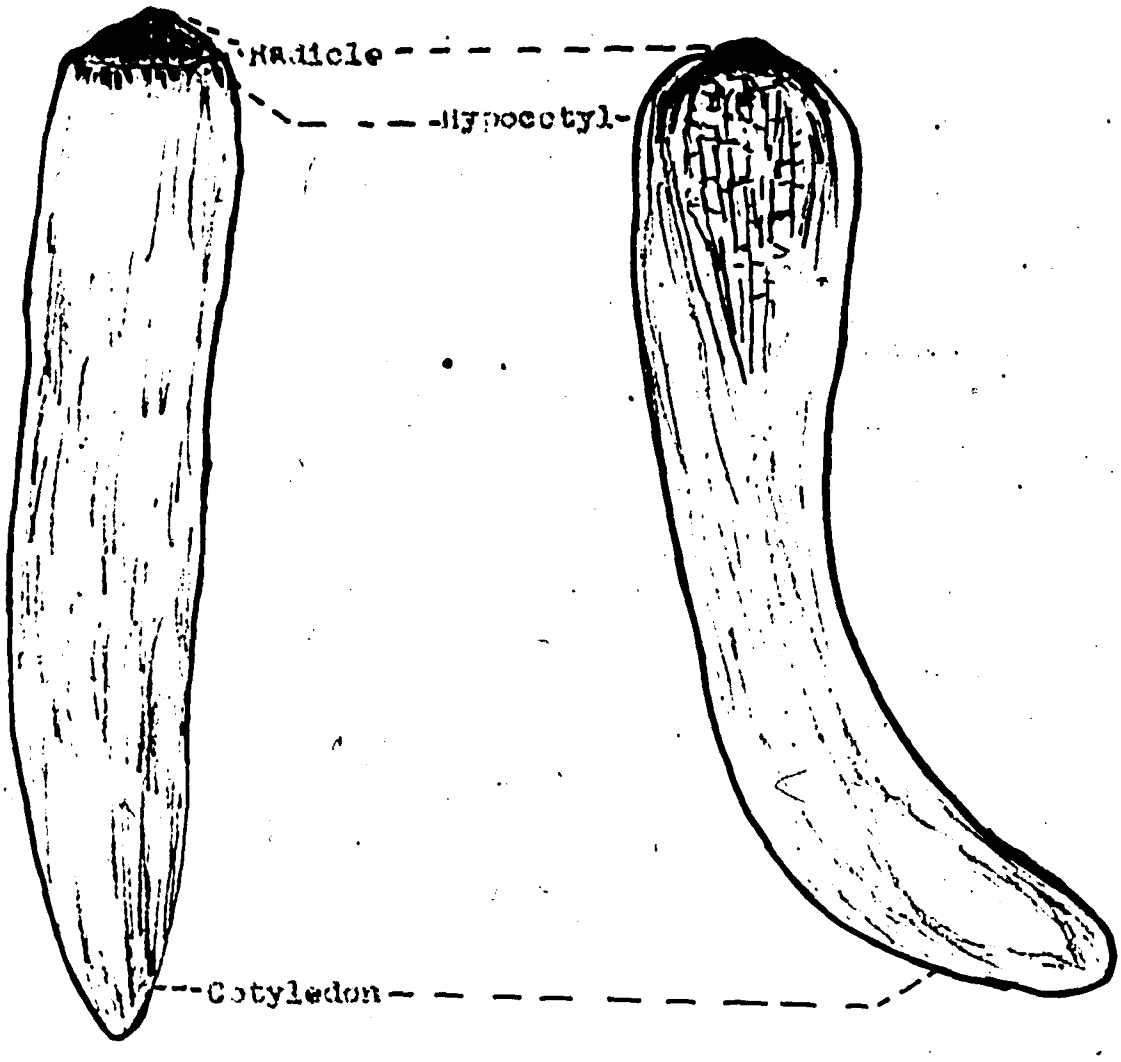
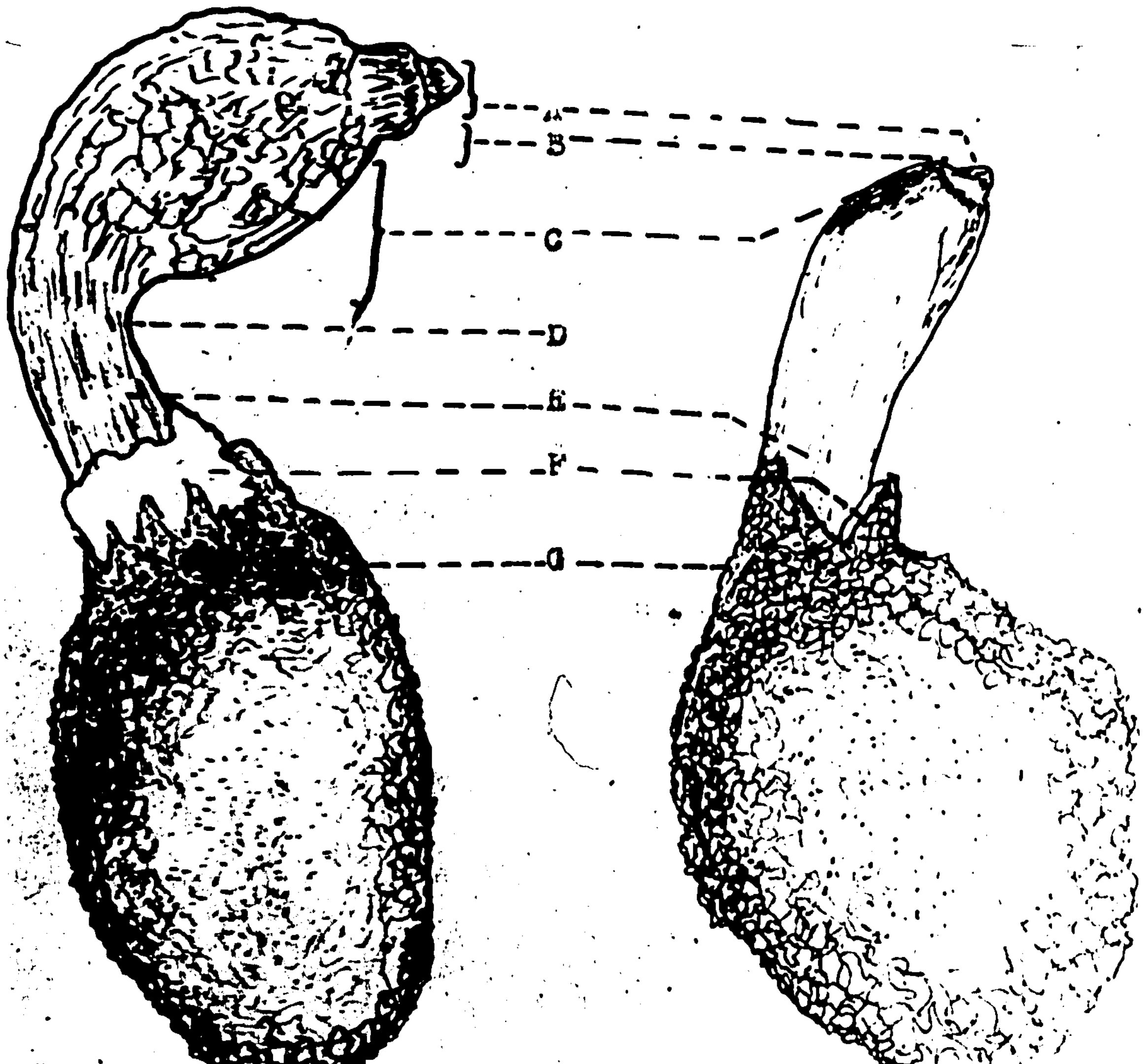


Plate 12. Excised embryos of cyclamen seeds at the time the radicle was emerging from the seed coat. Note beginning of hypocotyl swelling at this early stage.

15 X 7.5



15X2.0

Plate 1[illegible]. Cyclamen seed in two stages of germination.
Left: Swollen hypocotyl completely formed.
Right: Earlier stage with swelling of hypocotyl slightly evident.

A. Radicle
B. Transition zone
C. Upper part of hypocotyl
D. Area where second cotyledon arises
F. Endosperm
G. Seed coat containing cotyledon acting as an absorbing organ.

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