THE EFFECTS OF VARIOUS LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE GROWTH OF COLEUS

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Charles Allen Fountain

1948

This is to certify that the

thesis entitled

The Effects of Various Levels of Nitrogen, Phosphorus and Potassium on the Growth of Coleus.

presented by

Charles Allen Fountain

has been accepted towards fulfillment of the requirements for

M. S. **degree in** Horticulture.

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Major professor

Date August 22, 1948

M-795

THE EFFECTS OF VARIOUS LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE GROWTH OF COLEUS

By

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A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Horticulture

1948

THESIS.

ACKNOWLEDGMENT

The writer wishes to express his thanks to the following persons for their assistance during the period of this experiment: To Dr. Ray Lewis Cook, of Michigan State College Soil Science Department, for his suggestions in selecting materials and setting up this experiment; to Professor C. E. Wildon of Michigan State College Horticulture Department (in charge of Floriculture), for his suggestions on the best cultural practices to follow; and to Professor C. H. Sherwood and Mr. E. P. Roberts for their assistance in the routine of the experiment.

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THE EFFECTS OF VARIOUS LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE GROWTH OF COLEUS

INTRODUCTION

The extensive use of coleus as foliage plants in window gardens, conservatories, formal beds and pots makes it desirable to know what nutrient status is necessary for its best growth. A search of the literature reveals very little specific information on the nutrient requirements of coleus. It has been observed that optimum growth and development of foliage color in other plants are largely dependent on their nutrient status. Realizing that the value of coleus is directly dependent on its foliage development and color formation, this study was undertaken to determine the best combination and concentration of nitrogen, phosphorus, and potassium necessary for the most desirable growth and foliage color development of the coleus plant.

REVIEW OF LITERATURE

Dakers (2) has stated that one of the secrets in the culture of coleus is to give it plenty of food. He recommended that once rooted, grow in rich loam and peat to which two ounces of hoof and horn manure is added to each bushel of compost at each potting.

Free (3) suggested the use of a general potting mixture for coleus. He suggested a mixture consisting of four parts loam, two parts sand, one and one-half parts dried cow manure and two parts leafmold with the addition of one cup of bonemeal to each peck of the mixture.

The above recommendations readily show that very little is discussed concerning the optimum nutrient levels for coleus.

Jackson (4) found that geraniums responded to specific levels of nitrogen, phosphorus and potassium. He found that below and above the optimum levels stunted growth and other toxicity symptoms resulted. It was further observed that phosphorus was the most influential of all elements studied in determining the growth of geraniums.

Fuhr (5) determined the optimum levels of nitrogen, phosphorus and potassium for the growth of <u>Begonia semperflorens</u>. He found that improper nutrient levels and improper hydrogen-ion concentrations caused inferior crops of stunted growth and discolored foliage.

Scarseth (6) stated that the supplies of nitrates, inorganic

phosphates and potash are the most frequently encountered critical factors in plant nutrition.

Browne (7) 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 or harmonious 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 (8) 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 (9) said, "Absence or deficiency of any of the necessary mineral elements (including nitrogen) in the soil or other substratum iron which plants are rooted will

sooner or later become apparent in the development of that plant. 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 (10) 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.

METHODS AND PROCEDURE

Coleus was grown in five-inch ordinary clay pots. Nitrogen, phosphorus and potassium fertilizers were applied in such proportions as to give all combinations of 5 levels of NO_3, 5 levels of K, and 4 levels of P, a total of 100 treatments. All pots were kept in clay saucers to avoid loss by leaching.

Soil and Soil Testing:

The soil chosen for this experiment was Ostemo sandy soil which was collected from the vicinity of East Lansing by the Michigan State College Soil Science Department, and known to be very low in all plant nutrients. When tested at the beginning of this experiment it was found to contain plant nutrients in parts per million as follows: nitrogen, 2 ppm.; phosphorus 0 ppm.; and potassium, 5 ppm. Those levels above 0 ppm. tended to decrease soon after plants began to grow in the soil. The soil reaction showed a pH of 5.5.

All soil tests were made by the Spurway (1) Soil Method.

The soil was tested to determine its fixation capacity for nitrogen, phosphorus and potassium by the following procedure:

1. A quantity of soil was allowed to air-dry until it contained a minimum amount of moisture.
2. Twenty-four samples of 125 grams each were carefully weighed and placed in glass tumblers. Twelve samples

were used for duplicate tests.

3. A stock solution of nitrogen was prepared by dissolving one-tenth grams of chemically pure sodium nitrate ($NaNO_3$) in each milliliter of distilled water.

   Stock solution of potassium was prepared by dissolving five-hundredth grams of chemically pure potassium sulphate (K_2SO_4) in each milliliter of distilled water.

   Phosphorus was used as the dry form of Monocalcium phosphate ($CaH_4(PO_4)_2$).

4. Varying amounts of nitrogen, phosphorus and potassium were added to the soil samples as shown in Table 1.

5. Samples were allowed to stand for two weeks, after which time they were tested by the Spurway Test Method (1) to determine their fixation capacity for nitrates, phosphorus and potassium.

Table 1 and the following graphs show the fixation capacity of the soil used in the experiment.

Table 1. Nutrient Fixation Capacity of Ostemo Sandy Soil

Sample	Nutrient	Carrier	Distilled Water (ml.)	Amount of Carrier (gms)	Solution (ml.)	Soil (gms)	Level (ppm.)
1.	Nitrate	$NaNO_3$	1	.1	0	125	2*
2.	"	"	"	"	0.1	"	5
3.	"	"	"	"	0.2	"	10
4.	"	"	"	"	0.3	"	15
5.	"	"	"	"	0.4	"	25*
6.	"	"	"	"	0.5	"	35
7.	"	"	"	"	0.6	"	50
8.	"	"	"	"	0.8	"	50*
9.	"	"	"	"	1.0	"	75
10.	"	"	"	"	2.0	"	100*
11.	"	"	"	"	5.0	"	200*
12.	"	"	"	"	10.0	"	500
1.	Phosphorus	$CaH_4(PO_4)_2$	0	0	0	125	0*
2.	"	"	"	.02	"	"	.5
3.	"	"	"	.03	"	"	1.0
4.	"	"	"	.04	"	"	1.5
5.	"	"	"	.05	"	"	2.5
6.	"	"	"	.06	"	"	3.5
7.	"	"	"	.08	"	"	4.0
8.	"	"	"	.10	"	"	5.0*
9.	"	"	"	.15	"	"	10.0
10.	"	"	"	.20	"	"	10.0*

Table 1. Continued

Sample	Nutrient	Carrier	Distilled Water (ml.)	Amount of Carrier (gms)	Solution (ml.)	Soil (gms)	Level (ppm.)
11.	Phosphorus	$CaH_4(PO_4)_2$	0	.25	0	125	18.0
12.	"	"	"	.30	"	"	20.0*
1.	Potassium	K_2SO_4	1	.05	0	125	5*
2.	"	"	"	"	0.4	"	15*
3.	"	"	"	"	0.7	"	20
4.	"	"	"	"	1.0	"	30*
5.	"	"	"	"	2.0	"	40
6.	"	"	"	"	3.0	"	60*
7.	"	"	"	"	4.0	"	80
8.	"	"	"	"	5.0	"	100*
9.	"	"	"	"	6.0	"	120
10.	"	"	"	"	8.0	"	140
11.	"	"	"	"	10.0	"	160
12.	"	"	"	"	20.0	"	320

* Levels selected for use in the experiment.

Fig. 1. Nitrate Fixation Capacity of Ostemo Sandy Soil

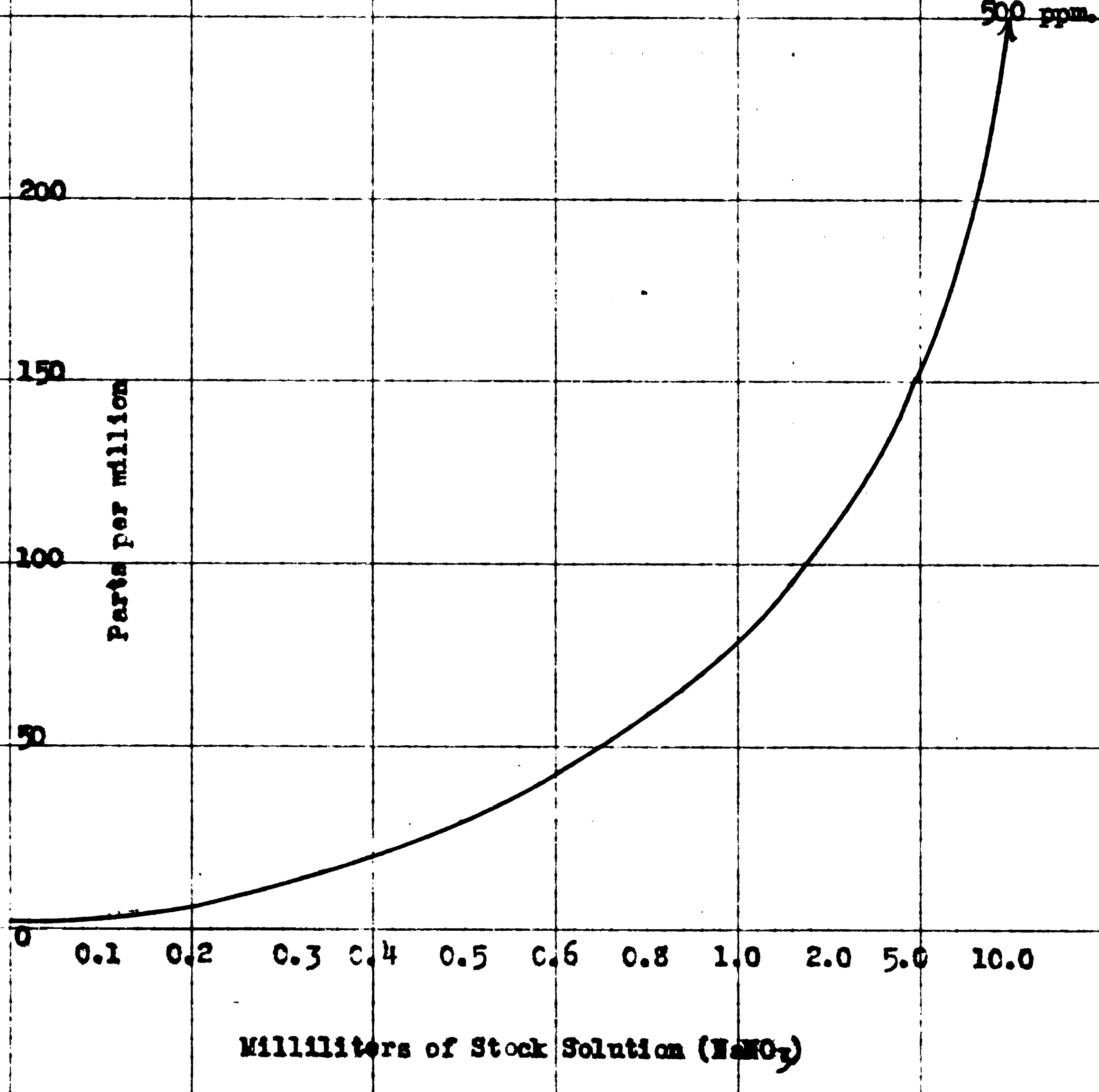


Fig. 2. Phosphorus Fixation Capacity of Ostemo Sandy Soil

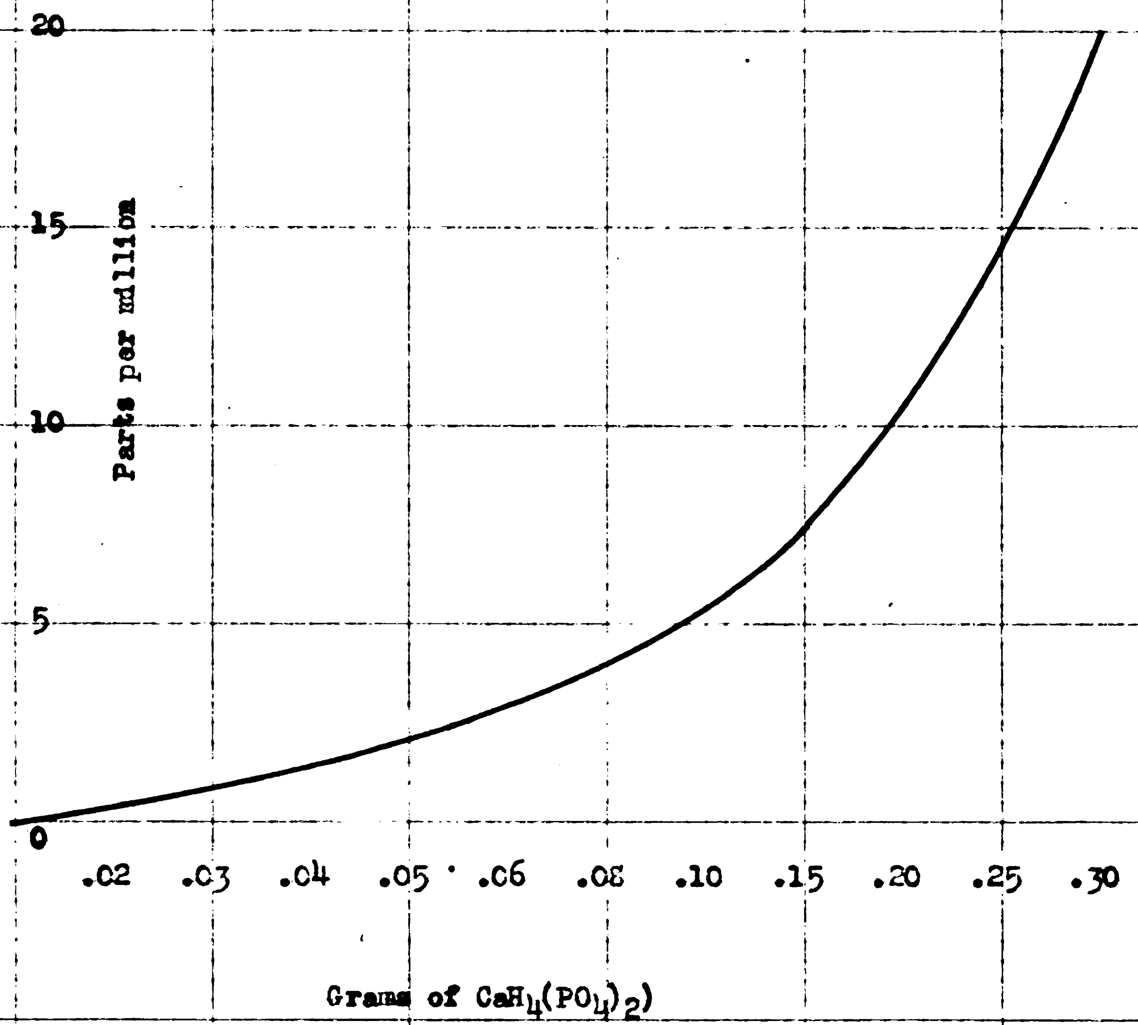
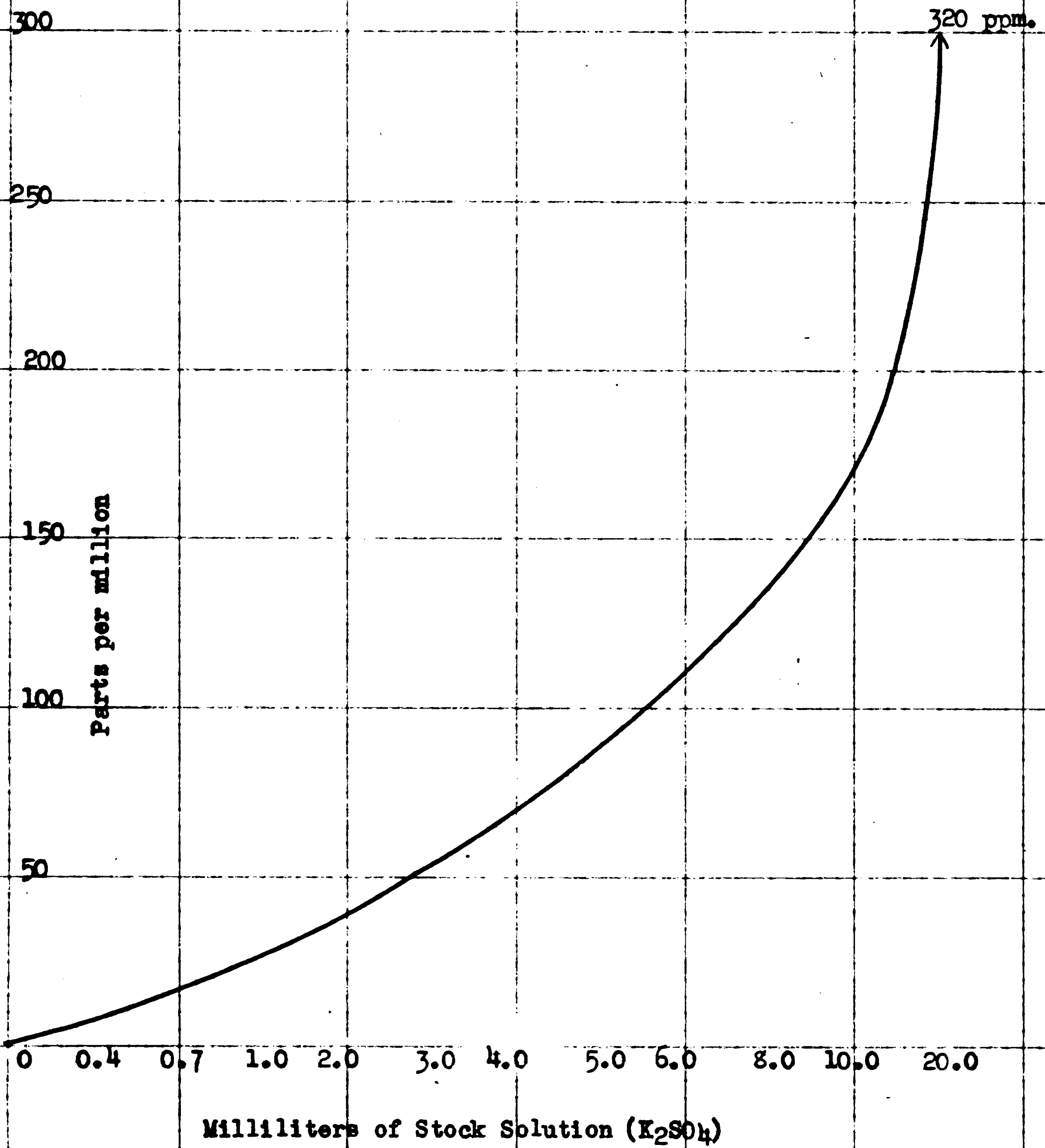


Fig. 3. Potassium Fixation Capacity of Ostemo Sandy Soil



Nutrient Levels Used:

Five levels of nitrogen, 0 ppm., 25 ppm., 50 ppm., 100 ppm., and 200 ppm. were used. Four levels of phosphorus, 0 ppm., 5 ppm., 10 ppm., and 20 ppm. were used. Five levels of potassium, 0 ppm., 15 ppm., 30 ppm., 60 ppm., and 100 ppm. were used. All possible combinations of the above levels were used to obtain 100 different treatments. Therefore, each plant was grown at a different nutrient level.

The following table shows the treatment numbers and the total parts per million of each nutrient used in the treatments.

Table 2. Nutrient Levels Maintained in Each Pot.

Treatment	NO_3	P	K	Treatment	NO_3	P	K
1.	0	0	0	25.	200	0	100
2.	0	0	15	26.	0	5	0
3.	0	0	30	27.	0	5	15
4.	0	0	60	28.	0	5	30
5.	0	0	100	29.	0	5	60
6.	25	0	0	30.	0	5	100
7.	25	0	15	31.	25	5	0
8.	25	0	30	32.	25	5	15
9.	25	0	60	33.	25	5	30
10.	25	0	100	34.	25	5	60
11.	50	0	0	35.	25	5	100
12.	50	0	15	36.	50	5	0
13.	50	0	30	37.	50	5	15
14.	50	0	60	38.	50	5	30
15.	50	0	100	39.	50	5	60
16.	100	0	0	40.	50	5	100
17.	100	0	15	41.	100	5	0
18.	100	0	30	42.	100	5	15
19.	100	0	60	43.	100	5	30
20.	100	0	100	44.	100	5	60
21.	200	0	0	45.	100	5	100
22.	200	0	15	46.	200	5	0
23.	200	0	30	47.	200	5	15
24.	200	0	60	48.	200	5	30

Table 2. Continued

Treatment	NO_3	P	K	Treatment	NO_3	P	K
49.	200	5	60	73.	200	10	30
50.	200	5	100	74.	200	10	60
51.	0	10	0	75.	200	10	100
52.	0	10	15	76.	0	20	0
53.	0	10	30	77.	0	20	15
54.	0	10	60	78.	0	20	30
55.	0	10	100	79.	0	20	60
56.	25	10	0	80.	0	20	100
57.	25	10	15	81.	25	20	0
58.	25	10	30	82.	25	20	15
59.	25	10	60	83.	25	20	30
60.	25	10	100	84.	25	20	60
61.	50	10	0	85.	25	20	100
62.	50	10	15	86.	50	20	0
63.	50	10	30	87.	50	20	15
64.	50	10	60	88.	50	20	30
65.	50	10	100	89.	50	20	60
66.	100	10	0	90.	50	20	100
67.	100	10	15	91.	100	20	0
68.	100	10	30	92.	100	20	15
69.	100	10	60	93.	100	20	30
70.	100	10	100	94.	100	20	60
71.	200	10	0	95.	100	20	100
72.	200	10	15	96.	200	20	0

Table 2. Continued

Treatment	NO_3	P	K	Treatment	NO_3	P	K
97.	200	20	15	99.	200	20	60
98.	200	20	30	100.	200	20	100

Source of Nutrients:

Sodium nitrate ($NaNO_3$) and ammonium nitrate NH_4NO_3) were used as carriers of nitrogen monocalcium phosphate ($CaH_4(PO_4)_2$) for phosphorus and potassium sulphate (K_2SO_4) for potassium. All of the above compounds were chemically pure. Ammonium nitrate was substituted for one-half of the sodium nitrate required at each level to alleviate the possibility of sodium toxicity in 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 by the preliminary tests .04 gms. $NaNO_3$ were required to raise the level of NO_3 in 125 gms. of soil to 25 ppm. (Figure 1.). Using that ratio of $NaNO_3$ to soil, .464 gms. were required for the 1450 gms. of soil used in each pot.

.04 x 11.6 = .464 gms. $NaNO_3$

One-half of the NO_3 was applied as $NaNO_3$ and the remainder as NH_4NO_3.

Therefore, each pot received .232 gms. $NaNO_3$ and the equivalent of that quantity of $NaNO_3$ as NH_4NO_3 (.109 gms.)

To the above chemicals a sufficient quantity of distilled water was added to give complete dissolution. Stock solution for each potassium level was prepared as shown below for the level of 15 ppm.

As the preliminary test indicated .020 gms. K_2SO_4 were required to raise the level of potassium in 125 gms. of soil to 15 ppm. (Figure 3.). Using that ratio of K_2SO_4 to soil, .232 gms. were required for the 1450 gms. of soil in each pot.

$$.020 \times 11.6 = .232 \text{ gms. } K_2SO_4$$

To the above amount of chemical a sufficient quantity of distilled water was added to give complete dissolution.

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

As indicated by the preliminary test .10 grams of $(CaH_4(PO_4)_2)$ was required to raise the level of phosphorus in 125 gms. of soil to 5 ppm. (Figure 2.). Using that ratio of $(CaH_4(PO_4)_2)$ to soil, 1.16 gms. were required for the 1450 gms. of soil used in each pot.

$$.10 \times 11.6 = 1.16 \text{ gms. } (CaH_4(PO_2)_2)$$

Table 3 which follows 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 the experiment.

Table 3. Nutrient Carriers Required to Obtain the Desired Levels

Nutrient	Nutrient Carrier	Amount of Soil (gms.)	PPM of Each Nutrient	Total PPM	Amount of Carrier (gms.)
NO_3	$NaNO_3$	1450	0	0	0
"	NH_4NO_3	"	0		0
NO_3	$NaNO_3$	1450	12.5		.232
"	NH_4NO_3	"	12.5	25	.109
NO_3	$NaNO_3$	1450	25.0		.464
"	NH_4NO_3	"	25.0	50	.21
NO_3	$NaNO_3$	1450	50.0		1.16
"	NH_4NO_3	"	50.0	100	.54
NO_3	$NaNO_3$	1450	100.0		2.9
"	NH_4NO_3	"	100.0	200	1.3
P	$CaH_4(PO_4)_2$	1450	0	5	0
"	"	"	5	10	1.16
"	"	"	10	15	2.32
"	"	"	20	20	3.48
K	K_2SO_4	1450	0	0	0
"	"	"	15	15	.232
"	"	"	30	30	.58
"	"	"	60	60	1.74
"	"	"	100	100	2.9

Cultural Practices:

On May 25, 1948 coleus cuttings were taken from stock plants which appeared to be nearly uniform in growth and foliar color pattern. The cuttings were placed in a propagation bench containing vermiculite as a rooting medium. On June 19th 100 five-inch pots were filled with 1450 grams of Ostemo sandy soil to which the proper amount of nutrients had been added and thoroughly mixed with the soil. Rooted cuttings of uniform sizes were selected and one planted in each pot. The potted plants were placed on a greenhouse bench and carefully watered. Partial shade was provided by covering the roof of the greenhouse with whitewash. During the ensuing growth period the plants were spot watered and kept uniformly moist. Periodic soil tests were made and sufficient nutrients added as their need was indicated by test results.

The experiment was terminated August 10th when the plants were cut-off at the soil-line and the green weights of the ground growth was determined as given in Table 7.

NUTRIENT CONSUMPTION

The following tables give the bi-weekly consumption of nutrients by each plant and the total amount of nutrients consumed by each plant during the entire growth period. These data were obtained by subtracting the total parts per million of each nutrient present in soil samples from each pot, taken during the growth period and at the end of the experiment, from the total parts per million present in each pot at the beginning of the experiment. The total consumption of nutrients by each plant was determined by adding the total parts per million lost from the soil between successive periodic tests.

Table 4. Amount of Nutrients Used From Soil During Successive Two Week Growth Periods.

Treat-ment	Nitrate 1st	Nitrate 2nd	Nitrate 3rd	Phosphorus 1st	Phosphorus 2nd	Phosphorus 3rd	Potassium 1st	Potassium 2nd	Potassium 3rd
							Amount of Nutrients Used (ppm.)		
1.	0	0	0	0	0	0	0	0	0
2.	0	0	0	0	0	0	0	0	5
3.	0	0	0	0	0	0	0	0	0
4.	0	0	0	0	0	0	0	20	0
5.	0	0	0	0	0	0	0	40	20
6.	0	23	15	0	0	0	0	0	0
7.	5	25	15	0	0	0	0	0	0
8.	0	20	15	0	0	0	0	10	5
9.	15	25	15	0	0	0	30	0	40
10.	5	10	15	0	0	0	30	40	20
11.	25	25	25	0	0	0	0	0	0
12.	0	30	25	0	0	0	0	0	5
13.	0	50	25	0	0	0	0	10	5
14.	0	30	25	0	0	0	0	0	20
15.	25	25	25	0	0	0	0	20	40
16.	0	100	50	0	0	0	0	0	0
17.	0	96	70	0	0	0	0	0	0
18.	0	100	70	0	0	0	0	10	10
19.	25	50	50	0	0	0	0	10	20
20.	0	100	50	0	0	0	0	60	40
21.	0	175	100	0	0	0	0	0	0

Table 4. Continued

Treat- ment	Amount of Nutrients Used (ppm.)								
	Nitrate			Phosphorus			Potassium		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
22.	0	175	100	0	0	0	0	0	0
23.	0	175	75	0	0	0	0	0	20
24.	0	180	100	0	0	0	0	40	40
25.	0	190	75	0	0	0	0	80	20
26.	0	0	0	0	0	2½	0	0	0
27.	0	0	0	0	0	0	0	10	5
28.	0	0	0	0	0	0	0	25	0
29.	0	0	0	0	0	0	0	0	20
30.	0	0	0	0	0	0	0	85	60
31.	0	25	0	0	0	0	0	0	0
32.	15	25	10	0	0	0	0	15	0
33.	20	20	23	0	0	0	0	15	25
34.	20	15	23	0	0	0	0	40	20
35.	0	25	25	0	0	0	0	70	60
36.	50	50	40	0	0	0	0	0	0
37.	30	30	45	0	0	2½	0	10	13
38.	30	50	30	0	0	0	0	15	20
39.	30	40	40	0	0	2½	30	10	30
40.	0	50	40	0	0	0	60	60	40
41.	0	85	50	0	0	2½	0	0	0
42.	0	95	50	0	0	0	0	0	5
43.	0	80	50	0	0	0	0	10	10
44.	0	90	75	0	0	0	20	10	20

Table 4. Continued

Treat-ment	Amount of Nutrients Used (ppm.)								
	Nitrate			Phosphorus			Potassium		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
45.	0	85	50	0	0	0	60	0	40
46.	0	160	75	0	0	0	0	0	0
47.	0	160	125	0	0	0	0	0	0
48.	0	175	100	0	0	0	10	5	0
49.	0	160	75	0	0	0	20	10	20
50.	0	160	75	0	0	$2\frac{1}{2}$	40	20	40
51.	0	0	0	0	0	0	0	0	0
52.	0	0	0	0	0	0	0	10	0
53.	0	0	0	0	0	0	5	0	0
54.	0	0	0	0	0	0	40	0	20
55.	0	0	0	0	0	0	60	20	40
56.	20	25	25	0	0	0	0	0	0
57.	20	25	20	0	0	0	10	0	5
58.	25	25	25	0	0	0	20	0	10
59.	20	20	23	0	0	0	20	0	20
60.	25	5	5	0	0	0	50	20	20
61.	50	40	30	0	0	0	0	0	0
62.	20	40	25	0	0	0	0	5	5
63.	40	40	25	0	0	0	15	0	5
64.	50	40	25	0	0	0	45	10	20
65.	45	40	30	0	0	0	60	20	40
66.	50	75	25	0	0	0	0	0	0

Table 4. Continued

Treat- ment	Amount of Nutrients Used (ppm.)								
	Nitrate			Phosphorus			Potassium		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
67.	50	75	50	0	0	0	0	15	0
68.	50	75	25	0	0	0	15	10	0
69.	50	75	25	0	0	0	30	0	0
70.	50	75	25	0	0	0	70	60	0
71.	100	150	140	0	0	0	0	0	0
72.	100	150	50	0	0	0	0	0	5
73.	100	170	120	0	0	0	15	0	10
74.	100	170	100	0	0	0	45	0	20
75.	100	150	200	0	0	0	85	20	90
76.	0	0	0	0	0	0	0	0	0
77.	0	0	0	0	0	0	0	0	0
78.	0	0	0	0	0	0	10	0	0
79.	0	0	0	0	0	0	40	0	0
80.	0	0	0	0	0	0	60	20	90
81.	15	25	25	0	0	0	0	0	0
82.	10	25	20	0	0	0	0	10	0
83.	25	25	23	0	0	0	10	10	0
84.	15	25	23	0	0	0	40	20	0
85.	25	25	15	0	0	0	60	0	95
86.	48	25	40	0	0	0	0	0	0
87.	50	25	0	0	0	0	0	0	0
88.	45	25	30	0	0	0	10	0	10

Table 4. Continued

Treat-ment	Amount of Nutrients Used (ppm.)								
	Nitrate			Phosphorus			Potassium		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
89.	50	25	40	0	0	0	30	20	20
90.	50	25	40	0	0	0	70	60	20
91.	75	50	25	0	0	0	0	0	0
92.	85	50	50	0	0	0	0	5	0
93.	75	50	25	0	0	0	10	0	5
94.	75	50	25	0	0	0	30	20	10
95.	85	50	25	0	0	0	60	20	40
96.	125	125	25	0	0	0	0	0	0
97.	150	125	25	0	0	0	0	0	0
98.	150	125	0	0	0	0	10	0	0
99.	190	125	25	0	0	0	40	0	40
100.	150	150	0	0	0	0	60	20	20

Table 5. Nutrients Consumed During the Entire Growth Period, ppm.

Treatment	Nitrate	Phosphorus	Potassium
1.	0	0	0
2.	0	0	5
3.	0	0	0
4.	0	0	20
5.	0	0	60
6.	48	0	0
7.	45	0	0
8.	35	0	15
9.	45	0	20
10.	30	0	60
11.	75	0	0
12.	55	0	5
13.	75	0	15
14.	55	0	20
15.	75	0	60
16.	150	0	0
17.	166	0	100
18.	170	0	20
19.	125	0	60
20.	150	0	100
21.	275	0	0
22.	275	0	0
23.	250	0	20

Table 5. Continued

Treatment	Nitrate	Phosphorus	Potassium
24.	280	0	80
25.	265	0	100
26.	0	$2\frac{1}{2}$	0
27.	0	0	15
28.	0	0	25
29.	0	0	20
30.	0	0	145
31.	25	0	0
32.	50	0	15
33.	63	0	40
34.	58	0	60
35.	50	0	130
36.	140	0	0
37.	105	$2\frac{1}{2}$	13
38.	80	0	35
39.	80	$2\frac{1}{2}$	70
40.	90	0	160
41.	135	$2\frac{1}{2}$	0
42.	145	0	5
43.	130	0	20
44.	165	0	50
45.	135	0	100
46.	235	0	0

Table 5. Continued

Treatment	Nitrate	Phosphorus	Potassium
47.	285	0	0
48.	275	0	15
49.	235	0	50
50.	235	$2\frac{1}{2}$	100
51.	0	0	0
52.	0	0	10
53.	0	0	5
54.	0	0	60
55.	0	0	120
56.	70	0	0
57.	65	0	15
58.	75	0	30
59.	63	0	40
60.	35	0	90
61.	120	0	0
62.	85	0	10
63.	115	0	20
64.	115	0	75
65.	150	0	125
66.	175	0	0
67.	150	0	15
68.	150	0	25
69.	150	0	30

Table 5. Continued

Treatment	Nitrate	Phosphorus	Potassium
70.	150	0	130
71.	390	0	0
72.	300	0	5
73.	390	0	25
74.	370	0	65
75.	450	0	195
76.	0	0	0
77.	0	0	0
78.	0	0	10
79.	0	0	40
80.	0	0	170
81.	65	0	0
82.	55	0	10
83.	73	0	20
84.	63	0	60
85.	65	0	155
86.	113	0	0
87.	75	0	0
88.	100	0	20
89.	115	0	70
90.	115	0	150
91.	150	0	0
92.	185	0	5

Table 5. Continued

Treatment	Nitrate	Phosphorus	Potassium
93.	150	0	15
94.	150	0	60
95.	160	0	120
96.	275	0	0
97.	300	0	0
98	275	0	10
99.	340	0	80
100.	320	0	100

RESULTS

The results given below are the general effects on growth and foliage color development of coleus caused by the use of different levels of nitrogen, phosphorus and potassium. The effect different nutrient combinations and the balance between nutrients will be given later.

Nitrogen Levels

<u>0 ppm</u>:

This level resulted in stunted and chlorotic plants. Very few of the plants produced secondary shoots. The leaves which should normally have a very deep red or maroon center surrounded by narrow margins of green along the edges of the leaf had centers which were light red or pink surrounded by wider margins of pale yellowish green.

<u>25 ppm</u>:

This level resulted in plants of good size and color. Secondary shoots were produced profusely. The foliage had deep red centers and narrow margins of a healthy green color. The plants of this group appeared to be as good as those of any group.

<u>50 ppm</u>:

This level resulted in plants of good size and color. They were very similar in growth and color to those growing at the level of 25 ppm.

<u>100 ppm</u>:

This level resulted in plants of reduced size and poorer color. The leaves were reduced in size and of dull colors. Plants of this group were almost as small as those observed in any group. Few secondary shoots were produced.

<u>200 ppm</u>:

This level resulted in plants of the smallest sizes observed in any group. They were very dull in color and the leaves were rosetted near the tips of the plants. There were very few secondary shoots produced.

Plants from different nitrogen levels are shown in the following figures.

Fig. 4. Response of coleus 44 days after potting to 0, 50, and 200 ppm. of nitrate when grown at 0 ppm. of phosphorus and 0 ppm. of potassium.

Left to right: 1. 0 ppm. nitrate

2. 50 ppm. nitrate

3. 200 ppm. nitrate

Note the extremely light color of the plant which did not receive nitrates.

Fig. 5. Response of coleus 45 days after potting to 0, 50, and 200 ppm. of nitrate when grown at 5 ppm. of phosphorus, and 0 ppm. of potassium.

Left to right: 1. 0 ppm. nitrate

2. 50 ppm. nitrate

3. 200 ppm. nitrate

Fig. 6. Response of coleus 45 days after potting to 0, 50, and 200 ppm. of nitrate when grown at 10 ppm. of phosphorus and 0 ppm. of potassium.

Left to right: 1. 0 ppm. nitrate

2. 50 ppm. nitrate

3. 200 ppm. nitrate

Fig. 7. Response of coleus 45 days after potting to 0, 50, and 200 ppm. of nitrate when grown at 20 ppm. of phosphorus and 0 ppm. of potassium.

Left to right: 1. 0 ppm. nitrate

2. 50 ppm. nitrate

3. 200 ppm. nitrate

Phosphorus Levels

0 ppm:

This level resulted in plants of normal appearance, but reduced in size. The colors of the foliage appeared to be slightly darker and smaller than on the phosphate treated plants.

5 ppm:

This level resulted in plants of normal appearance as to color of foliage. They were slightly larger than those of the first phosphorus level group.

10 ppm:

This level resulted in plants of normal appearance. They were slightly larger than those of the second phosphorus level group.

20 ppm:

This level resulted in plants of normal appearance. They were the largest of any group, being slightly larger than those of the previous level.

Plants from the four phosphorus levels are shown in the following figures.

Fig. 8. Response of coleus 50 days after potting to 0, 5, 10, and 20 ppm. of phosphorus when grown at 25 ppm. of nitrate and 15 ppm. of potassium.

Left to right: 1. 0 ppm. phosphorus

2. 5 ppm. phosphorus

3. 10 ppm. phosphorus

4. 20 ppm. phosphorus

Potassium Levels

0 ppm:

This level resulted in plants of normal appearance and good size in all cases except where the NO_3 level was too high. Their colors were ideal and branching was profuse. In the 5th nitrate level the plant which did not receive potassium showed symptoms of potassium starvation as shown by Figure 12.

15 ppm:

The plants of this group were very similar to those of the first potassium level group as to color, size and amount of branching.

30 ppm:

This level resulted in plants very similar to those found in the first two groups. There was very little apparent difference as to size, color and branching.

60 ppm:

This level resulted in plants that were slightly smaller in size. The colors of the foliage appeared to be slightly mottled by brown coloration. This was especially evident along the margins of the leaves.

100 ppm:

This level resulted in plants that were considerably reduced in size as shown by the weights presented in Table 7. The brown coloration mentioned above was more prevalent and in many instances burning of the tips of leaves resulted. Branching was also partly restricted.

Results of Nutrient Balance:

The following results especially indicate the value of nutrient balance.

High-N, Low-P, High-K ($N_{200}P_0K_{100}$):

The plant was very small chlorotic and showed symptoms of potash toxicity by the browning and burning of leaves.

High-N, Medium-P, High-K ($N_{200}P_5K_{100}$):

The plant was larger than the one above, but very dwarfed as compared to many other plants in the experiment. Other than its dwarfness it was of normal appearance, with fair branching.

Medium-N, Low-P, Medium-K ($N_{50}P_0K_{15}$):

The plant was much larger than those above, of good color and branching.

Medium-N, Medium-P, Medium-K ($N_{50}P_5K_{15}$):

The plant was the largest of this group, being of ideal size, color and branching.

The above results are shown in the figure on the following page.

Fig. 9. Coleus as affected by balance.

Plants 1 and 2 were grown at the highest levels of nitrate and potassium with the first level of phosphorus in 1 and the second level in 2. Note the response to phosphorus. Plant 3 was grown at the same phosphorus level as 1 but received a medium nitrate and potassium application. Plant 4 received nitrate and potassium equal to the application on 3 but with an application of phosphorus equal to that applied to 2.

Left to right:
1. 200 ppm. NO_3, 0 ppm. P, and 100 ppm. K.
2. 200 ppm. NO_3, 5 ppm. P, and 100 ppm. K.
3. 50 ppm. NO_3, 0 ppm. P, and 15 ppm. K.
4. 50 ppm. NO_3, 5 ppm. P, and 15 ppm. K.

Results of Nutrient Combinations:

The results discussed previously were those obtained when the presence and concentration of only one nutrient was considered, regardless to the presence and concentration of other nutrients. The results given below were those obtained when the presence and concentration of a nutrient in combination with other nutrients are considered.

Low-P, Low-N, Low-K ($N_0P_0K_0$):

The plant was of good height but its foliage was chlorotic, and branching lacking.

Higher-P, Low-N, Low-K ($N_0P_5K_0$):

The plant was slightly larger than above, but its foliage was chlorotic and it had very few branches.

Higher-P, Low-N, Low-K ($N_0P_{10}K_0$):

The plant appeared to be about the same as the one above.

Highest-P, Low-N, Low-K ($N_0P_{20}K_0$):

The plant's general appearance was about the same as the one above.

Low-P, Medium-N, Low-K ($N_{50}P_0K_0$):

The plant was of fair size, good color and fair branching.

Higher-P, Medium-N, Low-K ($N_{50}P_5K_0$):

The plant had good color, fair branching and was larger than the one above.

Higher-P, Medium-N, Low-K ($N_{50}P_{10}K_0$):

The plant was of increased size, good branching and good color.

Highest-P, Medium-N, Low-K ($N_{50}P_{20}K_0$):

The plant's general appearance was the same as the one above, but it was of greater size, being the largest of this group.

Low-P, Highest-N, Low-K ($N_{200}P_0K_0$):

The plant was of very small size, it had no branching and was of poor color, showing symptoms of severe potassium deficiency.

Higher-P, Highest-N, Low-K ($N_{200}P_5K_0$):

The plant was larger than the one above, and it showed decreased symptoms of potassium deficiency.

Higher-P, Highest-N, Low-K ($N_{200}P_{10}K_0$):

The plant was much smaller than one above and showed increased symptoms of potassium deficiency.

Highest-P, Highest-N, Low-K ($N_{200}P_{20}K_0$):

The plant was larger than one above and potassium deficiency was not as pronounced.

The above results are shown in the figures on the following pages.

Fig. 10. Response of coleus 50 days after potting to 0, 30, and 100 ppm. of potassium when grown at 50 ppm. nitrate and 0 ppm. of potassium.

Left to right: 1. 0 ppm. potassium

2. 30 ppm. potassium

3. 100 ppm. potassium

Fig. 11. Response of coleus 50 days after potting to 0, 30 and 100 ppm. potassium when grown at 200 ppm. of nitrate and 0 ppm. of phosphorus.

Left to right: 1. 0 ppm. potassium

2. 30 ppm. potassium

3. 100 ppm. potassium

Potassium Toxicity:

The results given below show the effect of nitrogen levels on deficiency and toxicity of potassium.

Medium-N, Low-P, Low-K ($N_{50}P_0K_0$):

The plant was of good size, normal color and good branching.

Medium-N, Low-P, Medium-K ($N_{50}P_0K_{30}$):

The plant was about the same size and general appearance as the one above.

Medium-N, Low-P, High-K ($N_{50}P_0K_{100}$):

The plant was reduced in size and shows symptoms of potash toxicity.

High-N, Low-P, Low-K ($N_{200}P_0K_0$):

The plant was severely reduced in size and showed symptoms of extreme potassium deficiency.

High-N, Low-P, Medium-K ($N_{200}P_0K_{30}$):

The plant was larger than the one above and showed no symptoms of potassium deficiency or toxicity.

High-N, Low-P, High-K ($N_{200}P_0K_{100}$):

The plant was of the same size and appearance as the first one above. It showed extreme symptoms of potash toxicity.

The figure found on the following page shows a plant deficient in potassium.

Fig. 12. Coleus showing potassium deficiency, as noted by the burning and curling of the tips and margin of leaves. Grown at 0 ppm. of potassium, 0 ppm. phosphorus and 200 ppm. nitrate.

Table 6. The Effect of Nutrient Levels on the Green Weight of Coleus.

Treatment No.	Weight	Treatment No.	Weight
1.	21 Grams	23.	12 Grams
2.	22 "	24.	8 "
3.	15 "	25.	6 "
4.	24 "	26.	24 "
5.	15 "	27.	32 "
6.	10 "	28.	20 "
7.	12 "	29.	24 "
8.	32 "	30.	22 "
9.	20 "	31	69 "
10.	15 "	*32.	16 "
11.	40 "	33.	85 "
12.	37 "	34.	56 "
13.	50 "	35.	32 "
14.	30 "	36.	50 "
15.	15 "	37.	88 "
16.	30 "	38.	32 "
17.	12 "	39.	50 "
18.	20 "	40.	26 "
19.	12 "	41.	30 "
20.	6 "	42.	30 "
21.	4 "	43.	54 "
22.	4 "	44.	32 "

Table 6. Continued

Treatment No.	Weight	Treatment No.	Weight
45.	26 Grams	67.	80 Grams
46.	26 "	68.	7 "
47.	33 "	69.	16 "
48.	12 "	70.	20 "
49.	26 "	71.	4 "
50.	22 "	72.	20 "
51.	24 "	73.	24 "
52.	28 "	74.	16 "
53.	22 "	75.	2 "
54.	10 "	76.	23 "
*55.	6 "	77.	26 "
56.	82 "	78.	20 "
57.	74 "	79.	28 "
58.	87 "	80.	25 "
59.	70 "	81.	77 "
60.	29 "	82.	80 "
61.	74 "	83.	52 "
62.	64 "	84.	36 "
*63.	12 "	85.	35 "
64.	32 "	86.	84 "
*65.	14 "	87.	64 "
66.	30 "	88.	20 "

Table 6. Contimued

Treatment No.	Weight	Treatment No.	Weight
89.	68 Grams	95.	13 Grams
90.	44 "	96.	18 "
91.	34 "	97.	6 "
92.	78 "	98.	4 "
93.	20 "	99.	12 "
94.	18 "	100.	1 "

* Plants of different variety

*Table 7. Average Green Weights of Plants Grown at Different Nutrient Levels.

Nitrogen		Phosphorus		Potassium	
Level (ppm)	Weight (gms)	Level (ppm)	Weight (gms)	Level (ppm)	Weight (gms)
0	22.6	0	18.9	0	37.4
25	49.9	5	38.9	15	40.0
50	46.6	10	38.5	30	30.0
100	24.8	20	35.2	60	29.0
200	13.0			100	22.0

* Above are data based on green weights as given in Table 6.

DISCUSSIONS AND CONCLUSIONS

From the data presented in this study one can readily see that the presence of various levels of nitrogen, phosphorus, and potassium greatly affect growth and foliage development in coleus. This information should be of great importance to the grower of coleus.

The results show that nitrogen is the greatest limiting factor. A medium level of nitrate is required, as shown in Figures 4, 5, 6 and 7 and also by Table 7. Table 7 indicates that the optimum level of nitrates was about 25 ppm., but the results obtained by the use of 50 ppm. was so very near those obtained with 25 ppm. that it would be better in commercial practice to use 50 ppm. because the application of a little excess would make it easier to maintain a sufficiently high level for a longer period, as nitrates are rapidly used by the growing plants, as shown by Table 4.

The use of increased potassium levels did not very appreciably increase growth and improve color. The plants grown at 0 ppm. potassium generally made as rapid growth as those grown at 15 ppm., and above the range of 15-30 ppm. the use of additional potassium had a decided toxic effect as shown in Figures 10 and 11 and also in Table 7. This was especially evident where the higher nitrate levels were used. Therefore, it seems best when making nutrient applications to coleus to use nutrient carriers which contain the lower level of potassium.

The addition of phosphorus tended to improve growth and foliage color. Where phosphorus was totally absent growth was restricted and the leaves were narrow and slightly darker than normal. Treatments with 5 ppm. of phosphorus caused a very definite increase in growth over the plants not receiving phosphorus, as Table 6 indicates. Among plants grown at optimum nitrate and potassium levels application of phosphorus above 5 ppm. gave only a slight increase in growth. This is shown in Figure 8.

The importance of balance between the nutrients was very vividly shown. When high levels of nitrates and potassium were used in combinations with low phosphorus it was observed that a pronounced decrease in growth resulted. There also occurred an increase in nitrogen and potassium toxicity symptoms when those plants were compared with plants grown at medium nitrate and low potassium levels in combination with low phosphorus levels. Because of the more balanced nutrient status the latter plants were of normal color and branching and were larger in size as compared to the chlorotic and non-branched condition of those grown at high nitrate, low potassium and low phosphorus levels. Only phosphorus restricted maximum growth in the more normal plants, while all three nutrients were limiting factors in the chlorotic plants. When the level of phosphorus was increased where it was in combination with high nitrate and high potassium an increase in growth resulted due to phosphorus being at a level better suited for growth and an increase in balance between the three nutrients but greater growth was not obtained because of the limiting effects of high nitrogen and high potassium. Where the phosphorus level was increased when in combination with medium nitrogen and low potassium maximum growth was obtained because all nutrients were at the optimum levels for growth. Phosphorus was no longer a limiting factor as it was when the combination of medium nitrate, low potassium and low phosphorus was used. The above effect of nutrient balance was shown in Figure 9.

The effect of potassium on growth was greatly influenced by the nitrate status of the culture medium. This was observed where plants grown at a medium nitrate level and varying potassium levels (Figure 10) are compared with those grown at high nitrate levels and varying potassium levels (Figure 11). Where nitrates were low the lack of, or an excess of potassium did not affect growth as drastically as it did under conditions of high nitrate. An excess of potassium was limiting in both cases. It was shown that the use of relatively high potassium levels (30-60 ppm.) in combination with high nitrogen tended to increase growth while that amount decreased growth under conditions of low and medium nitrate levels. The results in the former instance was probably due to improved nutrient balance.

In conclusion it can be stated that excessive nitrogen together with excessive amounts of potassium tended to limit growth and foliage color development in coleus. The optimum nutrient levels, as determined by the results obtained in this experiment were as follows: Nitrates 25-50 ppm; phosphorus 10-20 ppm; and potassium 5-15 ppm.

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