THE EFFECT OF VARIOUS NUTRIENT INTENSITIES ON THE GROWTH AND DEVELOPMENT OF SNAPDRAGON (*ANTIRRHINUM MAJUS* L.)

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This is to certify that the

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Major professor

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THE EFFECT OF VARIOUS NUTRIENT INTENSITIES ON THE GROWTH AND DEVELOPMENT OF SNAPDRAGON (*ANTIRRHINUM MAJUS* L.)

By

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A THESIS

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I. INTRODUCTION

A normal sequence of crop rotation in commercial floricultural greenhouses frequently has been the growing of snapdragons following a crop of chrysanthemums. This practice, without first removing some of the soluble fertilizer from the soil, often has resulted in serious injury. The belief has grown that the salt tolerance of the snapdragon is low in comparison to other crops. Fertilizer recommendations have been made largely on growers' observations, owing to the small amount of detailed investigation which has been devoted to this problem.

The work of Post and Bell (7) in 1936 indicated that snapdragons can be severely injured when subjected to excesses of single salts. Injury was observed as chlorosis of the young leaves, accompanied by a retardation of growth.

Laurie and Kiplinger (5) have stated that, except for initial additions of superphosphate, no nutrients need be added to a moderately fertile soil for satisfactory growth of snapdragons. Elaborating on this, they have mentioned that the snapdragon is strikingly non-responsive to nitrogen fertilizer during the fall and winter, but will respond to light applications in the spring.

Howland, in 1946 (4), working with the snapdragon, found flower production and quality to be affected very little by relatively large variations in nitrogen and potassium fertilization.

Post (6) has observed that excessive amounts of fertilizer in the soil caused chlorosis of the foliage. He suggested that in the soil extract nitrates be maintained at ten to fifty parts per million, phosphorus at five parts per million, and potassium at thirty parts per million, in terms of the Spurway acetic acid extraction.

The purpose of this investigation was to determine the effects of nutrient intensity on the growth and development of the snapdragon, as well as some of the relationships between nutrient intensity and nutrient absorption.

II. MATERIALS AND METHODS

A. Plant Material

Snapdragon plants used in this study were grown from seed. The following two varieties were selected for this work:

1. Margaret: an ivory-colored inbred variety, popular for commercial production.
2. M.S.C. #13: a rose-colored hybrid, recently developed at Michigan State College, which exhibits a high degree of heterosis.

April 5, 1952, seeds were sown in a mixture of equal parts by volume of soil, sand, and acid peat. May 6, seedlings were selected for uniform height and leaf development and transplanted into No. 8 grade quartz sand.* The plants were watered with a dilute nutrient solution until roots were established and evidence of new growth had appeared. The composition of this solution was: 0.00025 M KH_2PO_4, 0.00085 M $Ca(NO_3)_2$, 0.00065 M $MgSO_4$, 0.00065 M K_2SO_4, 0.0006 M $(NH_4)_2SO_4$, and 0.00025 M $CaCl_2$. Microelements were added at the following concentrations: 2.50 ppm Fe, 0.50 ppm Mn, 0.50 ppm B, 0.05 ppm Zn, 0.02 ppm Cu, and 0.01 ppm Mo. Treatments were started on May 17, 1952.

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*Purchased from the American Graded Sand Company of Chicago, Illinois.

B. Nutriculture Methods

1. Apparatus

The sand culture technique as described by Robbins (8), with some modification, was used. Plants were grown in two-gallon glazed earthenware crocks in quartz sand. This method was particularly suited to this type of study, since the inert medium could be washed free of nutrients and then provided with known concentrations. Each crock was connected to a five-gallon carboy containing the nutrient solution. The solutions were forced into the crocks by compressed air, as shown in Figure 1. The desired time of operation was set by the clock (A) which released the solenoid valve (B). This allowed compressed air to pass through the air line (C), which was open into the water column (G). In this way, pressure was exerted on the nutrient solution (D) in each carboy (E), forcing it into the crock (F). The clock was set to close the solenoid valve after five minutes of operation. When the valve was closed, the air pressure was dissipated into the water column (G) and the solutions drained back into the carboys by force of gravity. The height to which the solutions could rise in the crocks was governed by the height of the water column (G).

The crocks were spaced in two rows on a bench and the assigned treatments were randomized and replicated four times.

A general view of the apparatus is shown in Figure 2.

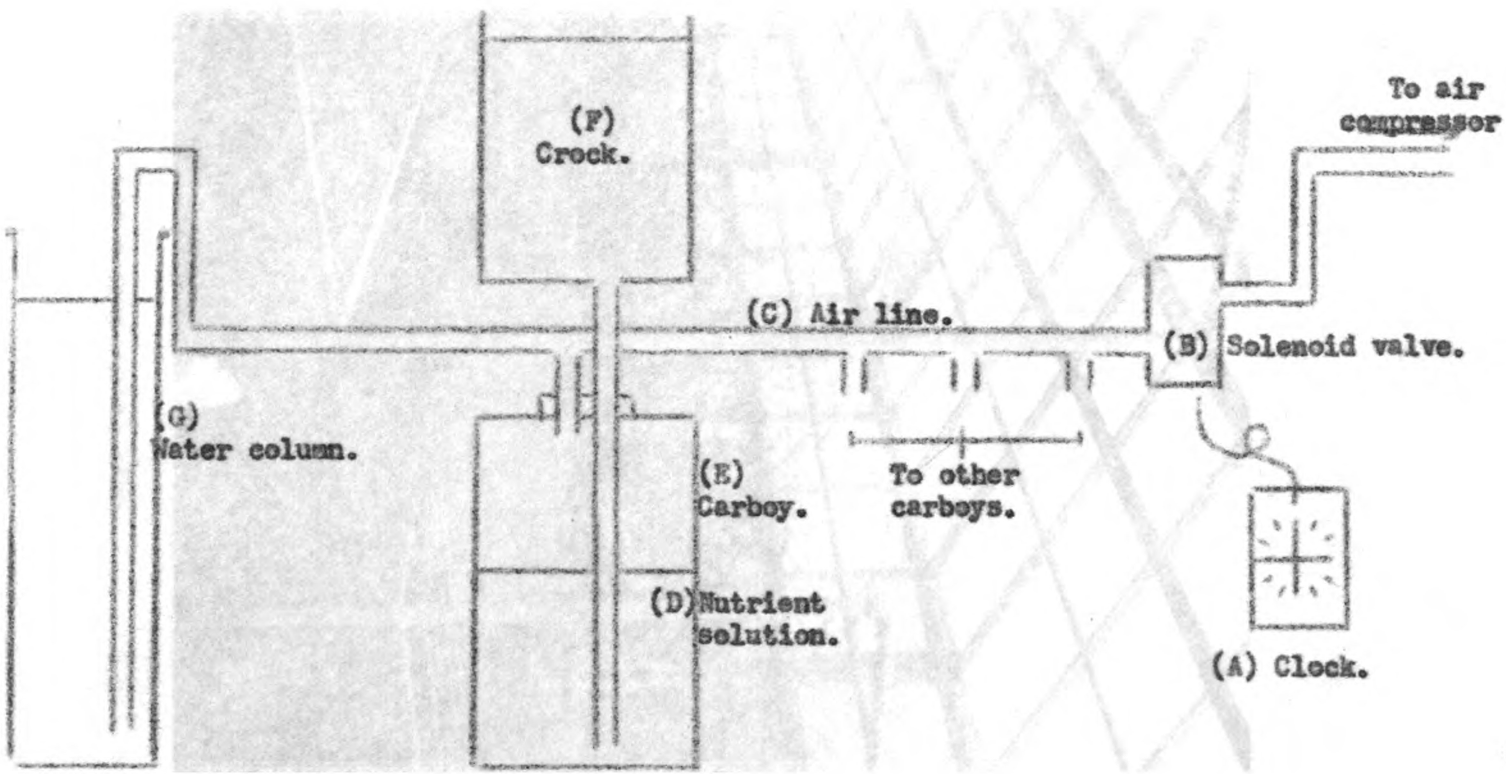

Figure 1. Modified sand culture technique used in growing plants.

Figure [illegible]. General view of the experimental area.

2. Nutrient solutions

A base nutrient solution was formulated from information obtained in preliminary studies. The solution was designated as the X salt concentration. The other treatment solutions used were one-fourth, one-half, two times, and four times the X concentration. Treatments were designated as .25X, .50X, X, 2X, and 4X. Concentrations of microelements were the same in all treatments. Details of the composition of the treatment solutions are given in Table 1.

These solutions were prepared from 0.5 molar stock solutions and were made to a volume of ten liters in each carboy. This volume was maintained throughout the experiment, distilled water being added through the crocks. This also prevented the accumulation of salts at the surface of the sand. Salts used were either Baker's Analyzed or Merck Reagent grade. Distilled water was used throughout.

When the solutions were prepared, pH measurements were obtained with a Beckman pH meter. These measurements also were made at two to eight day intervals while the solutions were in use. Since the values varied from pH 4.6 to pH 5.8 in a three-week period, no adjustments were made. The solutions were renewed every three weeks.

Osmotic pressure was calculated for each solution, using ionization values tabulated in the *Handbook of Chemistry and Physics*. The values calculated are given in Table 1.

TABLE 1

COMPOSITION OF THE TREATMENT SOLUTIONS

Treatment	Molar concentration of major salts						Calculated osmotic pressure (atm.)
	KH_2PO_4	$Ca(NO_3)_2$	$MgSO_4$	K_2SO_4	$(NH_4)_2SO_4$	$CaCl_2$	
.25X	0.00025	0.00085	0.00065	0.00065	0.0006	0.00025	0.19
.5 X	0.0005	0.0017	0.0013	0.0013	0.0012	0.0005	0.38
X	0.0010	0.0034	0.0026	0.0026	0.0024	0.0010	0.73
2X	0.0020	0.0068	0.0052	0.0052	0.0048	0.0020	1.46
4X	0.0040	0.0136	0.0104	0.0104	0.0096	0.0040	2.78

Concentration of microelements (parts per million)

Iron	2.50
Boron	0.50
Manganese	0.50
Zinc	0.05
Copper	0.02
Molybdenum	0.01

C. Analytical Methods

1. Physical measurements

Measurements to determine the effects of treatment on growth and development were as follows:

1. Dry weights of various plant parts.
2. Stem length: measured from the location of the cotyledons to the distal end of the inflorescence.
3. Number of flowers per inflorescence: total number capable of opening. The number of flowers capable of opening was determined from the appearance of the flower buds when approximately one-half of the inflorescence had opened.
4. Stem diameter: measurement made at a point equidistant from the location of the cotyledons and the base of the inflorescence.
5. Hardness of stem tissue. One-inch segments of green stem were taken from that place on the stem where the diameter measurement was made. This was done when two-thirds of the potential flowers had opened. Evaluation of hardness was expressed as shearing force in pounds per square inch as measured by a Tenderometer.*

In addition to these measurements, observations were made of leaf color, flower color, flower carriage, number of leaves, and time of maturity.

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*This apparatus was designed by the American Can Company for use in the canning industry.

2. Chemical analyses

Chemical analyses were made for nitrogen, phosphorus, potassium, calcium, and magnesium. The total leaf tissue was collected when two-thirds of the flowers had opened and was prepared for analysis as suggested by Ulrich (9).

Nitrogen was determined as total ammonium and amino forms by the Kjeldahl method (1). Phosphorus was determined by precipitation of ammonium phospho-molybdate and titration with standard potassium iodate. Potassium was determined with a Perkins-Elmer flame photometer. Calcium was determined by precipitation of the oxalate and titration with standard potassium permanganate. Magnesium was determined gravimetrically by precipitation of the dihydrous phosphate and ignition to the pyrophosphate.

III. RESULTS AND DISCUSSION

A. Observations

1. Leaf color

Observations of leaf color were made using color standards developed at Cornell University for apple trees (2). The color of the leaves of plants grown at the .25X, .50X, and X treatments was similar. The 2X treatment resulted in intervenal chlorosis on newly-formed leaves (see Figure 3). Similar but more extensive and severe chlorosis was observed on plants grown at the 4X treatment. It is difficult to attribute the chlorosis to any given cause, other than to consider it to be an indirect result of the high concentration of salts.

2. Flower color

No obvious differences in flower color were observed with the ivory-colored variety, Margaret. The rose-colored variety, M.S.C. #13, however, exhibited considerable fading at the 2X treatment. This was more pronounced at the 4X treatment.

3. Carriage of flowers

The carriage of the flowers in the inflorescence was compared by observing the angle between the axis of a fully open flower and the stem (see Figure 4). An angle of

Figure 4. [illegible] for the [illegible] treatment. [illegible] [illegible]

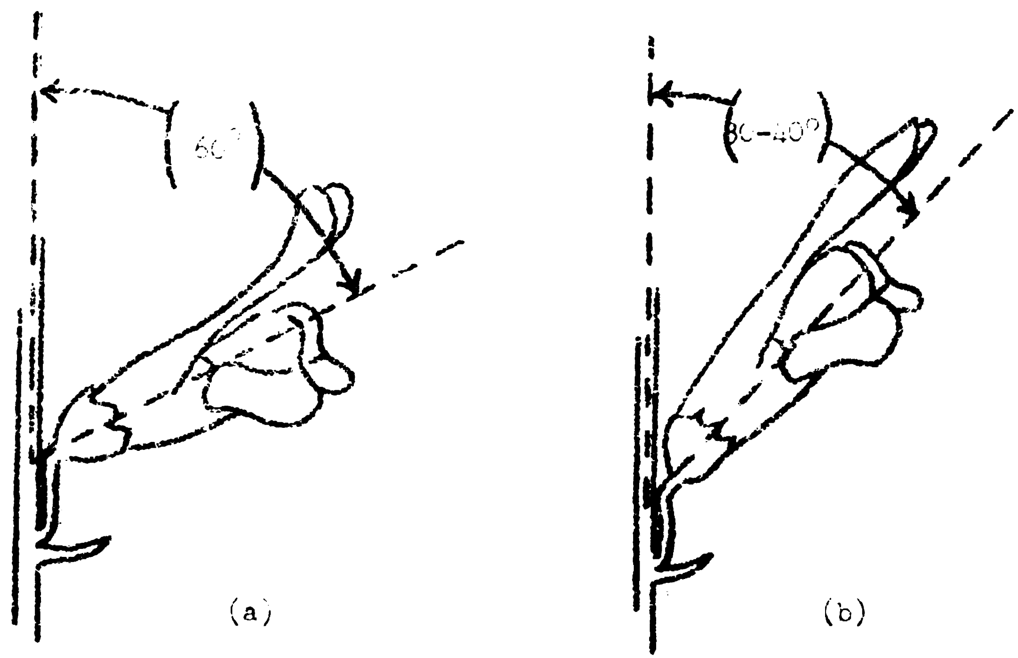


Figure [illegible]. Flower carriage: (a) normal, as in treatments .5 A and .5 [illegible].
(b) abnormal, as in treatments [illegible] and [illegible].

approximately sixty degrees was considered normal for these varieties. The flowers of plants grown at the .25X, .50X, and X treatments were normal. In the 2X treatment, the angle was smaller than normal. This became more pronounced at the 4X treatment, generally thirty to thirty-five degrees, as shown in Figure 4 and Figure 5.

4. Number of leaves

Counts were made of the number of leaves formed on a plant prior to the development of flower buds. All plants formed 25 ($\pm$ 2) leaves, no variation occurring between treatments. Apparently mineral nutrient intensity has little or no effect on the morphological age at which flowering occurs.

5. Length of time until maturity

Plants were harvested when two-thirds of the flowers in the raceme had opened. No differences were noted between the four treatments of lowest nutrient intensity. A decrease (five to six days) in time required for maturation was noted at the 4X treatment. This may have been due to retarded growth and accumulation of carbohydrates.

B. Physical Measurements

1. Dry weight

The dry weights of individual parts of plants grown under the various treatments are shown in Table 2. It is apparent from these data that the two varieties exhibited

TABLE 2

EFFECT OF NUTRIENT INTENSITY ON DRY MATTER PRODUCTION IN MARGARET AND M.S.C. #13 SNAPDRAGONS (Expressed as grams)

Treatment	Flowers	Leaves	Stem	Laterals	Total top	Roots	Total plant*
			Margaret (inbred)				
.25X	1.5	0.8	1.7	1.8	5.8	0.6	6.4
.5X	1.6	0.8	1.8	2.6	6.8	0.7	7.5
X	1.5	0.6	1.6	2.4	6.1	0.6	6.7
2X	1.2	0.7	1.2	1.8	4.9	0.5	5.4
4X	0.6	0.6	0.6	0.5	2.3	0.3	2.6
			M.S.C. #13 (hybrid)				
.25X	1.6	0.7	2.0	2.2	6.5	0.8	7.3
.5X	1.8	0.7	2.1	3.8	8.4	0.8	9.2
X	1.6	0.9	2.1	3.8	8.4	0.8	9.2
2X	1.1	0.7	1.0	1.4	4.2	0.6	4.8
4X	0.6	0.7	0.4	0.8	2.5	0.5	3.0

* Lowest significant difference in total plant weight: Treatment X variety: .05 level- 1.16; .01 level- 1.58.

differences in vigor and response to treatment. The inbred variety, Margaret, produced a significantly smaller amount of dry matter than the hybrid, M.S.C. #13, except at the .25X and .50X treatments.

The dry weights reflect serious injury to both varieties at the 2X treatment. This injury was further accentuated at the more intense 4X treatment. Plants grown at the 4X treatment produced approximately one-third as much dry matter as those grown at the X treatment.

The inbred variety showed a significant increase in the .50X treatment over both the .25X and X treatments, indicating that a point of maximum dry matter production probably occurred somewhere near the .50X intensity. The hybrid variety, however, exhibited no difference in dry matter between the .50X and X treatments, indicating that this hybrid, under conditions that prevailed, could utilize a more intense concentration of nutrients than the inbred variety.

It is interesting to note that, of the total top growth produced, the percentage contributed by lateral shoots increased to a maximum at the X treatment. Increasing the salt concentration from .25X to X resulted in an increase in the percentage of dry weight contributed by lateral growth from 31 to 39 percent for the inbred variety and from 32 to 45 percent for the hybrid. This is in agreement with Laurie and Kiplinger (5) who state that the

addition of nutrients, especially nitrogen, to a reasonably fertile soil will often result in "grassy" growth, or an abundance of lateral shoots. The relationship between lateral growth and nutrient intensity may suggest a growth regulator-nutrient interaction, resulting in the suppression of apical dominance.

2. Stem length

The influence of nutrient intensity on stem length is shown in Table 3. The hybrid produced a longer stem than the inbred at the .25X, .50X, and X treatments. Little varietal difference was expressed at the 2X and 4X treatments. It is evident that the hybrid was more severely injured than the inbred variety by the high salt concentrations, with respect to stem length as well as dry matter production.

Greatest stem length for the inbred variety occurred at the .25X and .50X treatments. For the hybrid variety this extended also to plants grown at the X treatment. This demonstrates that an "optimum" nutrient intensity for longitudinal growth would be slightly higher for the hybrid than for the inbred variety.

3. Number of flowers per inflorescence

As shown in Table 4, the number of flowers per inflorescence did not vary appreciably between the .25X, .50X, and X treatments, in either variety. However, at the 2X concentration the number of flowers was reduced in the

TABLE 3

EFFECT OF NUTRIENT INTENSITY ON STEM LENGTH OF MARGARET AND M.S.C. #13 SNAPDRAGONS
(expressed as centimeters)

Treatment	Margaret (inbred)	M.S.C. #13 (hybrid)
.25X	73.6	80.6
.5X	73.2	81.9
X	69.0	79.0
2X	60.0	59.0
4X	43.4	45.0

Lowest significant difference:
Treatment X variety: .05 level- 5.19; .01 level- 7.27

TABLE 4

EFFECT OF NUTRIENT INTENSITY ON NUMBER OF FLOWERS PER INFLORESCENCE IN MARGARET AND M.S.C. #13 SNAPDRAGONS

(Averages of twelve plants per treatment)

Treatment	Margaret (Inbred)	M.S.C. #13 (Hybrid)
.25X	25	24
.5 X	26	24
X	26	23
2X	20	16
4X	11	9

inbred variety by 23 percent, and in the hybrid by thirty percent. At the 4X concentration, the inbred variety showed a 58 percent decrease from the X concentration, and the hybrid showed a decrease of 61 percent.

4. Stem strength and hardness

Shearing force, as shown by the tenderometer readings in Table 5, was a measure of stem strength. Since these values do not take into account the differences in stem thickness, a factor of stem hardness was calculated. This factor was termed the Hardness Coefficient and was derived in the following manner:

$$H = \frac{T}{d^2}, \text{ where:}$$

H = Hardness Coefficient

T = Tenderometer reading (pounds per square inch)

d = diameter of stem (centimeters)

The diameter (d) is squared in the calculation in order that the correction might be for thickness of stem (proportional to the area of a cross section) rather than for stem diameter. Obviously, the Hardness Coefficient is only of value as a means of comparing; as an absolute value it is meaningless. Both the shearing force measurements and the stem diameter measurements were made on tissue from a point halfway between the location of the cotyledons and the base of the inflorescence.

It is shown in Table 5 that, with the varieties used, the .25X treatment produced stems with the highest Hardness Coefficient. With the inbred variety, a gradual decrease

TABLE 5

EFFECT OF NUTRIENT INTENSITY ON THE STRENGTH AND HARDNESS OF STEMS OF MARGARET AND M.S.C. #13 SNAPDRAGONS

(Average values for twelve plants in each treatment)*

Treatment	Margaret (Inbred)			M.S.C. #13 (Hybrid)		
	Tenderometer reading**	Stem diameter (cm)	H***	Tenderometer reading**	Stem diameter (cm)	H***
.25X	39.4	0.36	3.05	33.0	0.40	2.06
.5 X	41.0	0.38	2.85	32.1	0.42	1.82
X	37.0	0.38	2.57	30.2	0.42	1.72
2X	26.9	0.32	2.64	18.7	0.32	1.83
4X	15.2	0.26	2.26	11.4	0.24	1.99

* All measurements at point equidistant from cotyledon location and raceme base.

** Shearing force in pounds per square inch as measured by a Tenderometer

*** $H = \text{hardness coefficient} = \dfrac{\text{Tenderometer reading (Pounds per square inch)}}{\text{Stem diameter}^2 \text{ (cm)}}$

in hardness was observed as nutrient intensity increased. The greatest hardness for the hybrid also occurred at the .25X treatment, but little difference was observed between other treatments.

C. Chemical Analyses

The influence of nutrient intensity on the mineral composition of the snapdragon leaves is shown in Table 6. In general, the hybrid variety exhibited a lower percentage composition of nutrient elements than the inbred variety. This may well have been a function of dilution, owing to the greater production of dry matter by the hybrid.

Mineral nutrient content was found to be quite high in the snapdragon leaves. This is in agreement with the results of Gartner (3).

The nitrogen content of the leaves increased progressively with increased concentration of this and other elements in the nutrient solution. The contents of phosphorus and potassium showed strikingly similar trends. An increase of 1600 percent in the concentrations of nitrogen, phosphorus, and potassium in the nutrient solution (from the .25X to the 4X treatment) caused a fifty percent increase in the concentrations of these elements in the leaf tissue. While the treatment series was a geometric progression of concentrations in the nutrient solution, the content of these elements in the

TABLE 6

MINERAL COMPOSITION OF SNAPDRAGON LEAVES AS INFLUENCED BY NUTRIENT INTENSITY

(Expressed as percent of oven dry weight of leaf tissue)

Treatment	Margaret (Inbred)					M.S.C. #13 (Hybrid)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
.25X	4.83	0.448	2.38	1.40	0.674	4.16	0.335	2.20	1.42	0.413
.5 X	5.37	0.578	2.70	1.34	0.591	4.54	0.419	2.38	1.28	0.563
X	5.69	0.724	2.85	1.34	0.474	4.90	0.491	2.60	1.18	0.513
2X	6.18	0.778	3.33	1.39	0.842	5.80	0.537	3.02	1.23	0.494
4X	6.35	0.743	3.96	1.26	0.752	6.99	0.615	3.78	1.15	0.654

leaf tissue more nearly approached an arithmetic progression.

The calcium content of the leaves was not greatly affected by the intensity of the nutrient solution. Presumably the balance of macroelements in the nutrient solution was more instrumental in regulating calcium absorption than were the absolute amounts of calcium in the nutrient solution. If any effect is discernible, it would seem that the calcium content decreases slightly with increased nutrient intensity.

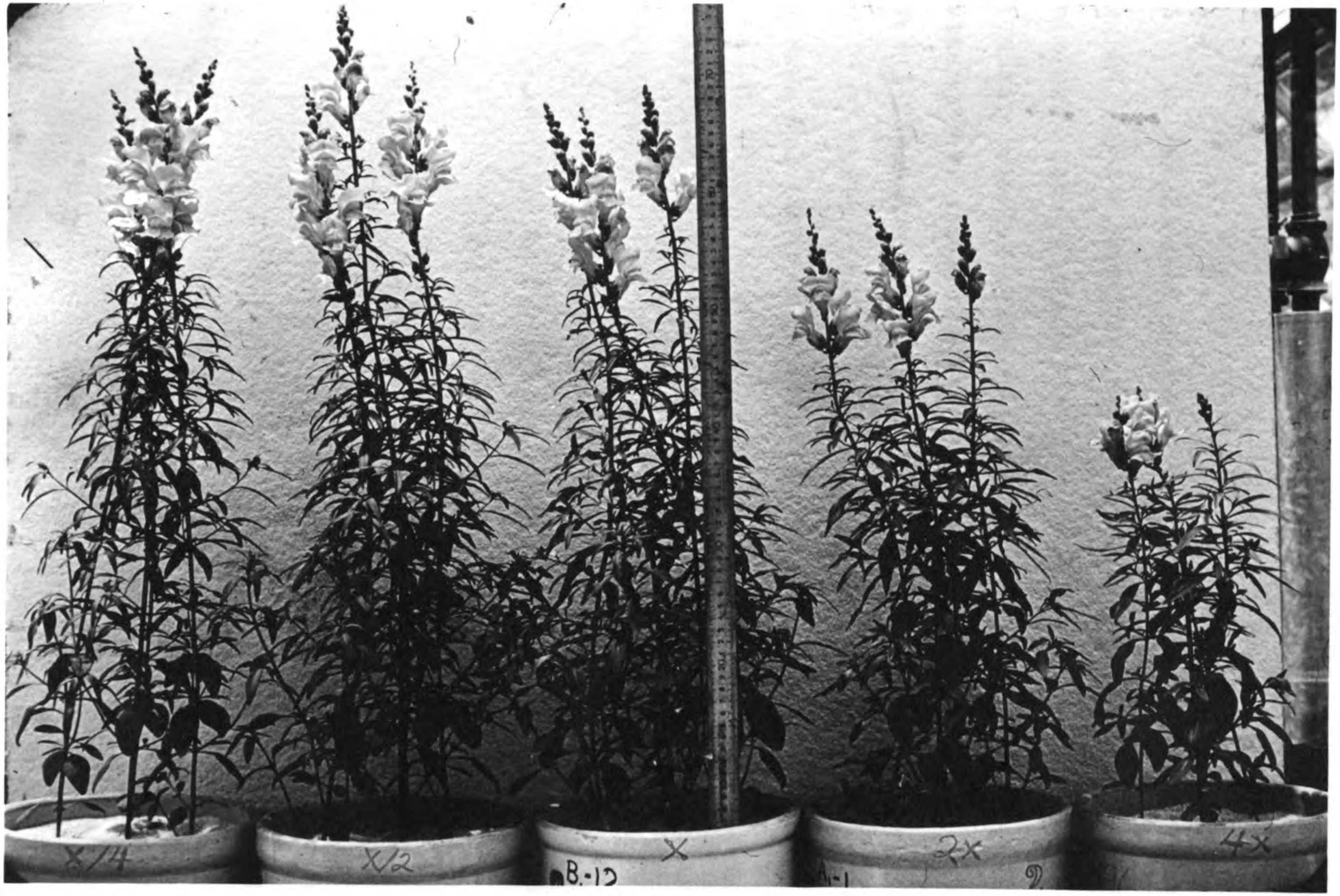
There seemed to be no correlation between nutrient intensity and magnesium content of the leaves, although considerable differences appeared between certain treatments.

D. General Discussion of Results

These results indicate that the snapdragon can be injured severely under an environment corresponding to the 2X or 4X treatment (Figures 6 and 7). The best growth, in terms of dry matter production, occurred with plants grown at the .50X treatment with the inbred variety, and at a slightly higher nutrient intensity with the hybrid.

For commercial snapdragon production, the .25X concentration could be designated as the "optimum" treatment, since the .50X and X treatments only increased lateral growth, but did not increase the commercial quality of the flowers. It is not necessary, nor even desirable in commercial production to obtain strong lateral growth, unless second-cropping is to be practiced.


X/4
X/2
X
2X
4X
B_2-2


X/4
X/2
X
B.-12
2X
4X

IV. SUMMARY

A. Snapdragon plants were grown in quartz sand and supplied with nutrient solutions of five different intensities. One of these five treatments was based on preliminary studies and designated as X concentration. The others were one-fourth, one-half, two times, and four times the X concentration.

B. Two varieties, Margaret (ivory-colored inbred) and M.S.C. #13 (rose-colored hybrid), were used.

C. Plants were seriously injured by the high salt concentration treatments, 2X and 4X. Symptoms of salt injury were:

1. Intervenal chlorosis on young leaves.
2. Fading of the flower color in the rose-colored variety, not noticeable in the ivory-colored variety.
3. A general retardation of growth.
4. Decrease in number of flowers per inflorescence.

All symptoms were more pronounced at the 4X treatment than at the 2X treatment.

D. The .50X treatment was found to be near-optimum for growth, in terms of dry matter production. However, the .25X treatment, which produced less lateral growth and blooms of good commercial quality, might well be considered to be nearer the optimum for commercial production.

E. Chemical analyses showed a direct relationship between nutrient intensity and the nitrogen, phosphorus, and potassium contents of the plant leaves. The calcium content was little affected by the treatments. The magnesium content differed between treatments, but not in a systematic manner.

F. The hybrid variety differed from the inbred variety in that:

1. It suffered more severe injury at the 2X and 4X treatments.
2. It responded to slightly higher intensity of nutrients.
3. It showed a slightly lower content of nutrient elements in the leaves, probably due to dilution as a result of greater dry matter production.

G. As a result of this investigation, it is recommended that commercial snapdragon growers avoid a high nutrient intensity. Apparently, the needs of the crop are much lower than those of many other crops commonly grown under glass.

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