GROWTH, DEVELOPMENT AND MINERAL UPTAKE IN TOMATO PLANTS, AS AFFECTED BY MALEIC HYDRAZIDE AND GIBBERELLIN.

Thesis for the Degree of Ph. D.

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Prithwish C. Bose

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This is to certify that the

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Prithwish C. Bose

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Charles L. Hamner
Major professor

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By

PRITHWISH C. BOSE

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and
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ABSTRACT

Tomato plants, var. John Baer were grown in quartz sand under Plant Science Greenhouse conditions (av. temperature 60 degrees F and av. day length 10:42 hours) at Michigan State University, East Lansing, Michigan. Hoagland and Arnon (1950) solution were used as a source of nutrient supply in the experiments involving the use of two growth regulators namely, maleic hydrazide and gibberellin.

The investigations were conducted to determine the effect of various concentrations of the two growth regulators, when used as a foliar applicant on the growth and subsequent development of plants. Analyses were also conducted for nitrogen, phosphorus, potassium, calcium, magnesium, iron, boron, manganese, copper and zinc content of plants.

The concentrations used were 10, 50 and 100 ppm of maleic hydrazide (MH) and 100, 250 and 500 ppm of potassium gibberellate.

Periodic measurements of height, stem diameter, number of leaves, size of the largest leaf, and fresh and dry weights of tops and roots were made for treated and check plants. The percent mineral composition was determined and also the uptake of different minerals were calculated periodically on the basis of dry weight per plant.

The data indicated that maleic hydrazide treated plants showed growth inhibition in all cases irrespective of the rate of application. However, root growth appeared to be affected more than shoot growth. Treatment produced a greater inhibition with 50 and 100 ppm as compared to low rate applications of 10 ppm which caused only a temporary growth inhibition. Plant analyses indicated highly significant differences between the treatments for percent composition and uptake of various minerals. However, all mineral analyses showed high values in favor of the check plants followed by 10, 50 and 100 ppm treatments indicating the magnitude of the metabolic changes resulting on account of the maleic hydrazide treatment.

Foliar applications of gibberellin, on the other hand, affected the growth mechanisms of the plants in such a way that stimulation of growth was observed for the treated plants. The data indicated that the magnitude of elongation of plant parts was related to the concentration of the compound used. These growth differences can be explained by the fact that the high application rates caused the plants to increase their uptake for water and potassium as compared to low rate treatments. However, no significant differences were found in the size of the largest leaf or the number of flowers between the various treatments. A significant decrease in number of fruits was found in all gibberellin treated plants in comparison with the check plants. Gibberellin treated plants indicated chlorosis and white patches on the 10-12 lower leaves which may be due to lower percent or total uptake of iron or manganese. The fruits produced by the gibberellin treated plants were malformed, russetted and smaller in size whereas the fruits of the check plants were early and free from these defects.

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INTRODUCTION

Since the very beginning of the history of plant science, man has endeavoured to understand and control plant growth. Discoveries of hormones and growth regulators in recent years have brought a better understanding of plant growth and mechanisms involved and is rapidly becoming a part of our agricultural economy.

Although many inorganic and organic compounds applied externally to plants may result in visible growth responses, all those physiologically active substances that are recognized as having growth regulatory properties are organic. A common characteristic of these compounds is great potency in inducing or repressing some growth process in the plant, which may be manifest in a diversity of responses.

Many of these compounds actively induce multiple responses though perhaps to different degrees; others are more specific. Often the effectiveness of the growth regulator for inducing a specific response is conditioned by the degree to which food reserves are available and are mobilized or demobilized in various organs. Since the effects of these chemicals as they alter the metabolism of intact plants and induce changes in composition are frequently pronounced, they deserve more consideration. Visible changes induced in morphology, growth, maturity and color may be accompanied by changes in chemical composition.

Two approaches to the mechanism of action of plant regulators have been used. One concerns the changes made by the regulator upon the morphological and anatomical structure of the plant, and the other involves a study of induced changes in the chemical composition of the plant. More progress has been made in studying the morphological and anatomical changes and also the changes in carbohydrates, proteins, amino acids, and vitamins induced by growth regulators, but very little work has been done on the mineral uptake of plants and as such deserves more attention.

It was thought advisable to select two compounds diversically opposing in their physiological activity in order to determine their influence on growth, development, and mineral uptake. For this experiment maleic hydrazide, a potent inhibitor, and gibberellin, which increases growth, were selected to determine their influence on growth, development, and mineral uptake of tomato plants.

REVIEW OF LITERATURE

1. Maleic hydrazide (MH):

The inhibiting effect of maleic hydrazide on plant growth has been known for some time. This material has been successfully used to check sprouting of potatoes and onions in storage. In high concentrations, this chemical accumulates in the meristem of herbaceous plants and checks growth completely and the plant dies, hence it's use as an herbicide.

The inhibiting effect of MH on growth of plants has been reported by various workers. Greulach (1951) treated Earliana tomato plants with 10 to 2000 ppm MH and found that dosage of 10 to 1000 ppm did not produce any significant inhibition whereas 2000 ppm inhibited growth to about half that of check plants after five weeks. There was no effect of any treatment on leaf development or stem diameter.

In another experiment, Greulach (1951) investigated the effect of 0.2 percent MH on various ages of tomato plants and reported that increase in stem diameter of plants 3, 4, and 5 weeks old at the time of treatment was inhibited in proportion to age with maximum inhibition being in 3 week old plants. Stems of 6 to 7 weeks old plants were not inhibited. Plants treated with MH had a higher shoot/root ratio and more pronounced in the youngest plants.

Shoene, et al. (1949) showed that MH application at 0.2 percent inhibited growth of tomato plants for two months and later the growth resumed from lateral buds and the plants bloomed.

Naylor and Davis (1950) applied 0.05 to 0.4 percent MH plus wetting agent as a foliar spray to oats, wheat, red top grass, corn, peas, peanut, sunflower, cocklebur, tomato, tobacco, and cotton and found the following similar effects:

a. Cessation of activity of terminal meristem.

b. Cessation of elongation of internodal region.

c. Increase in stem diameter.

Maleic hydrazide may inhibit growth of trees as well as small plants. Bynum (1952) reported that 0.1 to 0.5 percent solution of MH inhibited growth of Cleopatra manderines and sour oranges. Similar reports have come from Hamner and Rai (1958) who also have shown that high concentration of MH inhibited the growth of various ornamentals and shade trees.

Currier and Crafts (1950) reported that MH at 0.2% plus 0.024% Vatsol applied to barley killed the plants in six weeks. Cotton (var. Acala) 5 weeks old appeared unaffected. Cotton in cotyledon stage was severely inhibited but plants 16 inches high showed no apparent response. Young water grass, Echinochloa Crus-galli, and Johnson grass treated with MH stopped growing, developed anthocyanin pigmentation and died. The age of the plants was suggested critical with young plants most susceptible to maleic hydrazide.

By using standard pea growth test, Leopold and Klein (1951) investigated the action of MH on growth. They reported, "MH was found to be a growth inhibitor. In absence of auxin it inhibits growth at concentration as low as 0.1 mg./l. Since it is apparently incapable of promoting growth in the absence of auxin, it is not a growth regulator. The inhibition of growth by low concentration of MH is completely relieved by the addition of auxin. Conversely inhibition of growth by high concentration of auxin can be relieved by the addition of MH". Since they could not find any evidence which would indicate that the inhibitor acts directly combining with auxin in vitro they concluded that MH is an anti-auxin and acts in opposition to auxin in growth.

Activity of MH on root growth has also been studied by various workers. It has been reported by Choudhri and Bhatnager (1952) that MH spray at 1 to 10 ppm stimulated root elongation of corn seedlings and concentrations of 500 ppm and higher were inhibiting. Similar results were also reported by Bertossi (1950) who showed through the Macht test that MH up to 29 ppm inhibits growth of white lupine seedlings, while 0.226 to 14.5 ppm promotes the growth of lateral roots with optimum concentration of 3,62 ppm.

Carlson (1954) reported that the retardation of shoot and root growth in oats, soybean and maize by foliar application of MH is due to inhibition of mitosis. He also reported that the frequency of mitosis of the growing tissues drops quickly after MH treatment. This is substantiated by Smith, et al. (1957) who used radio-active MH. They reported that the concentration of MH was highest on growing tips and buds.

Compton (1952) working on the effect of MH on growth and cell division in pea plant found that the effect of MH on cell division is not coincident with its effect on total growth. Based on percent mitosis in treated plants as compared to controls, there was a greater percentage mitosis in shoot tips than root tips of all plants. In those plants in which mitosis reappeared after a period of complete inhibition, the greater percent of dividing cells occured in shoot tips, indicating that MH has a more pronounced effect on cell division in roots than in shoots.

The influence of MH on color and shape of leaves is very characteristic. Andersen, et al. (1950) reported that MH applied to leaves of wild oats six inches high at 12, 24 and 36 pounds per acre darkened the foliage in ten days and killed plants in 5 to 6 weeks.

Currier, et al. (1951) found that barley leaves became thicker, more brittle and sticky drops of exudates appeared after treating them with MH. Gifford (1956) found that by the second week after treatment with MH, barley plants were stunted and the leaves which were relatively mature at the time of treatment became much greener in color, thicker and more brittle than those of untreated plants.

Barnard, et al. (1950) reported that the higher dosage of MH caused leathery distorted outer leaves in lettuce.

Callaghan and Van Norman (1956) working on the effect of MH on photosynthesis, sprayed 0.0375 grams MH/liter and 3.0 grams MH/liter as amine salt on Swiss chard in the cotyledon stage or in 2-3 leaf stage and tobacco plants in the 5-6 leaf stage. Oxygen evolution was measured manometrically. Leaves developing after treatment were noticeably darker green than checks with fewer chloroplasts per palisade and spongy parenchyma cell but with a larger diameter. Photosynthetic rates were significantly increased after MH treatment. The increase in photosynthetic rate was spectacular at the lower rate of treatment although little effect on dry weight, respiration rate and chlorophyll concentration was evident. At the higher rate of MH treatment the depressed respiration and higher chlorophyll content may account for a part of the apparent increase in photosynthetic rate. At the lower concentration used here, however, there was little obvious morphological change in size or shape of leaves. The measured increase in photosynthetic rate seemed to be a modification of the physiology of the individual leaf cells. They did not suggest as to how the observed changes were brought about. However, the great change in rate per unit of chlorophyll was suggested as an alteration in the photochemical mechanism of photosynthesis. The low light intensity was used to contribute to that suggestion.

As regards the influence of MH on flower formation, Greulach (1951) reported that 100 to 1000 ppm did not produce significant inhibition of tomatoes. The 2000 ppm level inhibited growth about half of check after 5 weeks and caused a reduction in number of flowers. Klein and Leopold (1953) reported that MH inhibited flower formation in winter barley at a concentration as low as 4 X 10^{-5}M. Similar inhibition of flower formation has also been reported by Struckmeyer (1953) in croft lily and by Burr in sugarcane.

Ciferri (1951) reported that flowering of Virginia bright tobacco was retarded for 7.3 days at 100 ppm, 8.7 days at 200 ppm, and 10.7 days at 400 ppm. MH at 800 ppm inhibited flowering.

The influence of MH on growth of plants has been reported by various workers, as due to inhibition of respiration. According to Naylor and Davis (1951) inhibition of growth by application of MH was influenced by inhibition of respiration and they suggested that this may affect the normal function of dehydrogenase. Greulach (1954) has made the same suggestion.

Dugnani (1954) studied the effect of MH on dehydrogenase systems in preparations of cauliflower, pea and artichoke and reported that MH at 60-400 ppm inhibited dehydrogenation activity both in the soluble and mitochondrial systems. It was also suggested that MH may act on the $^{-}$SH group of the enzyme.

Differences between MH treated and untreated plants led investigators to believe that there might be some differences in the composition of plants. Petersen and Naylor (1953) studied frenching of tobacco plants and found that MH treated plants had high calcium and manganese, and lor phosphorus. Paper chromatographic analysis showed that the quantities of free amino acids were greater in treated plants. Treated plants had more reducing sugars and less protein than untreated plants. Similar results on sugar and protein content have also been reported by Greulach (1954) and Arnaud, et al. (1956).

2. Gibberellin:

Kurosawa reported in 1932 that a plant growth-promoting substance was present in the culture filtrate of *Gibberella-fujikuroi*. Little attention was given to this compound at the time. Only, however, within the last few years have intensive studies of practical uses begun.

Recently it has been shown by various workers that gibberellin promotes the growth of a wide variety of plants including grasses, vegetables, ornamental plants and fruit trees. It induces rapid lengthening of stems or internodes, broadening or elongation of leaves, increase in height, early flowering and fruiting.

Marth, et al. (1956) applied gibberellin as one percent lanolin paste on young stem tissue resulting in a 50 to 300 percent increase in height of geranium, poinsettia, rose, salvia, dwarf dahlia, petunia and aster under greenhouse conditions. Heights of snap beans, soy beans, peanut, pepper, eggplant, corn, barley and sunflower were doubled or tripled. Growth of 1 to 3 year old willow, oak, tulip poplar and maple trees were greatly increased, while white pine and white spruce showed only slight increase. Similar increase in height has been reported by Barton (1956) in crab apple seedlings; Bukovac and Wittwer (1956) in five varieties of tomato; Chardon (1956) in pineapples.

Brian and Hemming (1955) working on the effect of gibberellic acid on shoot growth of pea seedlings showed that the growth rate of shoots of dwarf pea seedling was significantly increased during the first 4 days by the application of 0.01 g of gibberellic acid (I) in ETOH solution to a leaflet of the first true leaf. In longer term experiments there was a linear relation between log dose and growth response in the dose range of 0.01 - 0.32 g/plant and a maximum response was obtained at 5.12 g of I. Slow growing varieties of pea respond more to I than fast-growing varieties, with suitable doses of I virtually eliminating the differences in growth rate between dwarf and tall varieties. Indoleacetic acid had a qualitatively similar but quantitatively much smaller effect.

Lang (1956) working on stem elongation induced by gibberellic acid in a rosette plant found that the effect was more pronounced under long day conditions than short days.

Various workers have reported earlier flowering, induced by gibberellin treatment. Rappaport (1957) reported this in tomato; Lindstrom and Wittwer (1957), and Lindstrom, et al. (1957) on various flower plants; Wittwer, et al. (1957) on beans, tomato, cabbage and lettuce.

Haber and Tolbert (1957) working on the photosynthetic activity in gibberellin treated leaves found that gibberellic acid did not enhance the rate of CO_2 fixation per unit of leaf tissue and also did not alter the general pathway of short-time metabolism of the newly fixed CO_2 in the sugars, organic acid and amino acid product.

Kato (1951) investigated the effect of gibberellin, extracted from cultured solution of <u>Gibberella fujikuroi</u>, which induces the elongation and light green color in seedlings of soybean, tomato, and sunflower. With 0.1% lanolin paste the increased elongation of the stem was 2 times or more the growth of the control but the growth of the leaf blade was suppressed. The green color did not become lighter or yellowish as in the case of treating them with nutrient solution containing gibberellin. In the standard Avena and pea tests for gibberellin in comparison with auxin, the concentrations of gibberellin were 1000, 500, 100, 50, 30, 20, 10, and 1 mg./l. Gibberellin was found inactive in all of the tests and it was suggested that gibberellin is a growth regulating substance of a nature quite different from the auxin.

Morgan and Mees (1956) reported that the nitrogen content of grass was lowered by about two percent after treatment with gibberellin. The growth was more rapid when treated with gibberellin as compared to nitrogenous fertilizers. Eventually the yield obtained with fertilizers was greater than with gibberellin. Increase in growth obtained after treatment with gibberellin was accompanied by chlorosis. Yield increase resulting from gibberellin and fertilizer applied together was additive.

Gray (1956) treated Bonny Best tomato plants with 50 ppm of gibberellic acid spray and found that treated plants developed smooth margined instead of notched or lobed leaflets. He also reported a 40 percent increase in yield of tomatoes, peas, runner beans and black currants and in the root crops (potatoes, turnips, and carrots), the yield was reduced, though an increased vegetative growth was found in all cases.

Fukuoka (1941) reported that gibberellin, induced overgrowth in rye plant without leading to the development of grains.

In one experiment Wittwer and Bukovac (1957) reported that application of gibberellin strikingly reduced production of marketable fruits of tomato. The fruits were small and often showed a peculiar russetting.

Induction of parthenocarpic fruits in tomato has been reported by Rappaport (1957) and Wittwer, et al. (1957) after application of gibberellin.

Effect of gibberellin on elongation, water uptake, and respiration of pea sections was studied by Kato (1956). He reported that after 24 hours, elongation, water uptake, and oxygen consumption of sections floating in solution containing 10 mg./l of gibberellin, was markedly increased.

It was believed that the behavior of enzymes was changed by the application of gibberellin. Hayashi, et al. (1956) analyzed leaf sheaths of rice plants grown in solution and treated with gibberellin to examine changes in the activity of various enzymes during the period of their growth, in comparison with that of control plants. They found that activities of phosphatase, alkalipyrophosphatase, dipeptidase, acetyllesterase, maltase, B-glucoside, X-galactosidase, amylase, urease, ascorbic acid oxydase, and catalase were decreased on extracts of sheaths on a fresh weight basis by treatment with gibberellin. Activities of peroxydase and invertase were markedly increased.

Increased growth in plants following application of gibberellin led some investigators to believe that there might be some changes in the composition of plants.

Kurosawa (1932) working with culture filtrate of Gibberella fujikuroi reported that potassium is essential element in the production of elongating substance in rice seedlings.

Yabuta, et al. (1943) working on the action of gibberellin on tea leaves found that tea buds became longer than the control, the total yield of tea leaves was not changed, and the analysis for vitamin C, peroxydase and oxydase, tannin, theine, total nitrogen, crude fiber, and soluble matter were similar to those for the control.

On the composition of rice seedlings as affected by gibberellin, Yabuta, et al. (1952) found that both the controls and treated plants had similar weights, moisture, ash, and total nitrogen but total sugars decreased in treated plants. Similar results were reported by Wittwer, et al. (1957) in Kentucky bluegrass.

Brian, et al. (1954) found that wheat seedlings grown in nutrient solutions containing 5 g of gibberellin per ml. showed increase in height due to increase in length of both stem and leaves. Leaf-blade width was slightly decreased. Chlorosis and leaf-roll developed, especially in the low nutrient solutions. Concentrations of gibberellin above 10 g./ml. gave no added response, and concentrations of 1000 g./ml. were inhibitory.

Under similar conditions, pea plants increased in height 500%. Petioles and internodes were greatly lengthened, but leaves were little affected in size. As in wheat, chlorosis was observed, and many concentrations decreased the growth promoting powers of gibberellin.

In general, fresh and dry weights for both wheat and peas were increased in shoots and decreased in roots, resulting in an overall increase. The carbon content especially was markedly increased, and ash, nitrogen, phosphorus and potassium were slightly increased. Carbohydrate concentrations, especially glucose, was also increased.

MATERIALS AND METHODS

In order to determine the effect of different concentrations of maleic hydrazide, 10, 50, and 100 ppm, and gibberellin *, 100, 250, and 500 ppm, on the plant growth experiments were arranged under greenhouse conditions at Michigan State University, East Lansing, Michigan. Tomato seedlings, var. John Baer, were selected as test plants.

Tomato seeds were sown in flats on October 1, 1957. The seedlings were transplanted, on October 29, 1957, into 5-inch pots filled with a mixture of medium and fine grade quartz sand for maleic hydrazide experiment. Another group of tomato seedlings, used for gibberellin experiments, was transplanted on the same day using medium grade quartz sand as the filling material in 8-inch pots.

Since the studies were also designed to determine the effect of the growth regulators, maleic hydrazide and gibberellin, on the mineral uptake, Hoagland and Arnon's (1950) nutrient solution was used throughout the experiment. Each plant, after transplantation, received a pint of nutrient solution and one quart of water every alternate day until January 1, 1958 after which the additions of nutrient solutions were increased to one quart per plant

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* Used as potassium gibberellate.

while the amount of water added was the same for the entire duration of the experiments.

The tomato plants, in 5-inch pots, were grouped into small and large plants and distributed evenly so that the difference in the physiological maturity of the plants ceased to be an influencing factor in the results. All the treatments were randomized and replicated twice in such a manner that each replicate consisted of four plants. However, inititial weight measurements and mineral analyses were made on 16 plants selected at random before the application of the compound.

Foliar applications of maleic hydrazide were made on December 12, 1957, taking due care so that the compound did not drip on the quartz sand in the pots.

In the other experiments, where gibberellin applications were made, plants in 8-inch pots were classified into three groups, i.e. large, medium and small, on the basis of their height. However, all the selected plants were so mixed in various combinations that there was no disproportionate uneveness which might lead to erroreous results. For that reason the shuffling process was thorough in all respects.

Out of these plants, a lot of 32 plants was selected for growth and development studies. Later, a sub-group of 8 plants was used for each concentration of gibberellin, i.e. 100, 250 and 500 ppm and check. Periodic observations were recorded for:

1. Height measurements: From the base to the tip of the plants.
2. Stem diameter: In all ten plants the diameter of the stem was measured between the first and leaf with vernier callipers.
3. Number of leaves: Counts were made of fully expanded leaves in each plant.
4. Size of the largest leaf: Length (in cms. from point of attachment to the leaf apex) of the largest leaf in each plant.
5. Number of laterals: shoots which were longer than 5 cms.
6. Number of flowers: on each plant
7. Number of fruits: on each plant

Another lot of tomato plants, in 8-inch pots, received gibberellin treatments on December 24, 1957, which consisted of three concentrations, and three harvest dates, i.e. 1 week, 3 weeks and 6 weeks period after the application date of the compound. All these treatments were randomized with three replications. The data was recorded for fresh and dry weights of tops and roots, and the analyses of the whole plant were made to determine the mineral content.

Nitrogen was determined by the standard Kjeldahl method, and potassium determinations were made by flame-photometer (A.O.A.C. 8th ed. 1955) while phosphorus, calcium, magnesium, iron, boron, manganese, copper and zinc were determined spectrographically (Bacon, R. A. and S. T. Bass, unpublished). The analytical work was conducted in the laboratories of the Agricultural Chemistry Department, Michigan State University, East Lansing, Michigan.

The mineral accumulation figures for each alement were obtained by the following formula:

$$\text{Total amount of each mineral per plant} = \frac{\text{Av. dry wt. per plant X Av. \% mineral}}{100}$$

Differences between the mineral content on any two dates was considered to show the amount of mineral taken up during that period.

Climatological data was obtained for the period of the investigations, that is, September 1957, to March 1958. The temperature of the plant science greenhouse room where studies were conducted, ranged from 58 degrees F. to 63 degrees F, with the average temperature being 60 degrees F. for the duration of the experiment.

The data relative to day length was calculated from the weather bureau table, "The time of sunrise and sunset for East Lansing", which is located on 75th meridian. Calculations were limited to the 21st day of each month. The day length ranged from 9:02 to 12:14 hours, with an average

of 10:42 hours.

EXPERIMENTAL RESULTS

All the different growth measurements and mineral determinations have been recorded in the Tables given in the Appendix. For the purpose of statistical comparison of the individual treatments the averages of each treatment for different data have been calculated and recorded, Tables I to VIII.

Maleic hydrazide:

Average of growth measurements for each treatment of this experiment has been recorded. Tables I and II.

Height: Statistical comparison of individual treatments showed that the heights of plants sprayed with 10 ppm maleic hydrazide was significantly less than the check. The heights of plants sprayed with 50 and 100 ppm were significantly less than those sprayed with 10 ppm maleic hydrazide, but there was no significant difference in heights of plants sprayed with 50 and 100 ppm maleic hydrazide. Heights of plants seem to be inhibited increasingly with increase in concentration of MH Graph-1.

Stem Diameter: It was found that all treated plants had significantly smaller diameter than checks; 50 and 100 ppm treated plants also showed a significantly smaller diameter than 10 ppm treated plants and no significant difference between 50 and 100 ppm treated plants.

Number of leaves: Individual treatments showed no significant difference in 10 ppm treated plants as compared to

TABLE - I

AVERAGE GROWTH MEASUREMENTS OF TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE.

MEASURE-MENTS.	* TREATMENTS				L.S.D. FOR TREATMENTS	
	Check	10 ppm	50 ppm	100 ppm	5%	1%
a. HEIGHT (in cms)	33.4	30.5	19.4	19.2	2.5	4.5
b. STEM DIAMETER (in mm)	5.27	4.62	4.35	4.31	0.18	0.33
c. NUMBER OF LEAVES	10.5	11.2	6.7	6.8	1.3	2.4
d. SIZE OF THE LARGEST LEAF (in cms)	21.5	19.7	15.2	15.4	3.3	6.1

* All measurements are averages from 5 observations of 2 replicates.

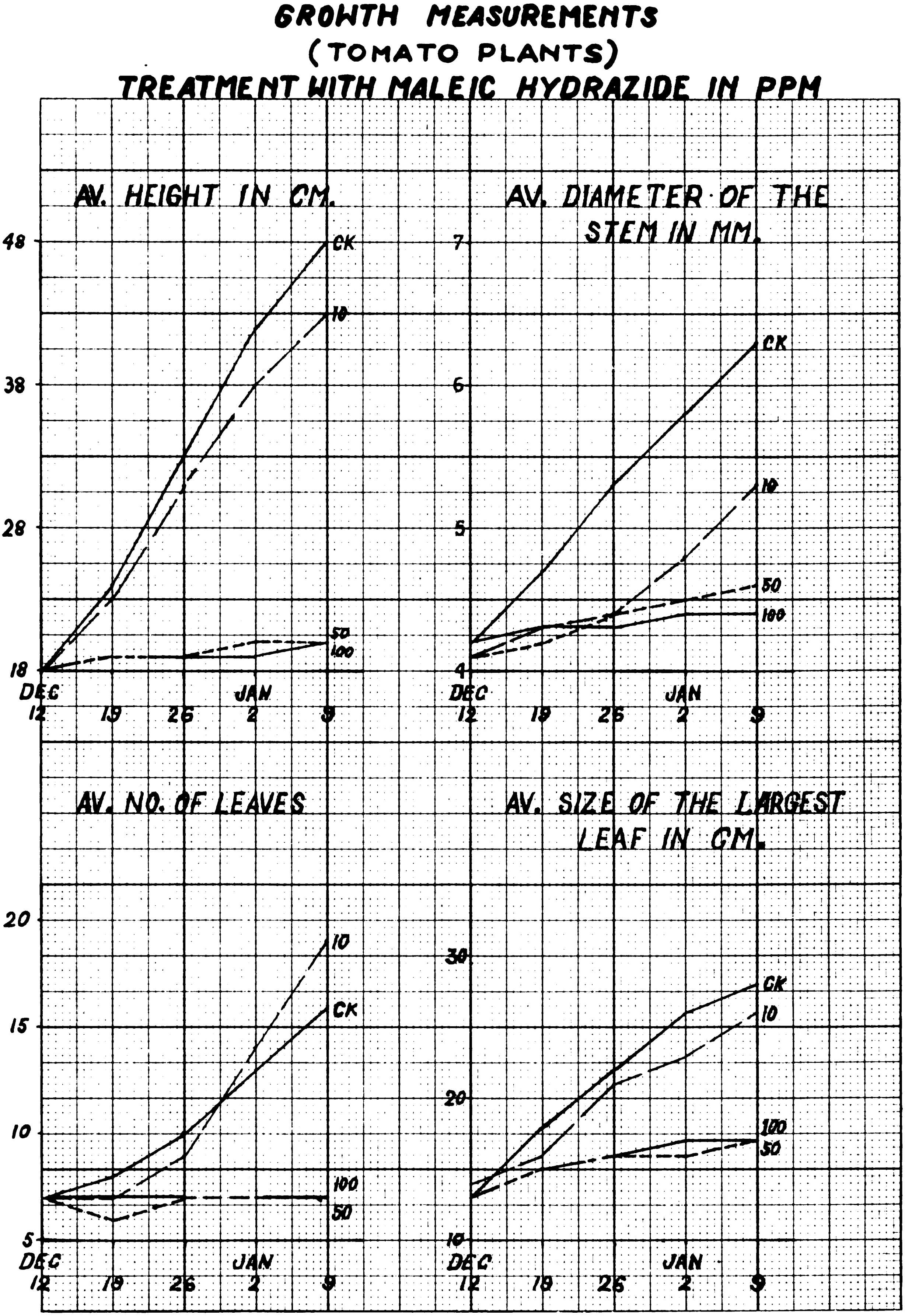
TABLE - II

AVERAGE FRESH AND DRY WEIGHT OF TOPS AND ROOTS OF TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE.

MEASURE-MENTS (gm.)	* TREATMENTS				L.S.D. FOR TREATMENTS	
	Check	10ppm	50 ppm	100 ppm	5%	1%
FRESH TOPS	39.7	27.2	11.2	12.3	8.1	12.0
FRESH ROOTS	7.4	5.6	2.1	2.0	1.7	2.5
DRY TOPS	3.7	2.6	1.5	1.7	0.7	1.1
DRY ROOTS	1.35	1.07	0.50	0.37	0.10	0.29

* All values are averages from two observations of two replicates.

GRAPH - 1


GROWTH MEASUREMENTS
(TOMATO PLANTS)
TREATMENT WITH MALEIC HYDRAZIDE IN PPM
AV. HEIGHT IN CM.
48
38
28
18
CK
10
50
100
DEC
12
19
26
JAN
2
9
AV. DIAMETER OF THE STEM IN MM.
7
6
5
4
CK
10
50
100
DEC
12
19
26
JAN
2
9
AV. NO. OF LEAVES
20
15
10
5
10
CK
100
50
DEC
12
19
26
JAN
2
9
AV. SIZE OF THE LARGEST LEAF IN CM.
30
20
10
CK
10
100
50
DEC
12
19
26
JAN
2
9

checks. Both 50 and 100 ppm treated plants had a significantly lower number of leaves than checks and 10 ppm treated plants. Number of leaves decreased with increase in concentration of MH applied with the exception of 10 ppm treated plants where number of leaves per plant were more than checks and 50 and 100 ppm treated plants seem to behave in the same manner, Graph-1.

Size of the largest leaf: The individual statistical comparison of treatments showed that there was a significant decrease in the size of the largest leaf of 50 and 100 ppm treated plants than check and 10 ppm treated plants. No significant differences were found between 10 ppm treated plants and checks, and also between 50 and 100 ppm treated plants. Size of the largest leaf was decreased by increase in concentration of MH, Graph-1.

Fresh and dry weights of tops and roots: In weights of fresh tops a significant decrease was found in all treated plants as compared to check. A significant increase was found in 10 ppm treated plants over 50 and 100 ppm treated plants. No significant difference was found between 50 and 100 ppm treated plants.

The fresh root weights showed similar differences.

Similar statistical differences were found in weights of dry tops and roots except that dry weight of roots of plants treated with 50 ppm MH was greater than that of roots of plants treated with 100 ppm MH.

In all cases checks had greatest weights followed by 10, 50 and 100 ppm treated plants, excepting for weights of fresh and dry tops where 100 ppm treated plants had slightly greater weights than 50 ppm treated plants, Graph-2.

<u>General observations</u>: One week after treatment, leaves of treated plants started to turn darker green in color. After the second week, leaves of 50 and 100 ppm treated plants appeared very dark green in color and remained the same way whereas 10 ppm treated plants showed slightly darker leaves than checks. From third week onwards leaves of 10 ppm treated plants appeared normal green in color.

The stems of all treated plants exhibited color changes.

The treated plants appeared inhibited in growth. Inhibition appeared greater with increase in concentration of MH applied, Figure-1.

Plants tested with 10 ppm MH showed an abnormal growth, Figure-2, like that of 2, 4-D injury, between second and third week of treatment but later bloomed like check plants whereas 50 and 100 ppm treated plants did not bloom at all.

Observation of roots two weeks after treatment with MH showed a great inhibition in roots of treated plants. Treated plants had fewer fine roots. Four weeks after treatment 10 ppm treated plants showed normal rooting system whereas 50 and 100 ppm treated plants had very few roots, Figure-3.

It was also observed that smaller plants in general were more affected by MH treatment than large ones.

GRAPH -2

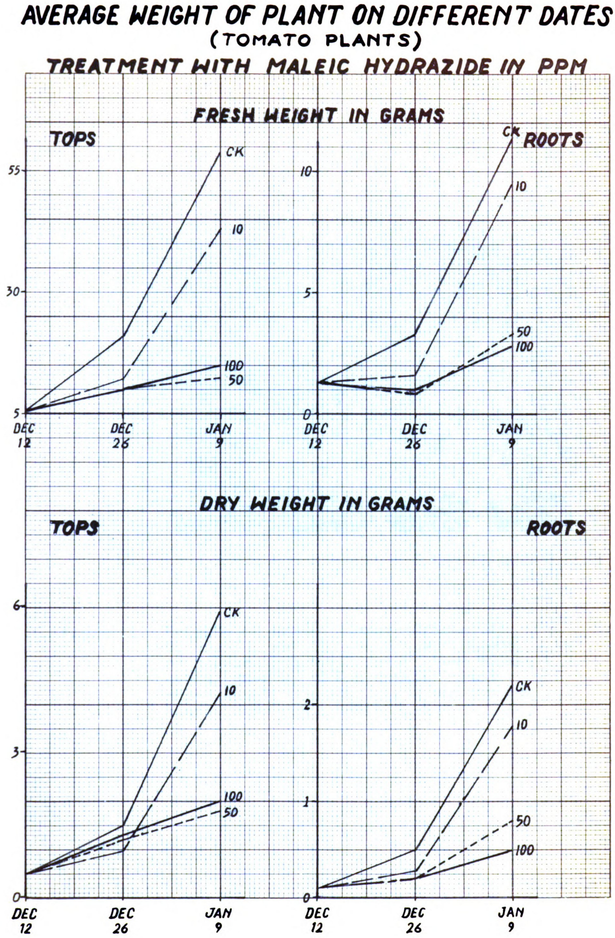

AVERAGE WEIGHT OF PLANT ON DIFFERENT DATES
(TOMATO PLANTS)
TREATMENT WITH MALEIC HYDRAZIDE IN PPM
FRESH WEIGHT IN GRAMS
TOPS
ROOTS
CK
10
100
50
55
30
5
10
5
0
DEC 12
DEC 26
JAN 9
DRY WEIGHT IN GRAMS
TOPS
ROOTS
6
3
0
2
1
0

Figure 1. Heights of tomato plants affected by 0, 10, 50, and 100 ppm concentrations of maleic hydrzide. Check plant shows normal growth, 10 ppm treated plant shows slight inhibition, 50 and 100 ppm plants show great inhibition.

Figure 2. Abnormal terminal growth produced by 10 ppm concentration of maleic hydrazide. Fully expanded leaves of abnormal growth are shorter than the normal.

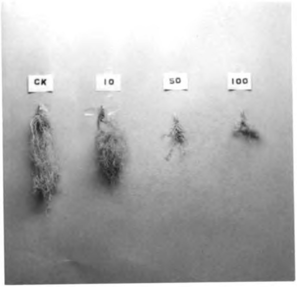


Figure 3. Root growth as affected by various concentrations of maleic hydrazide. Check shows more vigorous roots followed by 10, 50 and 100 ppm treatments.

<u>Mineral composition of plants</u>: The average percent, based on dry weight of ten mineral elements has been recorded, Table-III. Statistical comparisons of individual treatments for each of the mineral elements analyzed shows no significant differences between 10 ppm treated plants and checks except that percent potassium was significantly lower in 10 ppm treated plants. All ten elements were significantly less in 50 ppm treated plants than in 10 ppm treated plants with the exception of magnesium and zinc. No significant differences were found between 50 and 100 ppm treated plants, excepting for phosphorus, magnesium and zinc where a significant decrease was found in 100 ppm treated plants over 50 ppm treated plants.

<u>Mineral accumulation</u>: The average amount of accumulation for each of 10 mineral elements during the period of experiment have been recorded, Table-IV. Efficiency of mineral intake was calculated on the assumption that checks had 100 percent efficiency.

It was found that efficiency of 10 ppm treated plants ranged from 56.7 to [illegible]0.6 percent; for 50 ppm treated plants it ranged from 14.6 to 24.1 percent and for 100 ppm treated plants it ranged from 12.2 to 21.1 percent. Efficiency of mineral intake of tomato plants decreased with increase in concentration of maleic hydrazide applied.

Percent minerals for 10 ppm treated plants was higher

TABLE - III

AVERAGE PERCENT MINERALS PRESENT IN TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE.

MINERALS	* TREATMENTS				L.S.D. FOR TREATMENTS	
	Check	10 ppm	50 ppm	100 ppm	5%	1%
NITROGEN	3.67	3.59	3.12	3.11	.19	.28
PHOSPHORUS	.17	.16	.14	.13	.01	.02
POTASSIUM	5.30	4.89	3.81	3.84	.17	.25
CALCIUM	3.37	3.66	2.79	2.51	.36	.54
MAGNESIUM	.67	.67	.62	.55	.06	.08
IRON	.0309	.0302	.0200	.0201	.0039	.0058
BORON	.0029	.0027	.0023	.0020	.0003	.0004
MANGANESE	.0035	.0033	.0026	.0027	.0004	.0005
COPPER	.0029	.0025	.0020	.0019	.0005	.0007
ZINC	.0057	.0047	.0041	.0037	.0014	.0020

* All values are averages from 2 observations of 2 samples.

TABLE - IV

AVERAGE MINERAL ACCUMULATION BETWEEN DATES IN TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE.

MINERALS	*Average Accumulation				** Efficiency			
	Check	10	50	100	Check	10	50	100
NITROGEN (mg)	119.5	81.5	25.6	25.2	100	68.2	21.4	21.1
PHOSPHORUS (µg)	6077	3997	1220	993	100	65.7	20.1	16.3
POTASSIUM (mg)	161.1	113.8	30.1	28.2	100	70.6	18.5	17.5
CALCIUM (mg)	108.5	87.5	25.4	20.2	100	80.6	23.4	18.6
MAGNESIUM (µg)	2253	1528	541	455	100	67.8	24.1	20.2
IRON (µg)	934	661	136	130	100	70.8	14.6	13.9
BORON (µg)	95	65	19	15	100	68.4	20.0	15.8
MANGANESE (µg)	96	69	16	15	100	71.9	16.7	15.6
COPPER (µg)	90	51	17	11	100	56.7	18.9	12.2
ZINC (µg)	189	115	29	31	100	60.8	15.3	16.3

* All values are averages from 2 observations.

** Calculated on the basis that checks are 100% efficient.

at the end of four weeks than checks excepting for copper and zinc. Total accumulation for each of ten elements showed checks highest followed by 10, 50 and 100 ppm treated plants, Graphs-3, 4, 5, 6, and 7.

Gibberellin:

Average readings of growth measurements and weights of tops and roots for each treatment were recorded, Tables-V & VI.

Height: Statistical comparison of individual treatments showed that 250 and 500 treated plants were significantly taller than checks. No significant differences were found between 100 ppm treated plants and checks; 250 and 500 ppm treated plants nor between 100 and 250 ppm treated plants. Treated plants showed increase in height after first week of treatment, Graph-8.

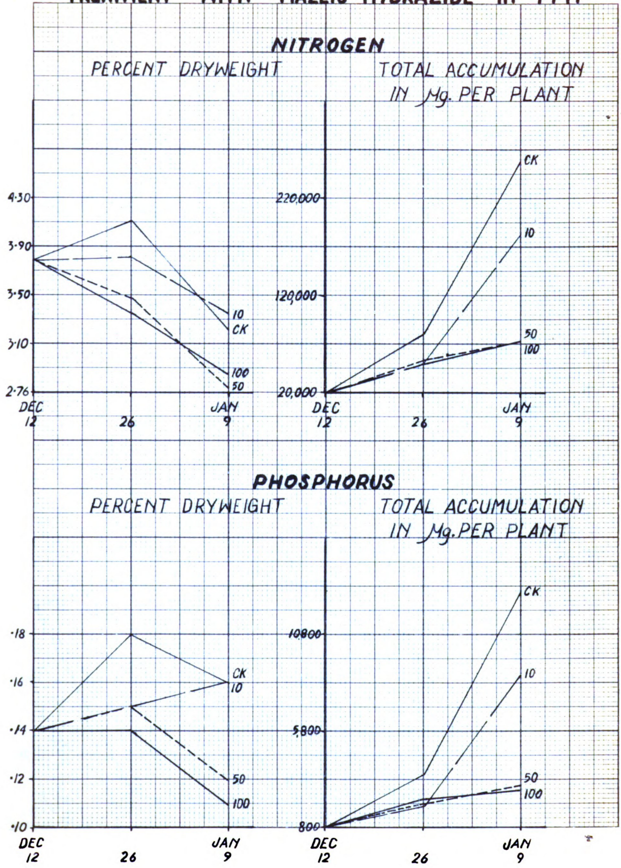
Stem Diameter: Statistical comparison of individual treatments showed that diameters of stems of 500 ppm treated plants were greater than checks. No significant differences were found between checks and 100 or 250 ppm treated plants. It could be clearly seen from last stages of growth of different treatments that an increase in diameter of stem was found with increase in concentration of gibberellin applied, Graph-8.

Number of leaves: Both 250 and 500 ppm treated plants had significant increase in number of leaves as compared to check. No significant differences were found between checks

GRAPH - 3

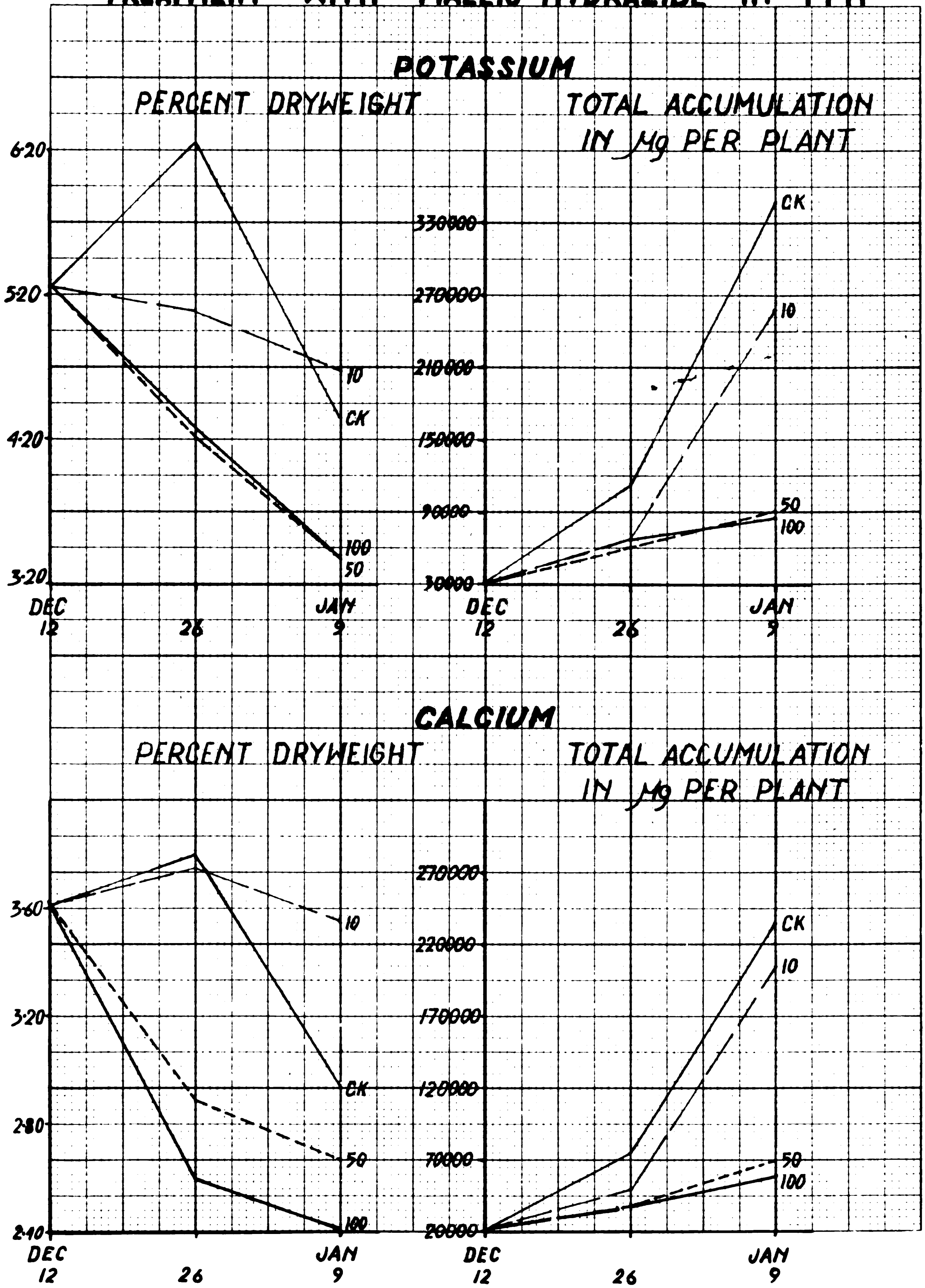
PLANT ANALYSIS AT DIFFERENT DATES
(TOMATO PLANTS)

TREATMENT WITH MALEIC HYDRAZIDE IN PPM



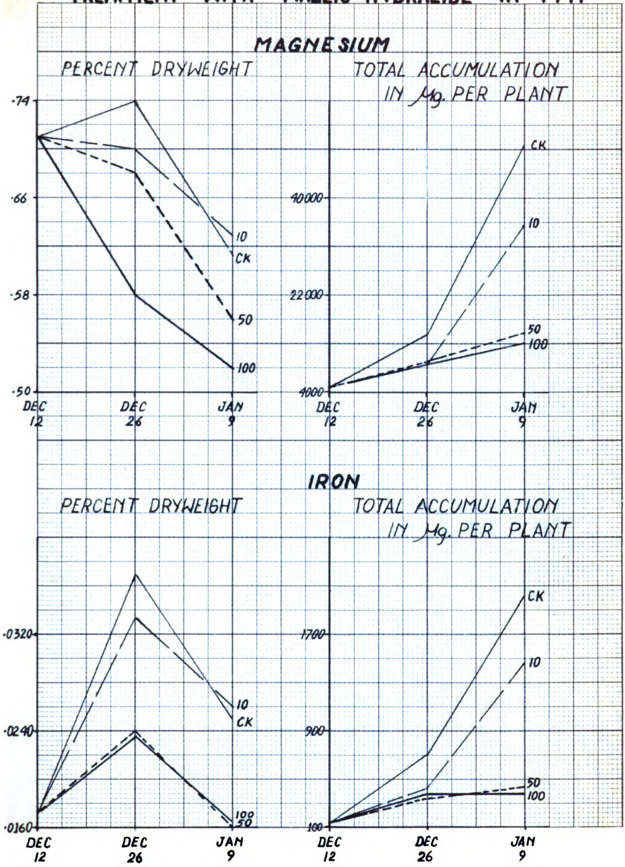
GRAPH - 4

PLANT ANALYSIS AT DIFFERENT DATES
(TOMATO PLANTS)
TREATMENT WITH MALEIC HYDRAZIDE IN PPM



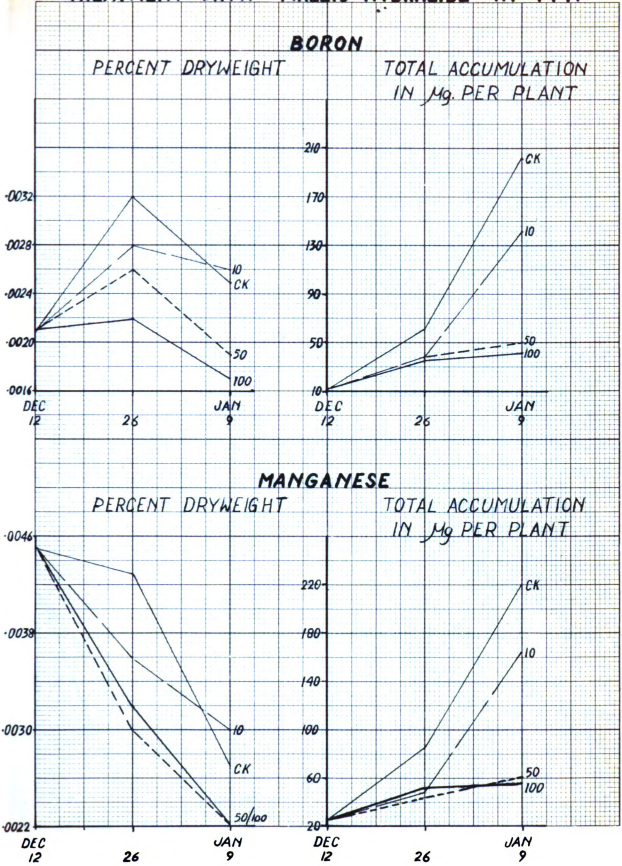
GRAPH - 5

PLANT ANALYSIS AT DIFFERENT DATES
(TOMATO PLANTS)
TREATMENT WITH MALEIC HYDRAZIDE IN PPM



GRAPH - 6

PLANT ANALYSIS AT DIFFERENT DATES
(TOMATO PLANTS)
TREATMENT WITH MALEIC HYDRAZIDE IN PPM



GRAPH - 7

PLANT ANALYSIS AT DIFFERENT DATES
(TOMATO PLANTS)
TREATMENT WITH MALEIC HYDRAZIDE IN PPM

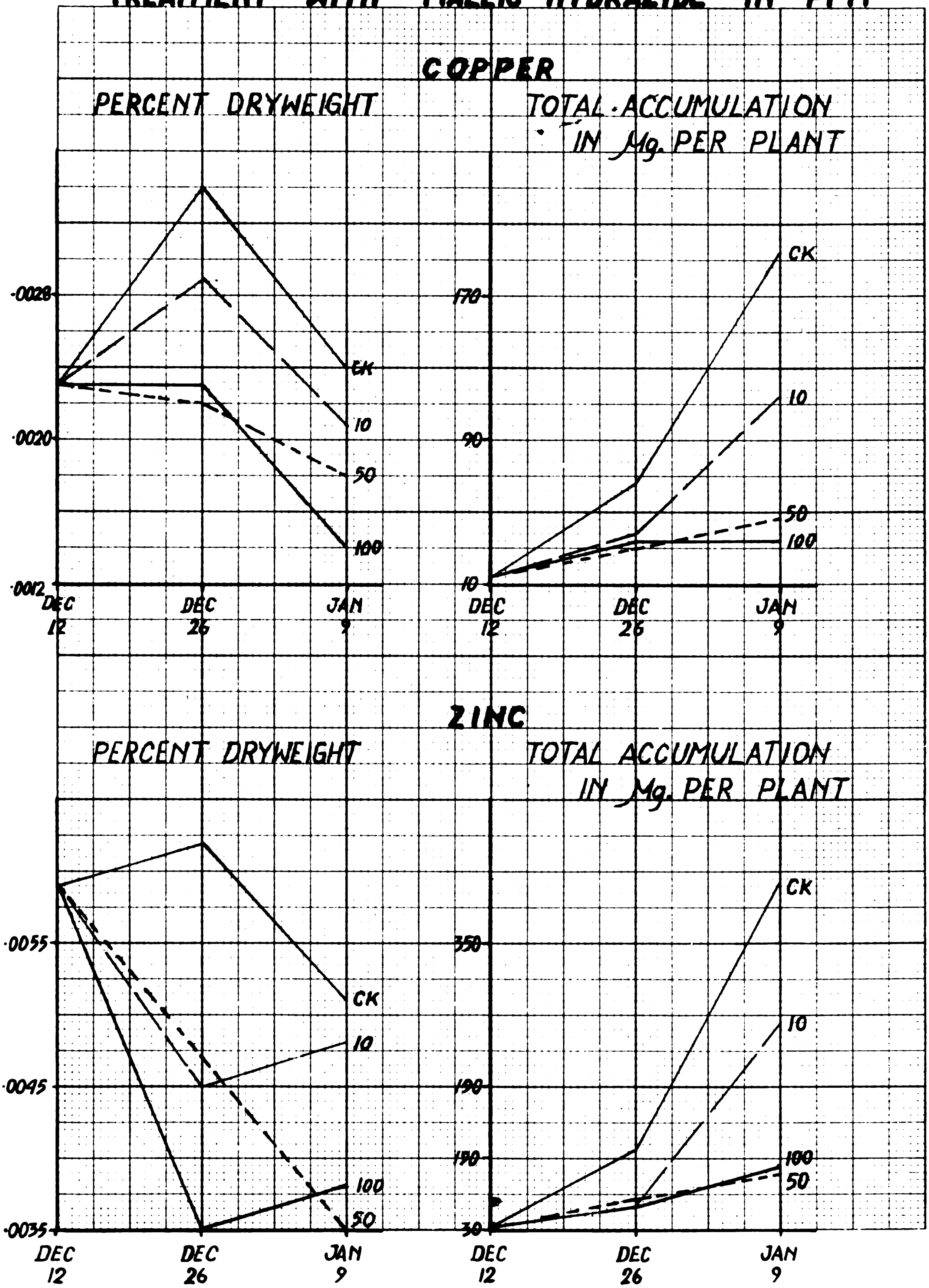


TABLE - V

AVERAGE GROWTH MEASUREMENTS OF TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF GIBBERELLIN.

MEASUREMENTS.	TREATMENTS				L.S.D. FOR TREATMENTS	
	Check	100 ppm	250 ppm	500 ppm	5%	1%
a. HEIGHT ** (in cm.)	62.1	65.2	68.6	72.3	4.9	6.6
b. STEM ** DIAMETER (in mm.)	6.14	6.06	6.42	6.76	0.43	0.58
c. NUMBER ** OF LEAVES	22.0	23.8	25.8	26.7	2.6.	3.6
d. SIZE OF** THE LARGEST LEAF (in cm.)	32.5	32.4	33.3	33.5	N.S.	N.S.
e. NUMBER * OF LATERALS	2.55	3.17	3.30	3.86	0.87	N.S.
f. NUMBER * OF FLOWERS	20.7	21.7	24.1	23.7	N.S.	N.S.
g. NUMBER *** OF FRUITS	4.61	2.25	2.70	2.45	0.93	1.26

* All values are averages from 5 observations of 8 replicates.

**All values are averages from 7 observations of 8 replicates.

***All values are averages from 8 observations of 8 replicates.

TABLE - VI

AVERAGE FRESH AND DRY WEIGHT OF TOPS AND ROOTS OF TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF GIBBERELLIN.

MEASURE-MENTS (gms)	* TREATMENTS				L.S.D. FOR TREATMENTS	
	Check	100 ppm	250 ppm	500 ppm	5%	1%
FRESH TOPS	93.93	96.76	109.52	105.65	5.23	9.94
FRESH ROOTS	28.39	29.66	29.75	26.77	N.S.	N.S.
DRY TOPS	9.23	9.15	10.32	9.80	N.S.	N.S.
DRY ROOTS	2.24	2.86	2.67	2.57	0.33	0.45

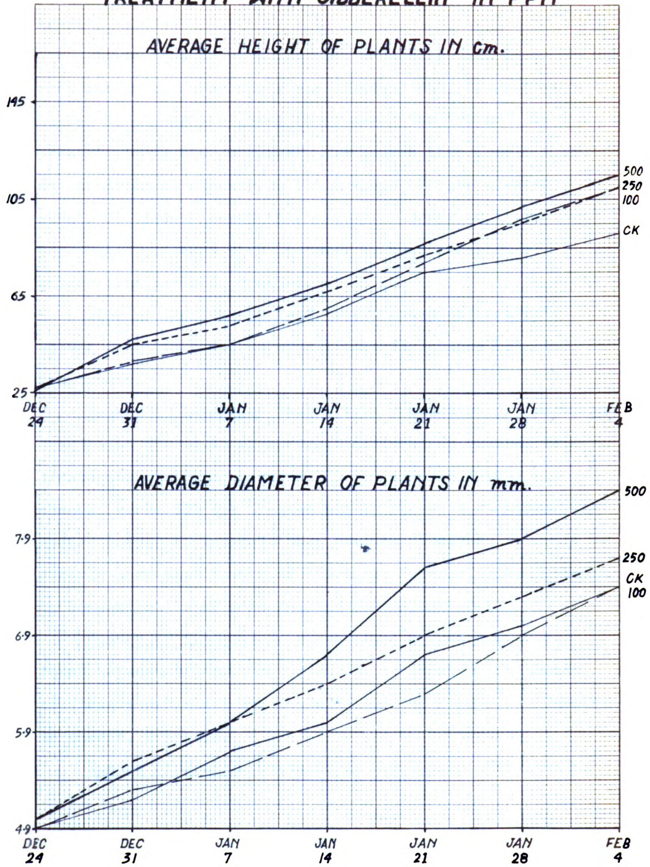
* All values are averages from 3 observations of 3 replicates.

GRAPH - 8

GROWTH MEASUREMENTS

(TOMATO PLANTS)

TREATMENT WITH GIBBERELLIN IN PPM



and 100 ppm treated plants and also between 250 and 500 ppm treated plants.

Plants treated with 100 ppm gibberellin had fewer leaves than checks in first two weeks of treatment; thereafter number of leaves per plant increased. The 250 and 500 ppm treated plants always showed more leaves than checks with an exception of January 9, 1958, where 500 ppm treated plants had fewer leaves than checks. Number of leaves per plant increased with increase in concentration of gibberellin applied, Graph-9.

<u>Size of the largest leaf</u>: The statistical analysis showed that there was no significant difference between treatments.

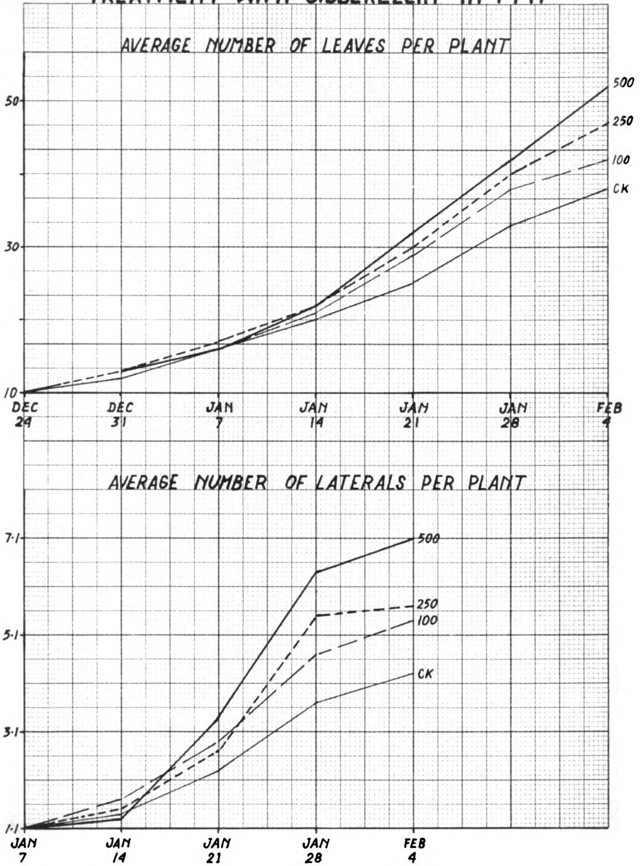
<u>Number of laterals</u>: Statistical comparison of individual treatments showed no significant differences existed between treatments excepting between 500 ppm treated plants and checks, where 500 ppm treated plants showed a significantly higher number of laterals than checks. However, it could be clearly seen that number of laterals increased with increase in concentration of gibberellin applied, Graph-9.

<u>Number of flowers</u>: No statistical differences were found between treatments. However, an increase in number of flowers per plant was found in treated plants as compared to checks, Graph-10.

<u>Number of fruits</u>: Statistical comparison of individual

GRAPH - 9

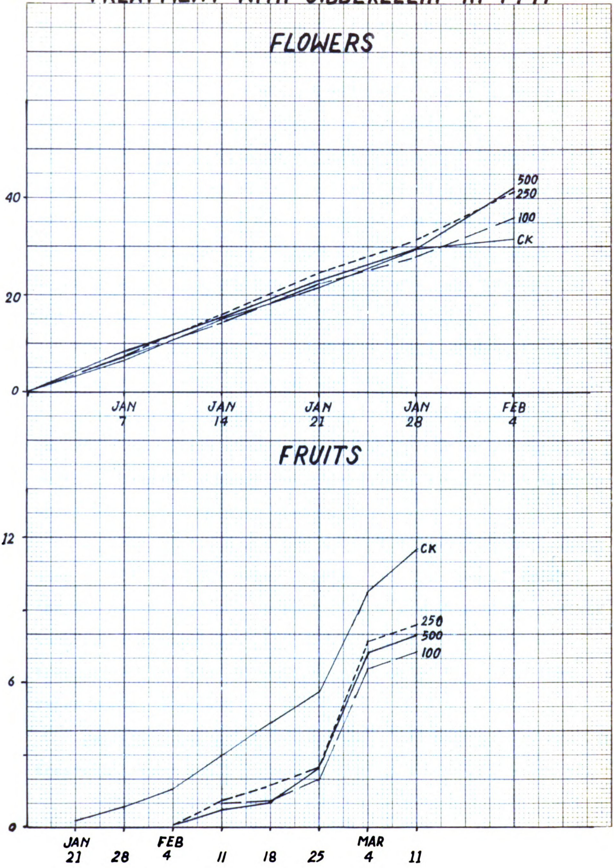
GROWTH MEASUREMENTS
(TOMATO PLANTS)
TREATMENT WITH GIBBERELLIN IN PPM



GRAPH - 10

AVERAGE NUMBER OF FLOWERS AND FRUITS
(TOMATO PLANTS)

TREATMENT WITH GIBBERELLIN IN PPM



treatments for number of fruits per plant showed that treated plants had significantly fewer fruits per plant than checks. No significant differences were found between treated plants. The checks showed early fruiting and more fruits per plant than treated plants, Graph-10.

Fresh and dry weights of tops and roots: A significant increase in fresh weight of tops was found in both 250 and 500 ppm treated plants as compared to checks and 100 ppm treated plants. No significant differences were found between checks and 100 ppm treated plants, and between 250 and 500 ppm treated plants.

No significant differences were found between treatments in weights of fresh roots and dry tops.

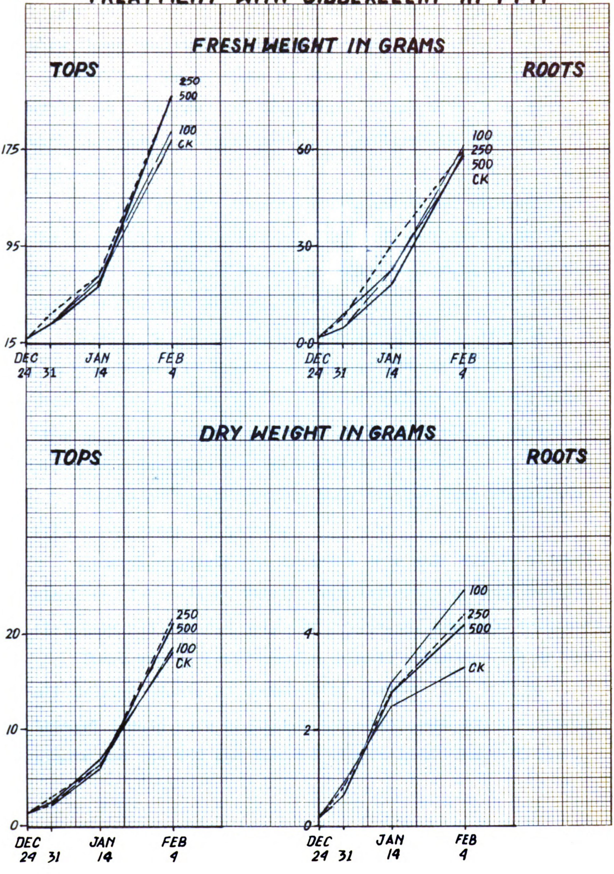
Statistical comparison of individual treatments for weight of dry roots showed significantly higher weights of roots in treated plants than checks. No significant differences were found between treated plants.

Weights of fresh and dry tops of 250 ppm treated plants were higher than all other treatments. In case of fresh and dry roots, 100 ppm treated plants showed a higher weight than other treatments. Differences in weights between treatments were more pronounced in case of dry roots than fresh roots, Graph-11.

General observation: After the first week of gibberellin treatment, very small dots appeared in the basal leaves of

AVERAGE WEIGHT OF PLANT ON DIFFERENT DATES
(TOMATO PLANTS)

TREATMENT WITH GIBBERELLIN IN PPM



all treated plants. By the third week these dots became bigger and white in color, Figure-4. The checks did not show these characteristic white patches.

Differences in sizes of plants could be clearly seen after the first week of treatment. Plant size increased with increase in concentration of gibberellin applied, Figure-5.

The gibberellin treated plants exhibited chlorosis on the lower 10 to 12 leaves of plants after three weeks of treatment. Chlorosis became progressively more intense with increase of time interval, Figure-6.

Fruits set in checks were earlier than in treated plants. Number of fruits set was greater in checks than in treated plants. The fruits ripened earlier in checks than treated plants. Ripened fruits in treated plants showed a peculiar russetting and malformation, Figure-7.

Fruits of treated plants were smaller than checks but with fewer seeds, Figure-8.

Mineral composition: Analysis were made for 10 mineral elements, Table-VII. Significant differences, as a result of treatments occured only for potassium, iron and manganese.

There was a significantly greater potassium content in all treated plants as compared to checks. The 100 ppm treated plants were significantly lower than 250 ppm treated plants and the 250 ppm treated plants lower than 500 ppm

Figure 4. Leaves of check and gibberellin treated plants. The treated plants show lighter green color of leaf with white patches.

Figure 5. Heights of check, 100, 250, and 500 ppm treated plants. Increase in height with increased concentrations of gibberellin applied could be clearly seen.

Figure 6. Chlorosis in the lower leaves of gibberellin treated plants. Check plant shows normal green color of leaves.

Figure 7. Russetted and malformed fruits developed by gibberellin treatments. Fruits on check plants did not show any of these symptoms.

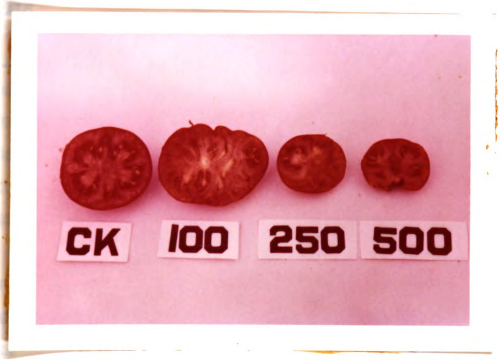


Figure 8. Fewer seeds appeared in the fruits produced by gibberellin treated plants whereas check had more seeds in fruits.

TABLE - VII

AVERAGE PERCENT MINERALS PRESENT IN TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF GIBBERELLIN.

MINERALS	* TREATMENTS				L.S.D. FOR TREATMENTS	
	Check	100 ppm	250 ppm	500 ppm	5%	1%
NITROGEN	3.47	3.45	3.46	3.49	N.S.	N.S.
PHOSPHORUS	0.17	0.16	0.16	0.16	N.S.	N.S.
POTASSIUM	5.07	5.31	5.44	5.67	0.06	0.09
CALCIUM	2.99	2.99	2.92	2.89	N.S.	N.S.
MAGNESIUM	0.65	0.66	0.65	0.64	N.S.	N.S.
IRON	0.0375	0.0271	0.0326	0.0302	0.0023	0.0031
BORON	0.0031	0.0029	0.0033	0.0028	N.S.	N.S.
MANGANESE	0.0038	0.0033	0.0034	0.0032	0.0002	0.0003
COPPER	0.0025	0.0026	0.0029	0.0025	N.S.	N.S.
ZINC	0.0059	0.0056	0.0063	0,0067	N.S.	N.S.

* All values are averages from 3 observations of 3 replicates.

treated plants.

From statistical comparison of individual treatments for average percent iron, a significant decrease in iron resulted from treatment. The 100 ppm treated plants showed a significantly lower percent iron than 500 ppm treated plants. The 500 ppm treated plants showed a significantly lower percent iron than 250 ppm treated plants.

Statistical comparison of individual treatments for percent manganese showed a significant decrease in all the treated plants as compared to checks. No significant differences were found between 100 ppm and 250 ppm treated plants nor between 100 and 500 ppm treated plants. However, a significant increase was found in 250 ppm treated plants over 500 ppm treated plants.

Mineral accumulation: The average accumulation for each of 10 mineral elements during the period of experiment have been recorded, Table-VIII.

Significant differences as a result of treatment were found for 5 elements but not for potassium, iron, boron, manganese, and copper.

From the statistical comparison of individual treatments for the amount of potassium accumulated by plants, a significantly higher amount was found in all treated plants as compared to checks, excepting for 100 ppm treated plants where no significant difference existed. No significant

TABLE - VIII

AVERAGE MINERAL ACCUMULATION BETWEEN DATES IN TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF GIBBERELLIN.

MINERALS	* TREATMENTS				L.S.D. FOR TREATMENTS	
	Check	100 ppm	250 ppm	500 ppm	5%	1%
NITROGEN (mg.)	197	218	237	224	N.S.	N.S.
PHOSPHORUS (mg.)	10	11	12	11	N.S.	N.S.
POTASSIUM (mg.)	297	341	399	376	45.1	61.5
CALCIUM (mg.)	213	218	236	195	N.S.	N.S.
MAGNESIUM (mg.)	45	50	50	51	N.S.	N.S.
IRON (mg.)	2.6	1.3	2.1	2.1	0.4	0.6
BORON (µg.)	272	247	300	238	36.8	50.2
MANGANESE (µg.)	234	195	247	249	37.3	50.8
COPPER (µg.)	199	207	291	179	62.1	84.6
ZINC (µg.)	361	296	427	408	N.S.	N.S.

* All values are averages from 3 observations of 3 replicates.

differences were found between 100 and 500 ppm treated plants nor between 250 and 500 ppm treated plants.

Statistical comparison of individual treatments for iron accumulation showed that all treated plants had significantly lower amounts of iron than checks. No significant differences were found between 250 and 500 ppm treated plants. A significant increase in the amount of iron was found in both 250 and 500 ppm treated plants over 100 ppm treated plants.

No significant differences in boron accumulation were found between treatments excepting for 250 ppm treated plants which showed a significantly higher amount of boron than both 100 and 500 ppm treated plants.

Statistical comparison of individual treatments for manganese accumulation showed no significant differences between treatments excepting for 100 ppm treated plants which showed a significantly lesser amount.

No significant differences in accumulation of copper were found between treatments excepting for 250 ppm treated plants which showed a significantly larger amount of copper than all the other treatments.

Analysis of December 31, 1957, for percent nitrogen showed that 250 and 100 ppm treated plants accumulated less nitrogen than checks and 500 ppm treated plants. The analysis of January 14, 1958, showed that all treated plants had accumulated more nitrogen than checks, and the final analysis of February 4, 1958, showed that all treated plants had lower accumulation of nitrogen than checks. Significant differences were also found between treatments on the analysis of January 14, and February 4, 1958. Total accumulation of nitrogen was greater for 250 ppm treated plants followed by 500, 100 and checks, Graph-12.

Percent phosphorus accumulated was always less in treated plants than in checks. No significant differences were found for percent phosphorus between treatments, at any date. Total accumulation of phosphorus showed similar trend to that of nitrogen, Graph-12.

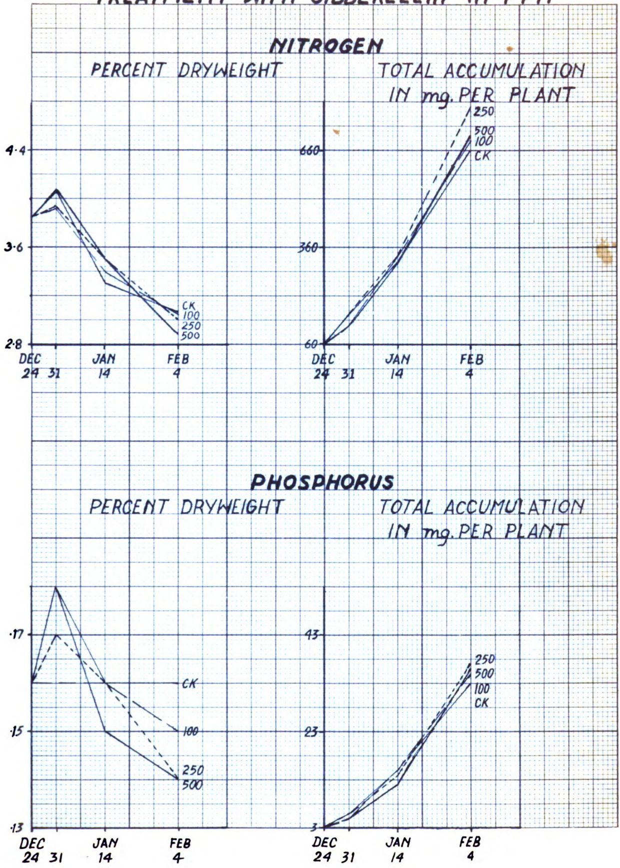
Analysis for percent potassium showed 500 ppm treated plants had higher values followed by 250, 100 and checks, excepting for the analysis of February 4, 1958, where 250 ppm was higher. Significant differences between treatments were also found in analysis of each date. Total potassium showed a greater accumulation in 250 ppm treated plants followed by 500, 100 and checks, Graph-13.

Percent calcium showed significant differences between treatments for the analysis of January 14, and February 4, 1958. The analysis of January 14, showed 500 ppm treated plants had a higher level than 250, 100 and checks, whereas the analysis of February 4, 1958, was reversed. Total accumulation showed small differences between treatments,

GRAPH - 12

PLANT ANALYSIS AT DIFFERENT DATES (TOMATO PLANTS)

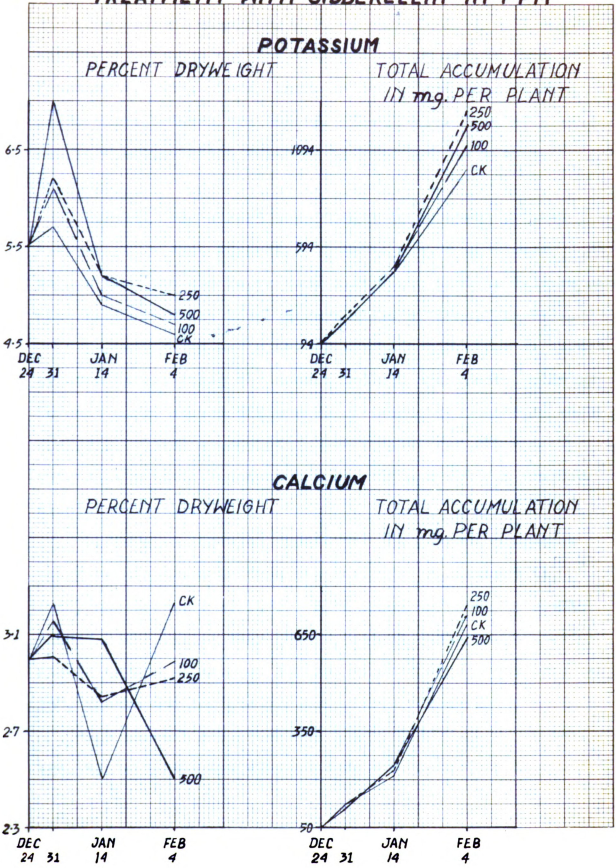
TREATMENT WITH GIBBERELLIN IN PPM



GRAPH - 13

PLANT ANALYSIS AT DIFFERENT DATES (TOMATO PLANTS)

TREATMENT WITH GIBBERELLIN IN PPM



Graph-13.

The percent magnesium was not significantly different between treatments for the analysis of January 14, and February 4, 1958. Total accumulation showed only slight differences between treatments. The 500 ppm treated plants had more accumulation followed by 250, 100 and checks, Graph-14.

Percent iron showed significant differences between treatments in each analysis. Treated plants had lower values than the checks in each analysis. Similar differences also existed in the total accumulation of iron, Graph-14.

Percent boron exhibited different pattern for different treatments excepting for checks and 250 ppm treated plants. Percent boron showed differences between treatments in each analysis. Total accumulation was greater for 250 ppm treated plants followed by checks, 100 and 500 ppm treated plants, Graph-15.

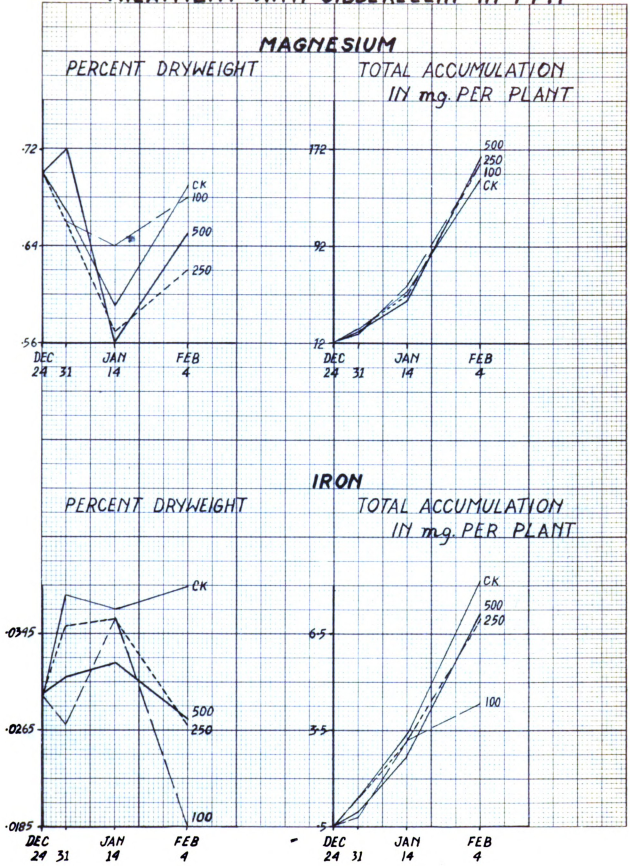
Differences between treatments for percent manganese could be clearly seen from the analysis of December 31, 1957, and February 4, 1958. Both times the treated plants showed lower values than checks, whereas total accumulation showed higher values for 500 ppm treated plants followed by 250, checks and 100 ppm treated plants, Graph-15.

The percent copper showed slight differences between treatments in the analyses of December 31, 1957, and

GRAPH - 14

PLANT ANALYSIS AT DIFFERENT DATES
(TOMATO PLANTS)

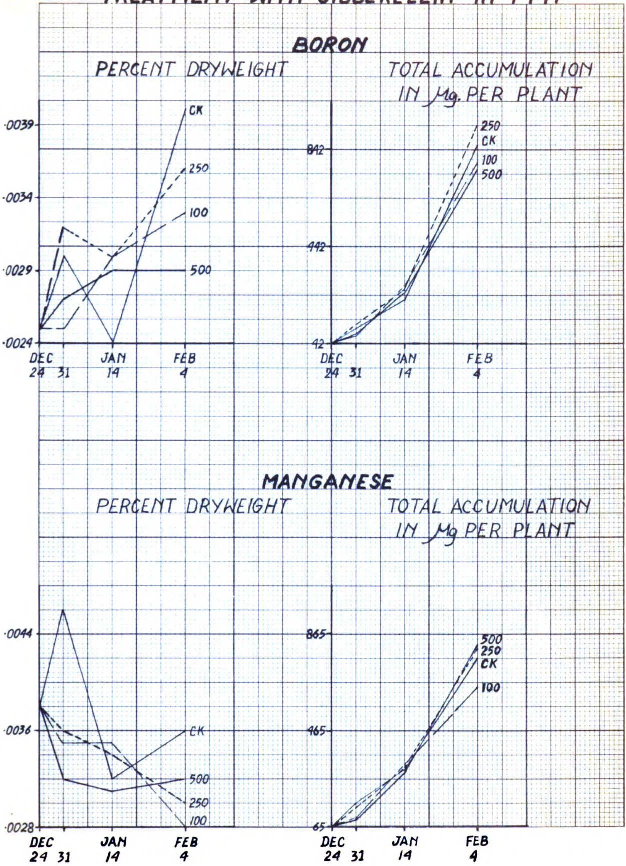
TREATMENT WITH GIBBERELLIN IN PPM



GRAPH - 15

PLANT ANALYSIS AT DIFFERENT DATES (TOMATO PLANTS)

TREATMENT WITH GIBBERELLIN IN PPM

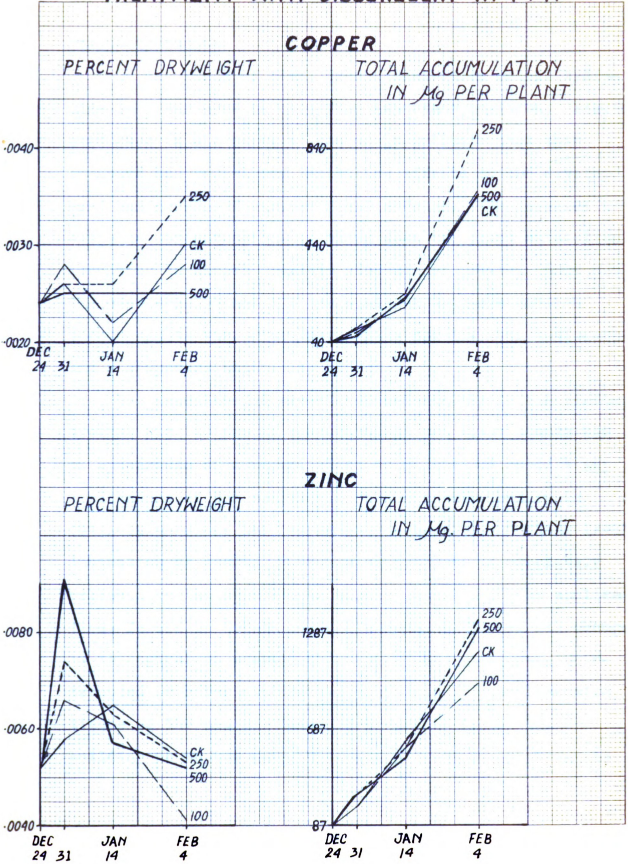


January 14, 1958, which were not statistically significant. Only analysis of February 4, 1958, showed significant differences between treatments. The 250 ppm treated plants showed higher percent copper followed by checks, 100 and 500 ppm treated plants. There was significantly greater accumulation only in 250 ppm treated plants, Graph-16.

Differences between treatments for percent zinc content of plants were maximum for December 31, 1957, and these were significant, while all other's were not. Differences in accumulation of zinc between various dates did not show any significant variations. The 250 ppm treated plants showed more accumulation of zinc followed by 500, checks and 100 ppm treated plants, Graph-16.

GRAPH - 16

PLANT ANALYSIS AT DIFFERENT DATES
(TOMATO PLANTS)
TREATMENT WITH GIBBERELLIN IN PPM



GENERAL DISCUSSION

Maleic hydrazide:

In the field of plant growth inhibition maleic hydrazide (MH) has come to occupy an important position. Studies conducted in all parts of the world indicate that this compound has transitory inhibiting effects on bud development and growth of various plant species. When applied in suitable concentrations it slows down the plant metabolism resulting in almost complete stoppage of growth. Such was the case when 50 and 100 ppm applications were made on tomato plants var. John Baer, while the low rate application had a temporary inhibiting effect.

The cessation of growth resumed shortly in the plants treated with 10 ppm MH concentration and these plants had an appearance of a normal plant which did not receive any application of the compound. Such a growth pattern is entirely possible for, according to Leopold and Klein (1952), inhibition of growth by low concentrations is completely relieved by the addition of auxin. Since low rate applications failed to induce any outstanding morphological changes it is logical to assume auxin production continued, uninterupted or after a brief interuption in the meristematic tissue of the plant. These auxin levels which keep on building up in the plant system finally makes it possible for the low rate-treated plant to recommence their growth.

According to Callaghan and Van Norman (1956) there is an increase in the photosynthetic rate at low rate MH application in swiss chard and tobacco seedlings accompanied by little or no change in dry matter. This type of induced physiological modification may as well, in some way, be responsible for the early renewal of growth in the plants with 10 ppm concentration.

Such an explanation for the resumption of growth in low rate treated tomato plants appears logical when mineral uptake is considered to be a factor in the development of plants. The data indicated, Table-III and Graphs-3 to 7, that mineral content of the dry tissue was significantly different for low rate MH treated plants as compared to the plants which received 50 and 100 ppm applications. It is interesting to point out that mineral uptake in the low rate treated plants was approximately similar to the check plants during the last date when the final analysis were made for the mineral content of the plant tissues. However, it may be brought out that these nonexisting differences were nevertheless present after MH treatments during early sampling dates.

Therefore, it is safe to state that low rate MH applications do not bring about any changes in the physiological developments of the plants to any significant level which may tend to shift the natural metabolic balances.

According to the data shown in Graph-2, it is evident that root development was inhibited by all concentrations of MH two weeks after treatments. The degree of growth inhibition was significantly different for low rate application of 10 ppm as compared to 50 and 100 ppm treatments after four weeks from the application date. Roots being more sensitive than the shoots, therefore, there was a wide range of differences in the growth pattern of roots and shoots. These findings are in conformity with the views of Compton (1952).

High rate applications of the compound, 50 and 100 ppm, on the other hand, affected the growth processes of the plants to a point of severe growth inhibition. This fact is borne out from the data; Height, stem diameter, number of leaves and size of the largest leaf of the plants; Table-I, Fig. 1 and Graph-1. The growth suppression, as noticed in these treatments, may be due to respiration inhibition in the plant tissue resulting from the high rate MH applications. Such a possibility has been mentioned by Naylor and Davis (1951) and Greulach (1954), who observed from their experiments on a wide variety of vegetation that the respiratory changes exert influence on the normal function of dehydrogenase. However, it is not possible to say how this induced malfunctioning in the developmental physiology of the plant affect the growth manifesting mechanisms.

Gibberellin:

In recent years there has been a great interest among horticulturists, agronomists and plant physiologists on the stimulation of growth resulting from the gibberellin applications. Accordingly, experiments were arranged to find some information on the mineral content of tomato plants as affected by this compound.

The data indicated, Table-V, that growth of plants increased with an increase in the concentration of gibberellin. Such an increase in plant growth have also been reported by various research workers. Kato (1956) pointed out that water uptake is increased by gibberellin treatment, a fact which is substantiated by the results of this experiment, Table-VI.

Fresh weights of the treated plants, tops only, were significantly different than the check plants. However, no significant differences in their dry weights were observed. Such an increase in growth on account of gibberellin treatments has also been reported by Kurosawa (1932) in rice seedlings, who suggested potassium as an essential element in it's elongation. Results of these investigations reported herein, also showed that percent and total accumulation of potassium was increased by gibberellin treatments.

Similar increase in potassium has also been found by Brian et al (1954) in both wheat and peas. It is suggested that the increased growth in gibberellin-treated plants may possibly be due to a greater uptake of potassium and water.

Periodic observations indicated a decreased number of fruits on gibberellin-treated plants, Table-V, with a peculiar russetting and malformation on the ripe fruits as has been reported by Wittwer and Bukovac (1957) in tomato fruits. It is suggested that deficiency of iron and/or manganese, Table-VII, caused by gibberellin treatments may be responsible for less fruit set and also for russetting and malformation of ripe tomato fruits.

However, when the total dry weight was considered gibberellin-treated plants exhibited an increase over the check plants. These results are in conformity with the findings of Brian et al (1954). Therefore, it is logical to assume that this increased dry weight of the gibberellin-treated plants may be due to higher accumulation of various minerals, Table-VIII and Graphs-12 to 16.

Visual observations indicated chlorosis and white patches of the leaves of the gibberellin-treated plants. However, Kato (1954) reported that he could not find this chlorotic condition on the case of plants grown in nutrient solution containing gibberellin. Although opposing views have been expressed by Morgan and Mees (1956) and various other research workers who described this chlorotic condition of the gibberellin-treated plants due to nitrogen deficiency.

Under the conditions of this experiment no significant differences between treatments, either in the percent or the total accumulation of nitrogen, were found. On the other hand, significant decrease in both percent iron and manganese were found as a result of gibberellin treatments, Table-VII. Therefore it is quite probable that lack of iron and/or manganese may be involved in the appearance of chlorosis and white patches on leaves of gibberellin-treated plants.

SUMMARY

The experiments were arranged to determine the response of tomato plants var. John Baer to different levels of maleic hydrazide, 10, 50 and 100 ppm, and potassium gibberellate, 100, 250 and 500 ppm, as foliar applications. The seedlings were grown in a quartz sand under greenhouse conditions (av. temperature 60 degrees F and av. day length 10:42 hours) and Hoagland and Arnon (1950) solution was used as a source of nutrient supply. Periodic observations were made for height, stem diameter, number of leaves, size of the largest leaf, and fresh and dry weights of tops and roots of tomato plants, while additional data was recorded for number of laterals, number of flowers and number of fruits in case of gibberellin treatments. Mineral content of the plant tissue was determined for N, P, K, Ca, Mg, Fe, B, Mn, Cu and Zn. The following results were obtained:

Maleic hydrazide:

1. The first and the most clearly noticeable effect of the MH treatments was the persistant and continued inhibition of growth in plants receiving 50 and 100 ppm foliar applications. While plants sprayed with 10 ppm MH concentration exhibited only temporary growth inhibition.

2. Visual observations indicated that leaves of the plants

treated with 50 and 100 ppm to be darker green in color, thicker and more brittle as compared to the leaves of check plants. No such textural differences were observed in the leaves of plants receiving 10 ppm applications.

3. Following the temporary inhibition of growth, the plants treated with 10 ppm indicated some abnormality in the morphological character, shape and branching, in comparison with the check plants which had less leaves.

4. There was no signs of flower initiation in plants treated with 50 and 100 ppm concentrations.

5. Plants receiving high rate of treatments, 50 and 100 ppm, produced growth of low fresh and dry weights.

6. Root growth was much reduced in the treated plants as compared to top growth which indicated roots to be very sensitive to the treatments.

7. Plant tissue analyses indicated that mineral content, percent composition and total accumulation, of all the elements in general, decreased on account of the treatments.

<u>Gibberellin</u>:

1. Growth of the plants was increased on account of the gibberellin treatments in all the cases. However, the rate

of growth in the plants receiving high rate of application of 250 and 500 ppm was much higher as compared to the plants receiving the 100 ppm only. This increased growth of the gibberellin treated plants was perhaps due to a greater accumulation of potassium and water as compared to check plants.

2. Total dry weight of gibberellin treated plants was also increased reflecting certain induced metabolic changes by higher total accumulation of certain minerals.

3. Visual observations indicated that leaves of gibberellin treated plants showed chlorosis and white patches. Such an appearance of the plants was perhaps due to low iron and/or manganese content of these plants.

4. There were no significant differences between the various treatments so far as the size of the largest leaf and number of flowers was concerned.

5. Treated plants exhibited delayed fruiting and less fruit set. The ripe fruits showed russetting and abnormal growth as a result of the gibberellin treatments.

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A P P E N D I X

TABLE - I a.

* Average height (cms) of tomato plants, as affected by various concentrations of maleic hydrazide.

Dates	Treatments			
	Check	10 ppm	50 ppm	100 ppm
Dec. 12, 1957	18.5	18.0	18.0	18.5
" 19, "	24.5	23.0	19.0	19.0
" 26, "	33.0	31.0	19.5	19.0
Jan. 2, 1958	43.0	37.5	20.0	19.5
" 9, "	48.0	43.0	20.5	20.0

* All values are averages from two replicates of 4 plants.

TABLE - I b.

* Average stem diameter (mm) of tomato plants, as affected by various concentrations of maleic hydrazide.

Dates	Treatments			
	Check	10 ppm	50 ppm	100 ppm
Dec. 12, 1957	4.20	4.15	4.15	4.15
" 19, "	4.65	4.30	4.25	4.25
" 26, "	5.35	4.45	4.35	4.35
Jan. 2, 1958	5.80	4.85	4.45	4.35
" 9, "	6.35	5.35	4.55	4.45

* All values are averages from two replicates of 4 plants.

TABLE - I c.

* Average number of leaves of tomato plants, as affected by various concentrations of maleic hydrazide.

Dates	Treatments			
	Check	10 ppm	50 ppm	100 ppm
Dec. 12, 1957	6.5	7.0	7.0	6.5
" 19, "	8.5	7.0	6.5	6.5
" 26, "	9.5	9.0	6.5	7.0
Jan. 2, 1958	12.5	14.5	6.5	7.0
" 9, "	15.5	18.5	7.0	7.0

* All values are averages from two replicates of 4 plants.

TABLE - I d.

* Average size (cms) of the largest leaf of tomato plants as affected by various concentrations of maleic hydrazide.

Dates	Treatments			
	Check	10 ppm	50 ppm	100 ppm
Dec. 12, 1957	13.0	13.5	13.0	13.0
" 19, "	18.0	16.5	15.0	14.5
" 26, "	22.5	20.5	15.5	16.0
Jan. 2, 1958	26.0	22.5	16.0	16.5
" 9, "	28.0	25.5	16.5	17.0

* All values are averages from two replicates of 4 plants.

TABLE - II

* Average fresh and dry weights (in gms) of tops and roots of tomato plants as affected by various concentrations of maleic hydrazide.

Dates	Treatments	Fresh weights		Dry weights	
		Tops	Roots	Tops	Roots
Dec. 12, 1957.	Check	5.4	1.3	0.5	0.1
Dec. 26, 1957.	Check	20.8	3.3	1.5	0.5
	10 ppm	11.8	1.6	1.0	0.3
	50 "	9.9	0.8	1.2	0.2
	100 "	9.7	1.2	1.4	0.2
Jan. 9, 1958.	Check	58.7	11.5	5.9	2.2
	10 ppm	42.6	9.6	4.2	1.9
	50 "	12.5	3.4	1.9	0.8
	100 "	14.9	2.8	2.0	0.5

* All values are averages from two replicates.

TABLE - III.

Mineral composition, based on percent dry weight of tomato plants, as affected by maleic hydrazide.

Date of picking & Treat-ments	* Percent Minerals/Dry weights									
	N	P	K	Ca	Mg	Fe	B	Mn	Cu	Zn
Dec.12, 1957										
Check	3.80	.14	5.25	3.61	.71	.0271	.0021	.0045	.0023	.0059
Dec.26, 1957										
Check	4.12	.18	6.25	3.80	.74	.0367	.0032	.0043	.0034	.0062
10 ppm	3.82	.15	5.08	3.75	.70	.0335	.0028	.0036	.0029	.0045
50 "	3.48	.15	4.22	2.89	.68	.0239	.0026	.0030	.0022	.0047
100 "	3.36	.14	4.27	2.60	.58	.0238	.0022	.0032	.0023	.0035
Jan. 9, 1958										
Check	3.22	.16	4.35	2.94	.61	.0250	.0025	.0027	.0024	.0051
10 ppm	3.36	.16	4.69	3.56	.63	.0269	.0026	.0030	.0021	.0048
50 "	2.75	.12	3.40	2.69	.56	.0161	.0019	.0022	.0018	.0035
100 "	2.85	.11	3.41	2.41	.52	.0164	.0017	.0022	.0014	.0038

* All values are averages from two samples.

TABLE - IV.

Accumulation of various minerals, between certain dates, as affected by various concentrations of MH.

Between dates	Treatments	Amount of minerals accumulated									
		N	P	K	Ca	Mg	Fe	B	Mn	Cu	Zn
		mg	µg	mg	mg	µg	µg	µg	µg	µg	µg
Dec.12 to Dec.26 1957	Check	58.5	2705	91.7	53.1	1035	560	50	58	53	87
	10 ppm	28.8	1182	37.1	28.9	519	288	25	22	25	26
	50 "	27.7	1332	29.9	20.4	561	185	25	17	18	33
	100 "	31.5	1417	37.6	20.5	512	222	23	25	22	21
Dec.26 1957 to Jan. 9 1958	Check	180.5	9450	230.5	164.0	3471	1309	140	135	128	292
	10 ppm	134.2	6813	190.6	146.1	2538	1035	106	117	77	204
	50 "	23.6	1058	30.4	30.4	522	88	14	16	17	26
	100 "	19.0	569	18.8	19.9	399	38	8	5	0	41

TABLE - V a.

* Average height (cms) of tomato plants, as affected by various concentrations of gibberellin.

Dates of observation	Treatments			
	Check	100 ppm	250 ppm	500 ppm
Dec. 24, 1957	26.9	26.6	26.9	26.5
" 31, "	36.7	38.1	44.6	47.4
Jan. 7, 1958	45.4	45.2	53.4	58.2
" 14, "	58.4	60.2	66.9	70.1
" 21, "	74.6	78.7	82.1	87.5
" 28, "	90.7	97.1	96.0	101.9
Feb. 4, "	102.2	110.2	110.1	114.7

* All values are averages of eight replicates.

TABLE - V b.

* Average diameter (mm) of stem of tomato plants, as affected by various concentrations of gibberellin.

Dates of measurements.	Treatments			
	Check	100 ppm	250 ppm	500 ppm
Dec. 24, 1957	4.9	4.9	5.0	5.0
" 31, "	5.2	5.3	5.6	5.5
Jan. 7, 1958	5.7	5.5	6.0	6.0
" 14, "	6.0	5.9	6.4	6.9
" 21, "	6.7	6.4	6.9	7.6
" 28, "	7.0	6.9	7.3	7.9
Feb. 4, "	7.4	7.5	7.8	8.4

* All values are averages of eight replicates.

TABLE - V c.

* Average number of leaves in tomato plants, as affected by various concentrations of gibberellin.

Dates of measurements.	Treatments			
	Check	100 ppm	250 ppm	500 ppm
Dec. 24, 1957	9.9	9.9	10.2	9.9
" 31, "	12.2	12.0	12.7	12.7
Jan. 7, 1958	16.0	15.6	16.9	15.8
" 14, "	19.6	20.6	22.5	22.4
" 21, "	25.5	29.4	30.5	32.1
" 28, "	33.1	37.7	40.2	41.6
Feb. 4, "	37.7	41.6	47.3	52.4

* All measurements are averages from eight replicates.

TABLE - V d.

* Average size of the largest leaf of tomato plants, as affected by various concentrations of gibberellin.

Dates of measurements	Treatments			
	Check	100 ppm	250 ppm	500 ppm
Dec. 24, 1957	22.8 cm	23.1 cm	24.5 cm	24.1 cm
" 31, "	27.6 "	29.4 "	31.0 "	30.0 "
Jan. 7, 1958	30.9 "	31.7 "	32.8 "	32.6 "
" 14, "	34.4 "	33.6 "	34.5 "	35.2 "
" 21, "	36.2 "	35.2 "	35.9 "	36.9 "
" 28, "	37.5 "	36.7 "	37.1 "	37.8 "
Feb. 4, "	37.9 "	37.2 "	37.5 "	38.1 "

* All measurements are averages from eight replicates.

TABLE - V e.

* Average number of laterals in tomato plants, as affected by various concentrations of gibberellin.

Dates of observation	Treatments			
	Check	100 ppm	250 ppm	500 ppm
Jan. 7, 1958	1.1	1.1	1.1	1.1
" 14, "	1.4	1.7	1.5	1.3
" 21, "	2.3	2.9	2.7	3.4
" 28, "	3.7	4.7	5.5	6.4
Feb. 4, "	4.3	5.4	5.7	7.1

* All values are averages from eight replicates.

TABLE - V f.

* Average number of flowers in tomato plants, as affected by various concentrations of gibberellin.

Dates of observation	Treatments			
	Check	100 ppm	250 ppm	500 ppm
Jan. 7, 1958	6.5	7.2	7.4	8.1
" 14, "	15.1	14.6	16.0	15.6
" 21, "	21.5	22.1	24.6	23.0
" 28, "	29.3	28.2	31.4	29.6
Feb. 4, "	31.6	36.2	41.2	42.0

* All values are averages from eight replicates.

TABLE - V g.

* Average number of fruits in tomato plants, as affected by various concentrations of gibberellin.

Dates of observation	Treatments			
	Check	100 ppm	250 ppm	500 ppm
Jan. 21, 1958	0.25	0.00	0.00	0.00
" 28, "	0.87	0.00	0.00	0.00
Feb. 4, "	1.62	0.00	0.12	0.12
" 11, "	3.00	1.00	1.12	0.75
" 18, "	4.25	1.12	1.75	1.12
" 25, "	5.62	2.00	2.50	2.50
Mar. 4, "	9.75	6.62	7.75	7.25
" 11, "	11.50	7.25	8.37	7.87

* All values are averages from eight replicates.

TABLE - VI.

* Average Fresh and Dry weights of tops and roots of tomato plants as affected by various concentrations of gibberellin.

Dates & Treatments	Weights in grams			
	Fresh		Dry	
	Tops	Roots	Tops	Roots
Dec. 24, 1957				
Check	13.75	2.98	1.46	0.23
Dec. 31, 1957				
Check	31.22	8.43	2.66	0.91
100 ppm	30.52	8.43	2.39	0.65
250 "	38.72	7.81	3.03	0.82
500 "	32.12	5.30	2.32	0.69
Jan. 14, 1958				
Check	68.99	21.79	6.85	2.54
100 ppm	71.75	21.65	6.42	3.02
250 "	71.41	21.66	6.29	2.83
500 "	66.34	17.51	5.89	2.84
Feb. 4, 1958				
Check	181.99	55.94	18.16	3.28
100 ppm	188.02	61.81	18.63	4.92
250 "	218.42	60.43	21.62	4.35
500 "	218.33	57.51	21.20	4.20

* All values are averages from three replicates.

TABLE - VII.

* Average mineral composition of tomato plants, as affected by various concentrations of gibberellin.

Dates of picking & Treatments.	Percent minerals/Dry weight									
	N	P	K	Ca	Mg	Fe	B	Mn	Cu	Zn
Dec.24, 1957										
Check	3.85	.16	5.52	2.99	.70	.0292	.0025	.0038	.0024	.0052
Dec.31, 1957										
Check	4.05	.18	5.73	3.23	.67	.0378	.0030	.0046	.0026	.0058
100 ppm	3.92	.16	6.14	3.16	.66	.0269	.0025	.0035	.0028	.0066
250 "	3.93	.17	6.16	3.01	.66	.0350	.0032	.0036	.0026	.0074
500 "	4.07	.18	6.99	3.09	.72	.0310	.0027	.0032	.0025	.0091
Jan.14, 1958										
Check	3.30	.16	4.89	2.50	.59	.0364	.0024	.0032	.0020	.0065
100 ppm	3.39	.16	5.05	2.82	.64	.0360	.0030	.0035	.0022	.0061
250 "	3.47	.16	5.20	2.84	.57	.0360	.0030	.0034	.0026	.0063
500 "	3.49	.15	5.22	3.08	.56	.0322	.0029	.0031	.0025	.0057
Feb. 4, 1958										
Check	3.06	.16	4.59	3.23	.69	.0383	.0040	.0036	.0030	.0054
100 ppm	3.05	.15	4.74	2.99	.68	.0185	.0033	.0028	.0028	.0041
250 "	2.99	.14	4.96	2.92	.62	.0267	.0036	.0031	.0035	.0053
500 "	2.90	.14	4.81	2.50	.65	.0275	.0029	.0032	.0025	.0052

* All values are averages from three replicates.

TABLE - VIII.

* Accumulation of various minerals, between certain dates, as affected by various concentrations of gibberellin.

Between Dates	Treatments	N mg.	P mg.	K mg.	Ca mg.	Mg mg.	Fe mg.	B µg.	Mn µg.	Cu µg.	Zn µg.
		Amount of minerals accumulated by plants									
Dec. 24 to 31, 1957.	Check	80	4	111	64	12	0.9	65	100	54	121
	100 ppm	54	2	92	45	8	0.3	31	42	45	114
	250 "	86	4	144	66	14	0.7	81	75	60	192
	500 "	57	3	117	42	10	0.4	40	33	35	185
Dec. 31, 1957 to Jan. 14, 1958.	Check	165	9	255	120	32	2.1	116	136	90	402
	100 ppm	202	10	290	171	41	2.5	209	219	125	378
	250 "	165	8	237	143	27	1.9	154	173	135	294
	500 "	183	7	245	176	27	1.8	173	193	146	221
Jan. 14 to Feb. 4, 1958.	Check	345	18	525	456	91	4.8	634	465	452	561
	100 ppm	398	20	641	438	100	1.0	501	325	452	395
	250 "	461	23	816	498	108	3.6	664	492	677	795
	500 "	432	24	767	366	116	4.2	490	521	357	819

* All values are averages from three replicates.