A STUDY OF THE HORMONE EFFECTS ON TOMATOES GROWN IN NITROGEN RICH SOIL

by

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INTRODUCTION

The use of fertilizers to increase the vigor and productiveness of garden and field crops has been practiced for centuries. Many of the older fertilizer materials such as manure, dried blood, hardwood ashes, urine, tankage and bonemeal were applied in considerable quantities. The effects of such applications were outstanding in some instances. In others, particularly the application of nitrogenous fertilizers, results were disappointing. The cause of these variable results have been the basis of much research in more recent years.

It has been fairly well established that plants utilize nutrients in a rather definite ratio and the application of either inadequate or excessive amounts of any one element will produce a disruption of this ratio with resultant detrimental effects to the plant. This is especially true with those elements, such as nitrogen, which are made readily available to the plant.

When using the older, organic fertilizer materials, the danger of applying excessive amounts of a particular element was minimized because of the small amounts that were contained in the fertilizer, and because of the balance already present in the fertilizer between the various elements. With the advent of new, inorganic fertilizers the danger of applying excessive amounts of a particular element was increased greatly because of the potency of the fertilizer and because single elements are now available.

The ratio of carbohydrates to nitrogenous compounds in the plant seems to play a very important role in controlling the various metabolic functions of the plant, especially when other essential elements are present in adequate amounts. Carbohydrates in the plant ordinarily are present in much greater quantity than nitrogenous compounds. When the nitrogen content is increased by any method to a point at which it throws the carbohydrate-nitrogen ratio out of balance the ability of the plant to set and mature fruit is reduced. On the other hand, an overabundance of carbohydrates in comparison to the normal nitrogen content tends to favor vegetative growth.

The carbohydrate-nitrogen ratio in plants may be adjusted by the use of one or more of the following methods:

Increase of carbohydrate content:

- Girdling
- Thinning
- Application of nitrogen at particular times

Decrease of carbohydrate content:

- Shading
- Shortening day length
- Defoliation
- Heading
- Manuring with high-content nitrogen

Increase of nitrogen content:

- Manuring, fertilizing
- Shading
- Defoliation
- Certain types of pruning

Decrease of nitrogen content:

- Girdling
- Defoliation early in the season
- Local suppression of growth through pruning
- Sods or intercrops

Of the elements studied in plant nutrition, probably nitrogen has attracted the greatest attention. Because of its rapid leaching it is quite often the limiting factor in plant growth. Also, the effects of applying nitrogen are quickest and most pronounced. Nitrogen is a constituent of plant proteins, tends to encourage the development of the vegetative portion of the plant, imparts a deep green color to the plant, increases plumpness of seeds, and governs, to some extent at least, the utilization of potash and phosphoric acid. However, nitrogen applied in excessive quantities produces "burning" of the foliage, retards maturity, and reduces the number of flowers. Because of these dangers, nitrogenous fertilizers are usually applied with care and discretion. Tomato plants to which excessive nitrogen is applied will often fail to set fruit. For this reason heavy application of nitrogenous fertilizers are not recommended for growing tomatoes.

Considerable attention has been given during recent years to the development and commercial use of plant growth substances or hormones that regulate plant growth in some way. Among these are a large number of compounds which have been found to increase fruit set in various crops, including the tomato. It is generally accepted that the fruit-setting hormones are of little or no benefit when conditions for normal pollination are favorable. The hormones seem to exert their greatest effect when unfavorable conditions exist, such as cloudy weather, low night temperatures, and short day length.

Nitrogenous fertilizers have been used sparingly on tomatoes in the past because of their deleterious effects on fruit set when they are applied in excessive amounts. For this reason, yields have been limited by the amount of nitrogen that could be applied without causing a reduction in fruit set. Many plant growth substances are now available which encourage fruit set, especially under unfavorable conditions. It would seem, therefore, that higher amounts of nitrogen may be applied and the yields increased by inducing fruit set artificially with plant growth substances.

OBJECTIVES OF THE STUDY

The objectives of this study are: (1) to review and summarize previous work on the related subjects, (2) to determine the effect of high levels of nitrogen on tomato plants, (3) to study the effectiveness of plant growth substances or hormones on plants growing in nitrogen-rich soil, (4) to study the effectiveness of the hormone in promoting earlier ripening of the fruit, and (5) to determine what relationships exist, if any, between the effectiveness of hormones applied under various carbohydrate-nitrogen levels.

REVIEW OF LITERATURE

Carbohydrate-Nitrogen Relations

The first intensive investigations in connection with the effect of carbohydrate-nitrogen relations on reproduction and vegetation in plants were undertaken by Kraus and Kraybill (1918). Working with the tomato plant, they found the most fruitful plants moderately low in nitrate nitrogen and total nitrogen and high in free reducing substances, sucrose and polysaccharides. Fruitfulness was associated neither with highest nitrates nor with highest carbohydrates, but with a condition of balance between the two. They believed fertilizers containing available nitrogen or that which may be made available, are mainly effective in producing vegetative response and that they may either increase or decrease fruitfulness, according to the relative available carbohydrate supply. The summarization of

Kraus and Kraybill's work by Miller (1938) is as follows:

(1) A very high carbohydrate-nitrogen ratio accompanying a weakly vegetative condition. Here nitrogen appears to be a limiting factor of growth and the high ratio is apparently due to the small amount of nitrogen present.

(2) A high carbohydrate-nitrogen ratio accompanying abundant fruit production. In this type, nitrogen compounds are available, but the high ratio is due to an excess of carbohydrates.

(3) A low carbohydrate-nitrogen ratio accompanying a vigorous vegetative condition. In this type there appears to be an available supply of both carbohydrates and nitrogen and the balance between them is such as to produce the best vegetative conditions without leaving a residue of carbohydrates.

(4) An exceedingly low carbohydrate-nitrogen ratio accompanying a weakly vegetative condition. In this type carbohydrates appear to be the limiting factor of growth, and the low ratio is due to the small amount of carbohydrate present, while the amount of nitrogen appears to be an indifferent factor.

Gurjar (1920) suggested a ratio between carbohydrates and nitrogen was responsible for fruitfulness in a plant. He found that carbohydrate-nitrogen ratios may vary from 2 to 19 in the tomato plant and that fruiting took place only between the ratios 4 to 6. He further found that the supply of nitrogen determined the relative proportion of carbohydrates and proteins in the plant.

The proportion of carbohydrates to insoluble nitrogen, and not the total amounts of either, was believed by Nightingale (1922) to be the important factor in determining the type of growth made by plants. He concluded that nitrates could be stored in the plant until proper conditions arose for synthesis to other forms of nitrogen and that this storage did not appear to affect the type of growth of the plant. He suggested that roots of the tomato plant do not serve as storage organs and that the nitrogen content in the roots remains fairly constant through different environmental conditions. Finally, he demonstrated that a tomato plant containing relatively high proportions of insoluble nitrogen as compared to the carbohydrate level was strongly vegetative but unfruitful.

Work (1924) found increasing applications of nitrate fertilizer caused a rise in the ratio of buds to blossoms but a decrease in the ratio of blossoms to fruit. In other words, under a condition of nitrogen shortage, the proportion of buds that come to bloom is large while the number of blooms that set fruit is small. Under the conditions of his experiment he was unable to induce a condition of heavy vegetation and fruitfulness by means of large applications of nitrate of soda.

In connection with fruit set in tomatoes, Murneek (1926) found a correlation between the amount of fruit set and low values of the carbohydrate-nitrogen ratio. He also found that under several planes of nutrition as regards nitrogen supply, a maximum crop of fruits had a retarding effect on vegetative growth and development. The presence of flowers probably had no influence on growth. This inhibition proceeded in approximately the following order: (1) destruction of fecundity of blossoms, (2) decrease in size of floral clusters, (3) yellowing and abscission of flower buds, (4) reduction and cessation of terminal growth of the stem and, (5) complete exhaustion and eventual death of all parts of the plant with the exception of the fruit. These signs are typical of a condition of nitrogen starvation of increasing severity. Murneek further found that the rate of growth, as measured by increments of height, declines at the exact time and in inverse proportion to the amount of fruit set and developing, and that fruit diverts and monopolizes in some manner almost all of the available nitrogen, accounting for at least a part of the marked carbohydrate accumulation in vegetative structures. He pointed out that apparently large quantities of nitrogenous nutrients are essential for the development of practically all parts of the tomato. If anything, the fruit requires even more nitrogen than the other portions of the plant.

According to Hooker (1925) the study of carbohydrate-nitrogen relations in connection with vegetative growth has indicated that either a limitation of nitrates or a limitation of carbohydrates results in poor vegetative growth. When carbohydrates are in excess an adjustment of the carbohydrate-nitrogen relations results in a rapid vegetative growth. The adjustment of the nitrogen upwards while holding the carbohydrate content uniform results in greater vegetative growth than by lowering the carbohydrate content and holding the nitrogen constant. Hooker further pointed out that experiments have shown also that the proper ratio to be maintained is not restricted to carbohydrates and nitrogen but includes water and the other essential mineral elements as well.

Growth-regulating Substances

Probably the first worker to suggest the presence of a growth-regulating substance in plants was Darwin (1881) who presented evidence that there was in some plants a localization of a substance producing phototropisms. Working with the coleoptile of Phalaris canariensis, he showed that no curvature resulted when the tip of the coleoptile was darkened, regardless of what other portion of the plant was illuminated. Further, he showed that curvature did result when the tip was illuminated, even though the lower part of the stem was darkened. Darwin concluded that in seedlings exposed to light, some influence is transmitted from the upper to the lower part of the stem, causing the lower part to bend.

Since Darwin's research many workers, particularly in Europe, have investigated the problem of phototropism. Rothert (1894) corroborated Darwin's findings as essentially correct and concluded that the phototropic stimulus is conducted in the parenchyma tissue from the tips of Avena coleoptiles to the lower portions of the stem. Fitting (1905) showed that the stimulus formed in the tip of seedlings was transmitted around incisions in the stem to the lower portions of the plant. He concluded that the stimulus was transmitted exclusively through living material. Paal (1918) and Boysen-Jensen (1936) postulated the existence of a diffusible carrier, a substance which is produced in the tip of plants and moves to the point of action. Paal's finding was the first evidence that something of a hormonal nature existed in plants.

The greatest impetus to the discovery of plant hormones was furnished by Went (1928) who described a quantitative method of using oat seedlings for judging plant hormone strength. Briefly, Went's method consists of applying blocks of agar containing unknown amounts of plant hormones to one side of decapitated oat shoots. If hormones are present in the agar, the shoots bend to a degree that is proportional, within limits, to the concentration of hormone in the agar blocks.

Using Went's quantitative method, Kögl et al (1933) found in human urine, a source of material from which to isolate and identify certain hormones. Later, the use of malt, yeast, corn, peanuts, sunflower, and linseed oils furnished other sources of active materials. From these tests indoleacetic acid was shown to be one of the active compounds in regulating plant growth.

Gustafson (1936) was one of the first workers to demonstrate that certain chemicals could induce ovaries of tomato flowers to develop into fruits without pollination. He also showed that hormones may produce seedless fruit.

Fruit set and total yield of tomatoes are usually increased by the use of hormone sprays. Howlett (1941) found that hormones, applied to tomato flowers in a lanolin paste, produced a greater number of fruits as compared with self-pollinated flowers. Roberts and Struckmeyer (1944) also found hormones effective in setting fruit but concluded that hormones do not prevent the drop of flowers due to nutritional deficiencies. They suggested that changed cultural treatments may be necessary to maintain plant vigor when heavy sets are induced on the lower clusters by hormone sprays. Murneek et al (1944) used p-chlorophenoxyacetic acid at 10 parts per million for flower cluster sprays and found it to be one of the most potent of the growth-regulating substances. Murneek (1947), in later research with the same hormone, concluded that the concentration of the hormone must be adjusted according to the relative amount of light the plants received. He thought that too high a concentration of the hormone during cloudy weather would result in the production of occasional abnormal fruit. He believed hormone sprays were of no practical value for field-grown tomatoes, except in regions, or years, of a subnormal amount of sunlight. On the other hand, Wittwer et al (1948) used the same hormone to produce significantly more and larger early fruit. They believed cool night temperatures (below 59° F.) to be the chief factor responsible for poor fruit set early in the season and thought hormone sprays could be used profitably when and where this condition existed. Odland and Chan (1950) believed that unfruitfulness of tomatoes grown in the greenhouse during the winter months was a result of low light intensities and short day length. They also believed these causes, as well as low temperatures, could be overcome by the use of hormone sprays.

Wittwer (1949) grew tomatoes under glass in the spring and fall and suggested that the wide difference in yield was due, in part at least, to solar radiation. He pointed out that, for the fall crop the progressively shorter photoperiods and days of decreasing light intensities during autumn and early winter provide an environmental reversal of the increasingly longer photoperiods and higher light intensities characteristic of spring crop production.

The methods of applying hormone sprays are varied. Roberts and Struckmeyer (1944) found that a single hormone application in lanolin paste to a well-developed flower cluster gave a more uniform size of fruit. Howlett and Marth (1946) used an aerosol treatment to apply their hormone sprays and found that it increased earliness of yield, total yield, and size of individual fruits. The size of their fruits were increased, in some cases, 34 to 70 per cent as compared with the fruit from untreated plants. Paddock (1948) attempted to mix two different hormones with a standard insecticide-fungicide spray but the results were negative. The treated plants either ceased growth or showed a slight rugosity of the leaves. Numbers of fruit and yield were reduced. Randhawa and Thompson (1949) applied p-chlorophenoxyacetic acid at 25 parts per million to increase both the early and total yield of tomato plants. They found that spraying a flower cluster twice resulted in greater set of fruits than untreated plants. Moore (1950) used p-chlorophenoxyacetic acid at 30 parts per million with two different pruning systems. He found that fruit size and yield were significantly increased by spraying the blossom clusters six times at weekly intervals. Singletary and Warren (1951), however, using the hormone at the same concentration, found no difference in total yields between hormone-treated and untreated plants. They did, however, obtain significant increases in early yield by applying the hormone as whole plant sprays in the field during periods with low night temperatures. Howlett (1942) also obtained earlier fruit from hormone-treated than from untreated plants.

Zimmerman and Hitchcock (1944) reviewed the work of the Boyce Thompson Institute for Plant Research with regards to plant growth substances. Optimum concentrations for many of the hormones are given. They suggested that the minimum effective concentration for each tomato variety must be determined and the minimum effective concentration should be used in preference to higher dosages, which may cause inhibition of growth, modification of shape or loss of the smaller buds. Methods of application were also reviewed. They recommended application of the hormone with an atomizer when only a relatively few plants are involved.

Wittwer and Schmidt (1950) applied "whole plant" hormone sprays to outdoor tomato plants but concluded they were of little value because of the damage resulting to the plant. They believed, however, that flower cluster sprays were of considerable value, especially in increasing the early yield. They caused no damage to their plants.

The time of application of hormone sprays undoubtedly affected the results. Hemphill (1949) has demonstrated that hormone sprays applied too early reduced both the size and set of fruit. He believed the optimum time to be four days after anthesis.

Quality of tomato fruits produced by hormone sprays was high according to research of Howlett (1939). In addition, many of the fruits were totally seedless. However, in later studies (1949) he believed that the seedlessness may be the cause of premature softening of fruit from hormone-treated plants. A higher respiration rate of hormone-produced fruit may also cause premature softening.

Murneek et al (1944) believed that high concentrations of hormone sprays, under cloudy weather conditions when pollination is difficult, produced "puffy fruit". On the other hand, they believed hormone sprays tended to make the fruits more uniform in size and weight.

PROCEDURE

Spring Experiment

Seeds of the tomato variety Southland were planted on December 22, 1951, and seedlings transplanted to three-inch clay pots ten days later. The plants were approximately eight inches high on February 22, 1952, when they were transplanted to a greenhouse bed. The soil in the bed, a sandy loam, was renewed prior to the start of the experiment and contained 0.045 per cent nitrogen. Potassium, as muriate of potash, at the rate of 250 pounds per acre, and phosphorus, as treble superphosphate, at the rate of 1,000 pounds per acre, were broadcast over the bed and spaded in.

The tomato plants were removed carefully from the pots so as not to loosen the soil around the roots, and transplanted 18 inches apart in rows spaced 34 inches apart. Ten treatments, each comprised of four plants, and replicated three times, were used in the experiment. A guard row was placed at each end of the bed. The treatments used in the experiment are shown in Table 1.

Nitrogen, in the form of ammonium nitrate, was placed in the bottom of trenches approximately 1-inch deep on both sides of the row and five inches from the row. The fertilizer was then lightly covered with soil. Dates of application of fertilizer are listed in Table 1.

Table 1. Amount and date of nitrogen applications to hormone-treated and untreated tomato plants in the spring experiment.

Hormone	Total nitrogen applied (lbs.)	Date and amount of applications			
		Mar. 1 (lbs.)	Mar. 12 (lbs.)	Mar. 22 (lbs.)	Apr. 5 (lbs.)
Check	0	---	---	---	---
Without hormone	50	50	---	---	---
	150	150	---	---	---
	150	75	75	---	---
	300	150	150	---	---
	300	75	75	75	75
With hormone	150	150	---	---	---
	150	75	75	---	---
	300	150	150	---	---
	300	75	75	75	75

Temperature during the experiment was maintained at approximately 65° F. during the night and 80° F. during the day. During the late stages of the experiment, June and July, day temperatures sometimes exceeded 80° due to the high outdoor temperatures.

The growth regulator used in the experiment, p-chlorophenoxyacetic acid, in concentration of 30 parts per million in distilled water, was applied to the flower clusters with a DeVilbiss No. 251 atomizer. Insofar as possible, sprays were applied only to the flower clusters and not to the foliage of the plants each fifth day from March 8 to the end of the experiment. Plants receiving no hormone treatment were tapped or lightly shaken on the same day that the hormone spray was applied to other plants.

All plants were pruned to a single stem and trained to an overhead wire. Water was applied as required throughout the experiment by flooding the bed with open garden hoses. Immediately after the fertilizer had been applied the stream of water was directed away from the fertilizer trenches and no water was permitted to accumulate which might have caused washing of fertilizer from one row to another.

The first fruit was picked on April 19, and harvesting continued until July 19 when the plants were removed from the bed. Fruits were counted and weighed immediately after picking and only ripe fruits were considered. Immature fruits at the end of the experiment were discarded and not included in the data.

Fall Experiment

The same general experimental plan used in the spring was followed in the fall.

The same variety of tomato, Southland, was used. Seeds were planted July 26 and transplanted on August 13 to 2-inch wooden plant bands. The tomato plants were set in the bed on September 27 after removing the plant bands. Ten treatments, each comprised of four plants, and replicated three times, were again used. Likewise, a guard row was placed at each end of the bed. The treatments and dates of nitrogen application used in the experiment are listed in Table 2.

The temperature during the experiment was maintained at approximately 65° F. during the night and 80° F. during the day. During the latter stages of the experiment, January and February, the temperature often dropped considerably below the preferred range because of low outdoor temperature.

The same hormone was used in both spring and fall experiments as well as the method of application and concentration. Flower clusters were sprayed from October 22 to January 16. Plants receiving no hormone treatment were tapped or lightly shaken on the same day that the hormone spray was applied to other plants.

The first fruit was picked on December 3, 1952, and harvesting continued until February 20, 1953, when the plants were removed from the bed.

Fruits were counted and weighed immediately after picking and only ripe fruits were considered. Immature fruits at the end of the experiment were discarded and not included in the data.

RESULTS

Spring Experiment

As indicated in Table 3, plants in the treatments receiving a hormone spray produced fewer fruits than the plants in comparable treatments without

Table 2. Amount and date of nitrogen applications to hormone-treated and untreated tomato plants in the fall experiment.

Hormone	Total nitrogen applied (lbs.)	Date and amount of applications: Oct. 4 (lbs.)	Oct. 18 (lbs.)	Dec. 26 (lbs.)
Check	0	—	—	—
Without hormone	50	50	—	—
	150	150	—	—
	300	150	150	—
	450	150	150	150
With hormone	0	—	—	—
	50	50	—	—
	150	150	—	—
	300	150	150	—
	450	150	150	150

Table 3. Number, average weight of fruit per plant, and average weight of individual fruits, for each of the treatments in the spring experiment.

Treatments	Ripe fruit harvested: Total number	Ripe fruit harvested: Average weight per plant (lbs.)	Ripe fruit harvested: Average weight per fruit (oz.)
Check (no nitrogen, no hormone)	308	7.1	4.45
Nitrogen, without hormone			
50 lbs. in 1 application	330	8.9	5.16
150 lbs. in 1 application	365	9.0	4.74
150 lbs. in 2 applications	377	8.4	4.29
300 lbs. in 2 applications	349	8.6	4.71
300 lbs. in 4 applications	354	7.1	3.86
Nitrogen, with hormone			
150 lbs. in 1 application	287	12.0	8.03
150 lbs. in 2 applications	254	11.0	8.29
300 lbs. in 2 applications	298	12.1	7.82
300 lbs. in 4 applications	339	12.2	6.93
L.S.D. 19:1.................	N.S.	1.15	
99:1.................	N.S.	1.53	

a hormone spray. However the difference was not statistically significant. Data from the experiment and the statistical analysis of the data are contained Appendix I.

Hormone spraying produced larger fruits. Plants in sprayed treatments produced fruits which ranged from 66 to 93 per cent larger than fruits from plants in comparable, unsprayed treatments. Plate I shows a comparison between fruits of one picking from hormone-treated and untreated plants. The plants in the two treatments, 300 pounds of nitrogen in four applications and 150 pounds of nitrogen in two applications, both without a hormone, produced smaller fruit than the plants in the check.

With one exception, all treatments showed a significant increase in the weight of fruit produced per plant as compared with the check. The 300 pound nitrogen treatment, in four applications without a hormone, produced significantly less fruit per plant, by weight, than the treatment receiving the same amount of nitrogen in two applications, and exactly the same weight of fruit per plant as the check. To a lesser degree, the same difference was manifest in the 150 pound nitrogen treatments receiving no hormone, with the single application of fertilizer producing slightly more fruit by weight than the split application.

The set of fruit was fairly uniform for all treatments through the harvest season with one exception: the 150-pound nitrogen treatment in two applications, with a hormone, set a large number of fruits early in the season (Plate II). While these fruits were maturing and after their harvest no additional fruit set in spite of the application of the hormone spray. After four and sometimes five consecutive clusters had failed to produce a single fruit, the plants again began to set fruit, but at a low rate.

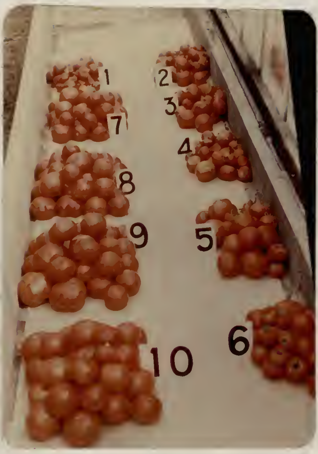
EXPLANATION OF PLATE I

Comparison of fruit size and yield of different treatments, harvest of June 11, 1952.

Nos. 1 to 6 inclusive are from treatments with no hormone.
Nos. 7 to 10 inclusive are from hormone-treated plants.

No. 1 is from check plants.
No. 2 is from plants receiving 50 pounds of nitrogen in 1 application.
Nos. 3 & 7 are from plants receiving 150 pounds of nitrogen in 1 application.
Nos. 4 & 8 are from plants receiving 150 pounds of nitrogen in 2 applications.
Nos. 5 & 9 are from plants receiving 300 pounds of nitrogen in 2 applications.
Nos. 6 & 10 are from plants receiving 300 pounds of nitrogen in 4 applications.

PLATE I



EXPLANATION OF PLATE II

Fruit set on plant receiving 150 pounds of nitrogen in two applications, with a hormone spray, early in the season.

PLATE II

The hormone, when applied to the tomato plants, produced a considerable number of puffy fruits as compared to unsprayed plants. Seeds often were absent in fruit from hormone-treated plants. Plate III shows the comparison between fruits harvested from hormone-treated and untreated plants.

Table 4 shows the per cent of fruit harvested from the treatments during three stages of the harvest season. The plants treated with the hormone produced a greater proportion of their total fruit in the early portion of the harvest season than the non-hormone treatments. The per cent of total yield during approximately the first month of harvest ranged from 21.0 to 27.6 for the hormone-treated plants, as compared with a range of 12.4 to 17.1 for the untreated plants. The same trend is evident during approximately the second month of harvest. During the last period of harvest, June 19 to July 14, the unsprayed plants produced a considerably higher percentage of their total yield than the sprayed plants.

Fall Experiment

The data in Table 5 indicates that plants receiving a hormone spray produced only a slightly greater number of fruits than the untreated plants. Overall, the treated plants produced 1249 fruits during the experiment as compared with 1179 from the untreated plants. The differences in the number of fruits produced were not great enough to be statistically significant. Data from the experiment and the statistical analysis are contained in Appendix I.

As in the spring experiment, hormone spraying produced larger fruit than the fruit formed from natural pollination (Table 5). Plants in sprayed treatments produced fruit ranging from 33 to 47 per cent heavier than fruit from comparable, unsprayed treatments. Fruits from the check treatment,

EXPLANATION OF PLATE III

Fruits from hormone-treated and untreated plants, showing puffiness, partial development of seeds, and normal development of seeds, from top to bottom, respectively.

PLATE III

Table 4. Percentage of fruits harvested from treatments during different periods of spring experiment.

Treatments	Harvest periods: April 19-May 23 (%)	May 24-June 18 (%)	June 18-July 14 (%)
Check (no nitrogen, no hormone)	9.9	58.0	32.1
Nitrogen, without hormone			
50 lbs. in 1 application	17.1	45.1	37.8
150 lbs. in 1 application	14.9	56.0	29.1
150 lbs. in 2 applications	15.3	49.0	35.7
300 lbs. in 2 applications	12.4	47.1	40.5
300 lbs. in 4 applications	15.0	44.0	41.0
Nitrogen, with hormone			
150 lbs. in 1 application	23.6	59.4	17.0
150 lbs. in 2 applications	27.6	65.6	6.8
300 lbs. in 2 applications	21.0	54.3	24.7
300 lbs. in 4 applications	27.2	48.9	23.9

Table 5. Number, average weight of fruit per plant, and average weight of individual fruits, for each of the treatments in the fall experiment.

Treatments	Ripe fruit harvested: Total number	Ripe fruit harvested: Average weight per plant (lbs.)	Ripe fruit harvested: Average weight per fruit (oz.)
Check (no nitrogen, no hormone)	221	4.3	3.73
Nitrogen, without hormone			
50 lbs. in 1 application	224	4.3	3.73
150 lbs. in 1 application	258	5.0	3.72
300 lbs. in 2 applications	247	4.6	3.59
450 lbs. in 3 applications	229	4.2	3.54
Nitrogen, with hormone			
0 lbs.	248	6.6	5.08
50 lbs.	265	6.8	4.96
150 lbs. in 1 application	250	6.7	5.14
300 lbs. in 2 applications	253	7.0	5.28
450 lbs. in 3 applications	233	5.8	4.81
L.S.D. 19:1.................	N.S.	0.96	
99:1.................	N.S.	1.32	

without a hormone spray, were as heavy or heavier than fruits from the other treatments receiving no hormone spray. Average size of fruits decreased with increasing amounts of fertilizer, i.e., 3.73 ounces per fruit from the check treatment which received no nitrogen; 3.73 ounces from the 50-pound nitrogen treatment; 3.72 ounces from the 150-pound nitrogen treatment; 3.59 ounces from the 300-pound nitrogen treatment; and 3.54 ounces per fruit in the treatment receiving 450 pounds of nitrogen per acre.

The average weight of fruit per plant from treatments receiving no hormone spray ranged from 4.2 pounds to 5.0 pounds. The differences between these several treatments were not significant. Also, there was no significant difference in weight of fruit produced between the treatments receiving hormone sprays. However, there was a highly significant difference between all hormone-treated and non-treated plants with regards to the average weight of fruit produced per plant. The plants receiving the highest rate of nitrogen per acre, without a hormone spray, produced the lowest weight of fruit of all treatments.

Color of the plants in the treatments varied with the amount of nitrogen applied. Plants in the check treatment were chlorotic while 450 pounds of nitrogen produced the darkest green plants. Intermediate in color were the plants receiving 50, 150, and 300 pounds of nitrogen per acre (Plate IV).

A limited number of fruits were slightly puffy due to unfilled locules. These were picked from both hormone-treated and untreated plants and, from observation alone, there seemed to be no correlation between the hormone spray and puffy fruits.

Table 6 shows the per cent of fruit harvested from all treatments during three stages of the harvest season. The hormone-treated plants produced a greater percentage of their total fruit during the early stage of harvest

EXPLANATION OF PLATE IV

Fig. 1. Range of color in tomato plants of the fall experiment; range being from light to dark with increasing amounts of nitrogen.

Fig. 2. Individual plants from the various treatments of the fall experiment. From left to right, the plants are from treatments which received 0, 50, 150, 300, and 450 pounds of nitrogen per acre.

PLATE IV

Fig. 1

Fig. 2

Table 6. Percentage of fruits harvested from treatments during different periods of fall experiment.

Treatments	Harvest periods		
	Dec. 3- Dec. 29 (%)	Dec. 30- Jan. 23 (%)	Jan. 24- Feb. 20 (%)
Check (no nitrogen, no hormone)	18.8	37.1	44.1
Nitrogen, without hormone			
50 lbs. in 1 application	28.0	34.3	37.7
150 lbs. in 1 application	19.6	38.3	42.1
300 lbs. in 2 applications	19.5	39.1	41.4
450 lbs. in 3 applications	22.9	38.7	38.4
Nitrogen, with hormone			
0 lbs.	31.2	35.2	33.6
50 lbs. in 1 application	31.0	37.5	31.5
150 lbs. in 1 application	26.7	42.3	31.0
300 lbs. in 2 applications	29.7	38.2	32.1
450 lbs. in 3 applications	34.3	39.0	26.7

than the untreated plants. For example, the per cent of total yield of the hormone-treated plants during the first period ranged from 26.7 to 34.3 as compared with a range of 18.8 to 28.0 for the non-treated plants. During the second period of harvest, December 30 to January 23, yields of hormone-treated and untreated plants were practically the same, while during the last period of harvest, January 24 to February 20, plants receiving no hormone spray produced a greater percentage of their total yield than the treated plants.

DISCUSSION

All applications of nitrogen without a hormone produced significantly greater yields than the check in the spring experiment, except the application of 300 pounds in four increments. The data in Table 3 show that 50 pounds of nitrogen, applied at one time soon after the plants were set in the bed, produced as great a yield as 150 pounds in either one or two applications, or 300 pounds in two applications. The application of 50 pounds of nitrogen per acre should not be interpreted as a recommendation, however, as less fertilizer may have produced similar yields. Also, the initial fertility of the soil and the level of the other fertilizer elements would influence the results, as well as the time of application of the nitrogen fertilizer.

Yields in the fall experiment were approximately one-half those obtained in the spring and were probably due, as pointed out by Odland and Chan (1950), to the low light intensities, short day lengths, and/or low temperatures present during the fall experiment. Large applications of nitrogen fertilizer produced no significant differences in yield, either when applied with a hormone spray or without. In fact, plants receiving the highest rates of nitrogen, 450 pounds per acre, produced slightly less fruit per plant than comparable plants receiving no nitrogen whatsoever. The fertility of the soil used in the fall experiment was apparently higher than in the spring due to fertilizer residues remaining after completion of the spring experiment. Thorough leachings of the bed probably removed some of the residue but some undoubtedly remained. Spading and mixing the soil tended to distribute the remainder evenly through the bed.

The number of times that nitrogen fertilizer was applied also affected the yields. In general, in the spring experiment, the highest yields were produced when nitrogen was applied once; two applications resulted in slightly lower yields; and four applications produced significantly less fruit, by weight, than any other treatment in the experiment. A comparison of the data from the two 300-pound nitrogen treatments without a hormone shows that by applying the fertilizer in two equal increments significantly greater yields resulted than if the fertilizer was applied in four increments. Apparently the time at which the fertilizer was applied, and not the total amount, affected the total yield of the plants.

Hester (1938) has shown that the requirement of nitrogen in an available form is highest in the early stages of plant growth and, if adequate fertilizer is applied at that time, later or heavier applications are of little or no benefit to the plant.

A comparison can be made between the effects of applications of 75 pounds of nitrogen at approximately 10-day intervals. When only two applications were made (March 1 and 10) the yield was significantly greater than that produced by four applications (March 1, 12, 22, and April 5). Applying the last two increments apparently depressed the yield.

Similar comparisons of the effects of the number of applications of fertilizer can be made using data from the fall experiment. In the treatments without a hormone, applying 150 pounds of nitrogen in one application produced slightly greater yields per plant than the application of 300 pounds in two equal increments, or 450 pounds in three equal increments. When a hormone spray was applied with the nitrogen, no definite trend was apparent in either the spring or fall experiment.

The findings are in accord with those of Wynd (1942) who studied the efficiency of single applications with repeated top dressings of nitrogenous fertilizers in increasing the yield of dry matter, nitrogen and Vitamin C of Sudan grass. He found that the greater effeciency per unit of added nitrogen in increasing the total yield of dry matter was found when the entire amount of fertilizer was added at seeding time. He suggested that, when the entire amount is added at seeding time, the combined action of rainfall and irrigation tended to move the fertilizer downward and distributed it throughout the soil profile. It then came in contact with the expanding root system in the lower zones of nutrient absorption. When several, smaller applications were made the nitrogen was used before it was able to penetrate to the lower feeding zones where the new roots were being formed. Being a deep-rooted crop, the tomato plant undoubtedly obtains much of its food at a considerable depth below the surface of the soil. Fertilizer, applied once early in the season, was apparently leached by the frequent waterings downward to the feeding zone of the plants where it was utilized. On the other hand, when the same amount of fertilizer was applied in several increments, the later applications may not have been available to the plant if they had not been leached to the feeding zone.

When a hormone spray was applied during the spring experiment to plants of the several different nitrogen treatments, the increase in yields was highly significant. This increase is especially striking in the treatment, 300 pounds of nitrogen in four applications. When only nitrogen was applied, the yield was 7.1 pounds per plant, the same as the check treatment. Similar plants, which had been treated with a hormone during the season, produced 12.2 pounds per plant, or an increase of 72 per cent. In this treatment the increase in yield attributable to the hormone was apparently 5.1 pounds per plant.

In the fall experiment also, significant increases in yield were obtained by applying hormone sprays. In every treatment receiving both nitrogen and a hormone spray, yields were significantly greater than comparable plants receiving only nitrogen. The increase in yield of hormone-treated plants ranged from 34 to 53 per cent greater than from comparable, non-hormone-treated plants. This increase was apparently attributable to the use of the hormone and ranged from 1.6 to 2.5 pounds per plant.

Application of the hormone produced very few misshapen fruits during the spring experiment. A considerable number were "puffy" due to unfilled locules although they were not lacking in flavor or color. Some of them appeared slightly ribbed. The cause of the puffiness in this experiment is not known. Salik, Hobbs, and Leopold (1951) have suggested that the hormone, if applied to the abscission layer of the pedicel, causes puffiness since they did not find puffy fruits when the flower clusters were sprayed directly from the front. Randhawa and Thompson (1949) found that high concentrations of the hormone sometimes caused the unfilled locules associated with puffiness. Taubenhaus and Allstatt (1939) showed that puffiness is not caused by a micro-organism or a virus, Also, the cause is not seed-borne, not affected by soil acidity nor diseases. The cause is, however, influenced by soil moisture and probably by certain fertilizers, as well as some environmental conditions.

During the fall experiment the number of puffy fruit was reduced considerably. Probably the difference in day length and other environmental conditions between the spring and fall experiments was responsible for the reduction in puffiness in the fruits.

The number of fruits produced during the spring experiment was increased by applying nitrogen without a hormone at any of the levels used in the experiment. It is probable that the nitrogen level in the check treatment was inadequate to supply the plant's need for both vegetative and reproductive functions. Vegetative growth was continued at a near-normal pace at the expense of reproduction. Nitrogen, at rates of 50, 150, and 300 pounds per acre, provided sufficient nitrogen for the plants to increase their reproductive functions. The greatest number of fruits were found in the 150 pound treatment, without a hormone.

In the fall experiment all plants receiving nitrogen without a hormone produced approximately the same number of fruit, and the differences between the treatments were too small to be significant. In this experiment, the increased fertility of the soil at the beginning of the experiment apparently was sufficiently high to supply the plants' needs for vegetative growth as well as reproduction. Under the conditions of this experiment the application of nitrogen was of no benefit in producing greater numbers of fruit.

While the application of nitrogen, without a hormone, produced more fruit than the check in all cases in the spring experiment, the application of both nitrogen and a hormone produced less fruit than the check in three of the four hormone treatments. Only the 300 pound nitrogen treatment in four applications and sprayed with a hormone, produced more fruit than the check. Murneek (1947) and Murneek et al (1944) have shown that hormones applied to tomato flower clusters will increase the fruit set. The cause of the reduced number of fruits in this experiment is not known. Applying the hormone every five days throughout the experiment could have been too frequent and had an inhibitory effect on fruit set. Roberts and Struckmeyer (1944), as a result of their investigations, suggested spraying the flower clusters only once for best results. Moore (1950) found that a maximum of six applications of the hormone to flower clusters produced the best set. A second possible reason for the reduced set was the concentration of 30 parts per million at which the hormone was used in this experiment. Murneek (1947), using the same hormone as used in this experiment, suggested a concentration of 10 to 15 parts per million as being optimum for flower cluster sprays. However, Moore (1950) and Singletary and Warren (1951) used the same concentration of the hormone as used in this experiment and reported no adverse effects.

Under the conditions of the fall experiment, slightly more fruit was produced by the plants receiving a hormone than the untreated plants. The differences, however, were not statistically significant. The data from both spring and fall experiments indicate that the application of hormone sprays do not produce a greater number of fruit when applied to plants growing under conditions of high nitrogen availability. As shown by Work (1924) large applications of nitrate fertilizer alone will not bring about a condition of heavy vegetation and fruitfulness in plants.

In the spring experiment the application of nitrogen, with or without a hormone, increased the average weight of individual fruits in most treatments.

Only the plants receiving 150 pounds of nitrogen in two applications, or 300 pounds of nitrogen in four applications, both without a hormone, produced smaller fruits than the check. When a hormone spray was applied to the plants, in conjunction with the nitrogen, the size of the individual fruits was increased considerably. For example, the treatment 150 pounds of nitrogen in two applications without a hormone produced fruits averaging 4.3 ounces. Other plants which received the same treatment but, in addition, a hormone spray during the season, produced fruits which averaged 8.3 ounces or almost twice as large. Because the hormone-treated plants produced fewer fruits, the competition for food was reduced and individual size was increased. This fact may account for a slight increase but the greatest impetus was apparently furnished by the hormone. The tendency of hormones to produce large fruits varies with the variety, the hormone, the concentration and environmental conditions, but these determinations were not within the scope of this experiment.

The application of nitrogen alone to plants in the fall experiment produced very little difference in the average weight of the fruits harvested. No amounts of nitrogen alone produced larger fruits than the check. This would indicate that ample nitrogen was available to the plants for the formation of fruit in the original soil and any added nitrogen was not utilized by the fruit. When a hormone spray was applied, in addition to the nitrogen, the average size of the harvested fruits was increased considerably. The increase in size due to the hormone spray ranged from 33 to 47 per cent in the various, comparable treatments. The hormone, applied to flowers, was apparently able to attract additional nutrients by some means to the fruit where it was utilized. Under the conditions of this experiment nitrogen was not limited, for the addition of high amounts of nitrogen fertilizer produced no larger fruits than the check. The plants, however, seemed unable to use all the nitrogen present unless a hormone was applied to the plants. This application increased the availability of the nitrogen to the fruit and, in consequence, larger fruits were produced by the use of hormone sprays.

One of the greatest values of a growth-regulator spray observed in both spring and fall experiments was its effectiveness in reducing the number of small tomatoes. Fruit too small to be marketed was seldom found on the hormone-treated plants, whereas a considerable number were found on the non-hormone-treated plants, especially during the middle and later stages of the experiment. The use of the hormone was especially favorable during the fall experiment, when the size of fruits was relatively small as compared with those harvested during the spring. Because of the small total yield any method which would produce all marketable fruit, or an increase in the number of marketable fruit, from those harvested, would be of considerable commercial value. Murneek et al (1944) also concluded from their research that hormone sprays tended to make the fruit more uniform in size or weight.

All treatments of the spring experiment produced earlier fruit than the check (Table 4), with the hormone-treated plants producing a higher percentage of their total fruits during the early part of the experiment than the plants receiving no hormone. During the latter part of the harvest season the situation was reversed with the hormone-treated plants producing less fruit. In the fall the same general trend was also apparent. The application of nitrogen alone produced slightly earlier yields than the check, while the application of nitrogen and a hormone spray resulted in a considerable increase in the early yield. When the harvest season is divided into three equal periods the hormone-treated plants produced approximately one-third of their total yield in each period. The untreated plants, on the other hand, produced slightly less than one-third in the first period and slightly more than one-third in the third period.

This general trend of harvesting is in agreement with that of Mann and Minges (1949) who suggested that the application of a hormone shifted the yield of fruit to an earlier period and did not necessarily increase the yielding capacity of the plants. It was extremely unlikely in this experiment, however, that the yields of non-hormone treatments could have approached those of hormone treatments, even in a longer harvest season.

Differences in color of the foliage of the various treatments were striking. As expected, the check plants in the spring experiment were chlorotic and vines were small and spindly. The 150 pound nitrogen treatment in two applications with a hormone produced plants similar in size and color to those of the check. This coincides with the findings of Murneek et al (1944) that sprayed plants were subsequently of a smaller stature and their foliage of a paler green color than unsprayed plants. However, the difference in weight of fruits produced by these two treatments was especially striking - 7.1 pounds per plant in the check as compared with 12.0 pounds per plant for the 150 pound nitrogen treatment. The other 150 pound nitrogen treatment, as well as the 50 and 300 pound nitrogen treatments, with and without a hormone, produced plants which were very vigorous and of a dark green color.

A definite gradation of color in the plants was observed during the fall experiment. The check and 50 pound nitrogen treatments contained the most chlorotic plants while the higher applications of nitrogen produced a deep green color in the plants. The application of hormone sprays apparently had little effect on the color of the plants in the fall experiment.

Height of plants varied with the treatment and the season. During the spring experiment the low rates of nitrogen produced the smallest plants. The largest plants were produced by the application of 300 pounds of nitrogen. Plants receiving 150 pounds of nitrogen were vigorous and large but those receiving, in addition, a hormone spray, were short and chlorotic. This difference probably can be accounted for by the number of fruit being produced. The hormone-treated plants produced the greater number of fruit and consequently diverted more nitrogen to the fruits. Murneek (1926) has suggested that the tomato fruit in some way is able to monopolize practically all of the incoming or elaborated nitrogen, thus causing an evident shortage in the strictly vegetative parts of the plant.

SUMMARY AND CONCLUSIONS

Tomato plants were grown in a greenhouse ground bed to which nitrogen in various quantities and number of applications was applied by banding. A hormone, p-chlorophenoxyacetic acid at 30 parts per million, was applied with an atomizer to approximately one-half the plants. The experiments were conducted in the spring of 1952 and in the winter of 1952-1953.

In both experiments the highest nitrogen applications without a hormone spray produced vigorous plants with a low yield of fruit, by weight, suggesting an approach to a highly vegetative, unfruitful condition. There was less variability in the fall experiment than the spring, which was probably due to the increased fertility of the soil at the beginning of the fall experiment. By applying a growth regulator to the vigorous, unfruitful plants, the unfruitful condition was overcome and increases in yields ranging from 31 to 72 per cent in the spring, and 34 to 58 per cent in the fall, were produced over the comparable, unsprayed treatments. The use of a hormone spray in tomato culture under glass would seem to be justified as a result of these increases in yield, and considering the time consumed in applying the hormone.

The spring experiment produced a significantly greater yield than the fall experiment which supports the belief of many commercial growers that raising only a spring crop is the most economical practice.

The number of applications by which the nitrogenous fertilizer was applied influenced the total yield and average weight per fruit. This influence was more readily apparent in the spring experiment. High amounts of nitrogen, applied over a period of several weeks, and extending well into the growing season, caused a decrease in total yield and size of individual fruits as compared with the same amounts of nitrogen applied over a shorter period early in the growing season.

All treatments receiving a hormone produced earlier fruits than untreated plants. The change in the time of harvest brought about by the use of hormone sprays should be of considerable interest to commercial growers of tomatoes who receive their highest prices for early produce.

Hormone treatments produced no significant difference in the number of fruits. In some instances the number of fruit set by using a hormone spray was actually less than that of untreated plants. However, the uniformity of size and the number of marketable fruits were increased by the use of a hormone.

Size of individual fruits was increased considerably by hormone sprays. This is of special importance in the fall experiment where the average size of fruits harvested is small in any event.

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APPENDIX I

TOTAL NUMBER OF FRUITS HARVESTED, SPRING EXPERIMENT

Date	Treatment 1			Treatment 2			Treatment 3			Treatment 4			Treatment 5		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
4/19-5/23	9	13	8	12	30	12	10	23	20	16	17	16	5	27	13
5/24-6/18	48	45	67	57	39	52	53	66	67	78	34	67	56	56	42
6/19-7/14	46	48	24	43	29	56	49	41	36	45	33	71	67	50	33
Total	103	106	99	112	98	120	112	130	123	139	84	154	128	133	88

Date	Treatment 6			Treatment 7			Treatment 8			Treatment 9			Treatment 10		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
4/19-5/23	15	19	9	24	17	25	18	36	16	14	21	25	29	31	26
5/24-6/18	49	47	54	38	52	65	47	49	63	42	45	55	46	31	69
6/19-7/14	54	35	72	35	18	13	3	7	15	46	24	26	27	33	47
Total	118	101	135	97	87	103	68	92	94	102	90	106	102	95	142

TOTAL WEIGHT OF FRUITS HARVESTED IN OUNCES, SPRING EXPERIMENT

Date	Treatment 1			Treatment 2			Treatment 3			Treatment 4			Treatment 5		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
4/19-5/23	44	52	40	60	160	71	52	103	102	75	89	84	25	114	65
5/24-6/18	236	219	339	301	217	249	272	272	425	338	182	271	220	295	258
6/19-7/14	194	191	99	205	155	284	194	140	169	204	125	248	234	265	167
Total	474	462	478	566	532	604	518	515	696	617	396	603	479	674	490

Date	Treatment 6			Treatment 7			Treatment 8			Treatment 9			Treatment 10		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
4/19-5/23	78	83	44	181	147	215	165	258	157	130	132	178	205	220	215
5/24-6/18	241	208	152	345	474	551	395	401	579	380	392	493	363	257	523
6/19-7/14	204	131	226	211	106	74	11	49	84	301	140	133	164	138	260
Total	523	422	422	737	727	840	571	714	820	811	714	804	732	615	1003

TOTAL NUMBER OF FRUITS HARVESTED, FALL EXPERIMENT

Date	Treatment 1			Treatment 2			Treatment 3			Treatment 4			Treatment 5		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
12/3-12/29	13	8	11	19	10	20	15	7	15	12	11	13	21	17	9
12/30-1/23	32	23	29	29	17	24	36	37	28	30	44	18	33	25	28
1/24-2/20	37	24	44	29	31	45	35	50	35	43	35	41	39	38	19
Total	82	55	84	77	58	89	86	94	78	85	90	72	93	80	56

Date	Treatment 6			Treatment 7			Treatment 8			Treatment 9			Treatment 10		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
12/3-12/29	21	29	17	19	26	26	14	14	26	17	25	23	24	24	24
12/30-1/23	34	32	29	39	33	27	48	39	32	36	36	29	39	24	28
1/24-2/20	36	26	24	38	28	29	20	28	29	32	31	24	21	23	26
Total	91	87	70	96	87	82	82	81	87	85	92	76	84	71	78

TOTAL WEIGHT OF FRUITS HARVESTED IN OUNCES, FALL EXPERIMENT

Date	Treatment 1			Treatment 2			Treatment 3			Treatment 4			Treatment 5		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
12/3-12/29	65	31	59	97	49	88	67	41	80	54	55	64	65	85	36
12/30-1/23	122	72	112	153	54	79	151	117	100	133	156	57	122	98	94
1/24-2/20	114	71	178	111	98	106	109	167	128	158	112	97	114	126	71
Total	301	174	349	361	201	273	327	325	308	345	323	218	301	309	201

Date	Treatment 6			Treatment 7			Treatment 8			Treatment 9			Treatment 10		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
12/3-12/29	136	175	82	114	155	138	76	93	174	101	151	144	127	145	113
12/30-1/23	142	166	135	186	177	130	190	178	175	190	158	162	165	153	119
1/24-2/20	149	143	131	175	128	112	112	137	149	129	158	142	86	116	97
Total	427	484	348	475	460	380	378	408	498	420	467	448	378	414	329

STATISTICAL ANALYSIS

Fall.

Analysis of covariance with X= number of tomatoes per plot and Y = weight of tomatoes per plot showed that the estimate of linear correlation between X and Y within the same treatment, date, and replication is r = 0.77 with 57 degrees of freedom. This is statistically significant far beyond the 0.1% level. Also the 95 per cent confidence interval on the true coefficient of linear correlation is:

$$CI_{95}: \quad +0.64 \leq \rho \leq +0.86.$$

It was concluded that treatment, data, and treatment x date effects should be studied by the analysis of covariance. Results are as follows:

Sources of Variation	D/F	$S(x^2)$	$S(xy)$	$S(y^2)$
Treatments	9	226.63 ns	2,341.78	49,184.00***
Dates	2	3,909.43***	9,425.82	25,075.29***
Replications	2	142.29 ns	519.96	2,195.49 ns
Treatment x Date	18	1,790.57***	5,450.96	18,366.93 ns
Remainder	58	2,229.04	7,910.70	47,825.18
Total	89	8,297.96	25,649.22	142,646.89

Sources of Variation	D/F	Sum of Squares of EE	Ms.
Remainder	57	19,750.68	346.50
Adjusted Treatment x Date	18	2,025.69	112.54 ns
Adjusted Treatments	9	34,454.15	3,828.20***
Adjusted Dates	2	4,187.28	2,093.60**

Treatment	No.	Observed Weight	Adjusted Weight
1	24.56	91.56	100.1
2	24.89	92.78	100.2
3	28.67	106.67	100.7
4	27.44	98.44	96.8
5	25.44	90.11	95.6 ***
6	27.56	139.89	137.8
7	28.44	146.11	140.9
8	27.78	142.67	139.8
9	28.11	148.33	144.3
10	25.89	124.56	128.4

DATE MEANS

	No.	Observed Weight	Adjusted Weight
12/13 - 29	17.7	95.3	128.2
12/30 - 1/23	31.3	134.9	119.6
1/24 - 2/20	32.0	124.1	106.3

Spring.

The correlation between number of fruits on a plot and their weight is at least as high as in the fall. Specifically,

$$CI_{95}: \quad +0.73 \leq \rho \leq +0.90,$$

and again it is concluded that treatment, date, and treatment x date effects should be studied by the analysis of covariance. Following is the analysis obtained:

Sources of Variation	D/F	$S(x^2)$	$S(xy)$	$S(y^2)$
Treatments	9	1,492.54 ns	-7,851.76	145,307.66***
Dates	2	17,518.20***	104,711.60	712,526.42***
Replications	2	366.87 ns	2,477.04	17,555.49 ns
Treatment x Date	18	5,081.36**	30,331.73	265,677.58***
Remainder	58	7,407.13	33,101.96	212,977.84
Total	89	31,866.10	162,770.57	1,354,044.99

Sources of Variation	D/F	Sum of Squares of EE	Ms.
Remainder	57	65,047.43	1,141.2
Adjusted Treatment x Date	18	91,404.66	5,078.0**
Adjusted Treatments	9	221,598.04	24,622. **
Adjusted Dates	2	98,477.86	49,239. ***

Treatment	No.	Observed Weight	Adjusted Weight
1	34.22	157.11	166.1
2	36.67	179.11	177.1
3	40.56	192.11	172.8
4	41.89	179.56	154.3
5	38.78	182.56	171.2] ns
6	38.22	151.89	143.0 *
7	31.89	256.00	275.4
8	28.22	233.78	269.6
9	33.11	258.78	272.7
10	37.67	261.11	254.7

DATE MEANS

	No.	Observed Weight	Adjusted Weight
4/19-5/23	18.5	119.8	199.0
5/24-6/18	52.6	328.6	255.4
6/19-7/14	37.5	170.2	164.5

Explanation of Symbols Used:

ns - Not significant
** - Significant at 1% level
*** - Significant at 0.1% level
* - Significant at 5% level

A STUDY OF THE HORMONE EFFECTS ON TOMATOES GROWN IN NITROGEN RICH SOIL

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1952

AN ABSTRACT OF A THESIS

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ABSTRACT

The objectives of this study are: (1) to review and summarize previous work on the related subjects, (2) to determine the effect of high levels of nitrogen on tomato plants, (3) to study the effectiveness of plant growth substances or hormones on plants growing in nitrogen-rich soil, (4) to study the effectiveness of the hormone in promoting earlier ripening of the fruit, and (5) to determine what relationships exist, if any, between the effectiveness of hormones applied under various carbohydrate-nitrogen levels.

Tomato plants were grown in a greenhouse ground bed to which nitrogen in various quantities and number of applications was applied by banding. A hormone, p-chlorophenoxyacetic acid at 30 parts per million, was applied with an atomizer to approximately one-half the plants. The experiments were conducted in the spring of 1952 and in the winter of 1952-1953.

In both experiments the highest nitrogen applications without a hormone spray produced vigorous plants with a low yield of fruit, by weight, suggesting an approach to a highly vegetative, unfruitful condition. There was less variability in the fall experiment than the spring, which was probably due to the increased fertility of the soil at the beginning of the fall experiment. By applying a growth regulator to the vigorous, unfruitful plants, the unfruitful condition was overcome and increases in yields ranging from 31 to 72 per cent in the spring, and 34 to 58 per cent in the fall, were produced over the comparable, unsprayed treatments. As a result of these increases in yield, and considering the time consumed in applying the hormone, the use of a hormone spray in tomato culture under glass would seem to be justified.

The spring experiment produced a significantly greater yield than the fall experiment which supports the belief of many commercial growers that raising only a spring crop is the most economical practice.

The number of applications by which the nitrogenous fertilizer was applied influenced the total yield and average weight per fruit. This influence is more readily apparent in the spring experiment. High amounts of nitrogen, applied over a period of several weeks, and extending well into the growing season, caused a decrease in total yield and size of individual fruits as compared with the same amounts of nitrogen applied over a shorter period early in the growing season.

All treatments receiving a hormone produced earlier fruits than untreated plants. The change in the time of harvest brought about by the use of hormone sprays should be of considerable interest to commercial growers of tomatoes who receive their highest prices for early produce.

Hormone treatments produced no significant difference in the number of fruits. In some instances the number of fruit set by using a hormone spray was actually less than that of untreated plants. However, the uniformity of size and the number of marketable fruits were increased by the use of a hormone.

Size of individual fruits was increased considerably by hormone sprays. This is of special importance in the fall experiment where the average size of fruits harvested is small in any event.