THE EFFECT OF N-M-TOLYLPHTHALAMIC ACID AND INDOLE ACETIC ACID ON CERTAIN MORPHOLOGICAL RESPONSES IN THE TOMATO AND PROBABLE INFLUENCE ON THE ACTION OF CERTAIN GENES

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INTRODUCTION

The tomato is a important food crop which has a high vitamin content, and is a favorite vegetable everywhere.

Oklahoma's climate generally is not favorable to tomato production, due to certain environmental conditions, especially warm weather. Because of this, tomato breeding for climatic adaptation is a major phase of the vegetable improvement work of the Oklahoma Agricultural Experiment Station. In this work, the growth habit of the tomato plant is of special interest.

As the tomato plant grows, the inflorescence is differentiated as terminal structure. Leaves differentiate at the side, and shoots develop in the axil. The shoots carry the inflorescences upward so they appears to come from the internodes of the stem. When the stem continues to elongate throughout the life of the plant, the inflorescence is said to be indeterminate. When growth of the stem is eventually terminated by the inflorescence it is determinate.

The characters of tomato which express the determinate and indeterminate inflorescences are referred to as alleles Sp and sp. The intermediate or partly determinate type of tomato is said to result from the interaction of a modifier of the sp allele. A similar modifier might also account for the extremely determinate type of growth. These modifiers all relate to the correlative relationship between the flower cluster and vegetative shoot.

It is reasonable to assume that the different growth habits depend on natural hormones. These hormones may be at different levels in plants, thus accounting for the different types of growth, which are attributed the alleles Sp, sp, and their modifiers. Since it is known that the growth habit of the tomato can be modified or changed by the application of certain plant growth substances it is likely that these materials might be used to disclose the physiological basis for the action of the "growth-habit" genes.

The strongly linked leafy-cluster and jointless pedicel characteristics (lf and j respectively) are of similar interest. It has been suggested that these may arise from the action of a single gene. It also has been demonstrated that the number of leaves in the cluster is reduced when the j factor is associated with the sp gene for indeterminate growth. The question might be asked, "Can the leafyness of the cluster be reduced in plants caused to be strongly determinate by the application of a growth substance?"

The growth substance n-meta-tolylphthalamic acid commercially known as Duraset, is known to modify the growth habit of the tomato. Specifically it increases the degree of determinateness in the plant.

Modern geneticists and biochemists have come to the conclusion that genes are able to influence the plant or to cause the formation of enzymes which in turn promote or catalyze a given biochemical process. The "one-gene, one-enzyme, one-chemical reaction principle" is a basic concept in modern genetics.

It has been shown that a chemical growth substance such as n-meta-tolylphthalamic acid can be used to block the action of a gene (Sp) in the tomato. It is possible that continued studies with this

chemical may reveal the true basis for the action of this and other genes in this species.

Geneticists have shown that in many instances the dominant gene represents the presence of something, the recessive gene, its absence (presence-absence theory). When this relationship exists it might be expected that the dominant gene represents the presence of an enzyme capable of synthesizing a specific plant hormone which causes a specific growth response.

The objectives of this study were:

A. To observe the effect of n-meta-tolylphthalamic acid alone on the growth habits of determinate and indeterminate varieties of tomatoes.

B. To see if an auxin (indoleacetic acid) when applied in conjunction with n-meta-tolylphthalamic acid, will neutralize the effects of the latter when applied to determinate and indeterminate plants.

C. To obtain additional information on the genes j and lf by means of the application of a growth substance.

D. To observe the effect of chemically induced determinateness on the leafiness of the clusters in plants bearing the lf gene.

REVIEW OF LITERATURE

1. Genetics and Growth Habit of Tomato

Crane (3), first to describe mode of growth of the tomato, observed that the inflorescence originates as a terminal bud and that the vegetative bud is lateral to this. He also observed that the vegetative shoot arose from the axil of the leaf. He classified plants as having simple infloresences as normal or usual type.

Determinate type of growth in the tomato was described by Yeager (25). It is illustrated by the terminal "self-pruning" plant having inflorescences at the terminal of the branches.

Jones and Rosa (7) in describing the growth pattern for the tomato, indicated that lateral branches may arise from each leaf axil, though not all of them develop, unless the growing point of the stem is removed (2). After initiation of the infloresence, an axillary shoot arises from the adjacent node, develops 3 to 6 nodes, and is terminated again in an inflorescence. This may be repeated an indefinite number of times, until the stem becomes several feet long, bearing fruit clusters throughout its length. The peduncle is often adnate, being united with the main axis for a short distance. This arrangement makes the inflorescences appear to arise from the internode.

The common tomato was described by Morrison (14) as a tender, herbaeous, short-lived perennial plant having slender, more less hairy,

decumbent stems and commonly attaining a height of two feet or more while in full vigor of growth, before being borne down by the weight of fruit. He also described dwarf tomato types with short internodes that are determinate in habit of growth; e.g., the branches terminate in a cluster of blossoms, suggesting the term "self-topping".

Young and MacArthur (24) reported on indeterminate and determinate, or self-topping, stem-alleles, Sp-sp, the F_2 segregating 3 indeterminate to 1 self-topping. Some of the plants have the determinate habit of growth so extremely that they are almost leafless. They also reported leafy alleles Lf and lf, and jointless alleles J and j. The leafy inflorescence alleles segregated 3 ordinary to 1 leafy while jointless flower pedicel alleles segregated 3 jointed (J) to 1 jointless (j) in the F_2 generation. The same authors also described the "giant terminal flower" (fasciation) as being associated with extreme determinate growth habit. The Early Red variety exhibited extremely determinate growth and fasciation in its flowers and fruit (15,27). Fasciation is assumed to be due to a recessive gene (f) which is intensified by environmental conditions such as low temperature and high nitrogen (22).

Rick and Sawant (16) also described jointless pedicel (j) and leaf cluster (lf). These workers indicated that the tendency for these two genes to appear together in so many mutants hints very strongly that are closely associated in development. They further stated that the tendency for the gene sp, which supresses vegetative growth, also apparently subdues leafy growth of the inflorescence. This leads us to the conclusion that leafiness and jointlessness may be pleiotropic effects of a single gene, (j). The sp gene, therefore, offers a partial solution to the problem of leafiness associated with (j).

2. Previous Work on N-meta-tolylphthalamic Acid

The n-arylphthalamic acids were first described by Hoffmann and Smith (6). At low concentrations they stimulated fruit set in the tomato, and the production of seedless fruits. Thus, the test plants actually seemed to be more vigorous than unsprayed check plants. However, as the concentration of the chemicals was increased, the formative effects became more pronounced and fruit set was inhibited.

Leopold (12) indicated that phthalamic acid derivatives are auxin synergists which promote growth at low concentrations, in the presence of auxin, and inhibit growth at high concentrations.

Wittwer and Teubner (20) indicated that treatment of tomato plants with Duraset when the cotyledons were expanded had no effect on flower differentiation. Application of 300 ppm one week later showed an increase in flower number that was significantly greater than that in the controls. Although the number of flowers was also increased by 400 ppm of Duraset, the main axis tended to terminate with the first flower cluster.

These same authors (21,23) further showed that increased flower number and fruit production of Spartan Hybrid and Michigan-Ohio Hybrid tomato varieties may also be attained by spraying with n-meta-tolylphthalamic acid at 200 ppm during the time when inflorescences are being formed. The resulting compound clusters had two to four times the normal number of flowers and were composed of several branches.

Applied to field grown tomatoes, Duraset at 500 ppm caused the formation of large flowers; at 750 ppm increased yields to about 250 percent (13).

Cordner and Hedger (5) reported that the primary effect of the

growth regulator, Duraset, at 400 ppm with 1 to 4 applications and with 5 varieties, Margolbe, Okla 35, 19-1-2, 20-1-1, and Okla 20 D was to delay or to prevent the resumption of growth in the stem following the initiation of the terminal inflorescence. The functioning of the gene for indeterminate growth was neutralized temporarily or permanently. This resulted in more flowers, larger and longer peduncles, and finally the fasciation or multiplication of the parts of the individual flowers.

3. Effects of Auxins

In 1950 Bonner (1) stated that indoleacetic acid is known to occur widely in the tissues of higher plants, where it is phsiologically active in the promotion of cell elongation. It also is active in increasing the number of flower primordia (10), and in the development of new roots (26). It may also cause the promotion of a number of other morphological of histological changes, such as epinasty, new root growth, callus growth, axillary buds, etc.

The position of lateral shoots is determined by the balance derived from the effect of auxin from the terminal (17). Skoog also reported that in many species the change in the apical meristem from vegetative to reproductive growth is characterized by a broadening and thickening of the cells at the expense of elongation, indicating, the existence of specific reproductive stimuli or flowering hormones.

It has been suggested by Loomis (9) that the application of high concentrations of auxin to young tissues causes swelling, a reaction that may entail both cellular enlargement and division.

The principal modifications induced by growth substances are changes in flowering habit, size, shape, patterns, and venations of organs (32).

The blade of the leaf is reduced in area and its veins converge toward the midrib. Leaves often fail to separate from each other, flower buds may become tubular and form large modified organs or cups where sepals fail to separate, and ovaries frequently develop into seedless fruit. Flowering may be modified, especially by derivatives of benzoic acid.

Regardless of the method of treating plants with growth substances, there are a number of responses which are more or less characteristic for certain groups of chemicals, such as a-phenoxybutyric acid, a-(m-chlorophenoxy)propionic acid and 2,4-dichlorophenoxyacetic acid (31). With tomato plants as the only test subjects, these active growth substance reponses in general may be as follows: induced cell elongation (local curvatures from unilateral application and epinasty of leaves), adventitious roots on stems (leading to the practical propagation of plants), parthenocarpy of ovaries without fertilization of eggs (production of seedless fruit), inhibition of growth of buds and death of tissue with higher concentrations (leading to the use of hormones as selective herbicides), and modification of the pattern of leaves with certain growth substances.

Zimmerman and Hitchcock (30) reported that 2-chloro-3,5-diiodobenzoic acid applied to growing tomato plants was sufficient to cause modification of growth of the stem, leaves and flowers. It caused axillary buds to grow flower clusters instead of the normal leafy shoots and induced the terminal bud to terminate with flower clusters instead of continuing with leafy shoot. The flowers on tomato plants grown under the influence of 2-chloro-3,5-diiodobenzoic acid were small with inconspicious petals and with sepals supported by an abnormally stout peduncle.

In another study (28) Zimmerman and Hitchcock showed that tomatoes treated with 2,3,5-triiodobenzoic acid had similar internodes and axillary and terminal flower clusters (29). They were characterized by heavy peduncles, with extremes from short to long, and fasciated flowers mixed with small buds.

In 1949 Kramer and Went (8) stated that auxin production in tomato plants was found to increase with age.

Clark and Kerns (4) found that low concentrations of a-naphthaleneacetic acid applied as foliage sprays, induced formation of inflorescences in advance of the normal period in pineapple. High concentrations, particularly when applied at the apex, delayed flowering (11).

It was demonstrated by Skoog, Schneider and Malan (18) that tissues, such as roots and shoots or adjacent tissue layers in the stem, may have different auxin concentration requirements for growth. These requirements will vary for each organ in successive stages of development. They stated that high concentrations highly active auxins also lead to growth inhibition because of the effective blocking of one molecule by another from simultaneous contact with both enzyme and substrate.

A small amount of auxin brings about a disproportionate amount of growth (19). Auxin brings about its growth promoting action by combining with special substrates, while 2,3,5-triiodobenzoic acid apparently acts as an auxin synergist.

EXPERIMENTAL METHODS AND MATERIALS

I. Varieties:

The special characteristics of the experimental tomato varieties under consideration in this study are given in Table I.

A. Okla 20 D is dwarf (d) in growth habit. It is upright and has a stout stem with broad deep green leaflets. It is never spreading. It usually has about 6 flowers in clusters which are separated by an average of 1.3 nodes. A few flowers (about 4.5%) are fasciated.

B. Okla 35 is an "intermediate" (Sp-) type plant and is moderately vegetative. The flower clusters appear more frequently than these in Rutgers (separated by 2.0 nodes). They are separated by two to three leaves at first, but appear more frequently later. Some of the plants become determinate with the fourth inflorescence and about 6 flowers are found in each cluster.

C. Rutgers is a typical indeterminate (Sp) type with plants that are quite vegetative. Flower clusters appear at every third internode and the stems elongate indefinitely. This variety has the dominant gene for all alleles under consideration in this study. It usually has about 6 flowers in cluster.

D. Okla 55 is partially determinate (Sp-) or intermediate with an average of 2.4 nodes between the clusters. The flowers are characterized by jointless pedicels, (j) and by leaves in the cluster

TABLE I

CHARACTERISTICS OF SPECIAL INTEREST OF THE EXPERIMENTAL TOMATO VARIETIES IN THIS STUDY

Variety	Degree of Determinateness	No. of nodes cotyledon to 1st cluster	Nodes between clusters: 1st to 2nd	2nd to 3rd	3rd to 4th	Ave.	Fl./cl.** clusters 1-3	Ave.*** leaves per cl.	% ** fasc. flowers	Genes of Interest
Okla 20 D*	Determinate	6.7	1.3	1.3	1.2	1.3	6.4	0	4.5	sp@, f, j, LF, d
Okla 35*	Intermediate	8.0	2.7	1.6	1.6	2.0	6.1	0	0	Sp@, F, J LF, D
Rutgers*	Indeterminate	7.3	5.0	3.3	3.3	3.9	6.4	0	0	Sp@, F, J LF, D
Okla 55**	Interminate	8.5	2.6	2.1	2.5	2.4	3.5	1.7	0	Sp@, F, j lf, D

* Each figure represents the average of 6 untreated plants.
** Each figure represents the average of 10 untreated plants.
*** Average for first 3 clusters on main axis.
** See Young and MacArthur (24). Note that Rutgers has all dominant genes.
@ Sp- indicates intermediate determinateness and sp- indicates a strongly determinate growth habit.

(1f). Clusters on untreated plants average about 1.7 leaves and 3.5 flower.

2. Methods:

A. The conditions of plant growth.

Seeds were planted in vermiculite on February 12, 1959. After 15 days plants were set in 2½" pots, which contained a mixture of soil, sand and peat with a ratio of 2:1:1. Twenty-two days later they were transplanted to 6" pots. These pots were placed on a bench in a greenhouse where the temperature was maintained at 60°F. at night and 70°-80°F. during the day time. All plants were grown under conditions of optimum moisture supply; i.e., watered as needed. To assure good growth during the experimental period, the plants were fertilized twice with 16:20:0. Late in the experimental period some of the laterals which were of no significance to the study were pruned off.

B. Preparation of chemicals.

In preparing the indoleacetic acid (hereafter referred to as IAA), 25 ppm was made up in aqueous solution from a stock solution of 250 ppm prepared in 95% ethanol. N-meta-tolylphthalamic acid (hereafter referred to as Duraset) was prepared directly by dissolving the technical preparation* in a minimum amount of acetone and adding this solution to water with 3 drops of detergent, so that the final concentration was 500 ppm.

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* Supplied by Dr. A. W. Feldsman of Naugatuck Chemical Division of U. S. Rubber Company.

The chemicals were sprayed on all actively growing foliage and terminal stems as a fine mist from an atomizer.

C. Treatments:

Three plants of the varieties, Okla 20 D, Okla 35 and Rutgers, and 10 plants of Okla 55 were used per treatment which began 10 days after the plants were set in the $2\frac{1}{2}$" pots. The chemical sprays were applied at four day intervals: Duraset at 500 ppm and IAA at 25 ppm. The treatment schedule is shown in Table 2.

As indicated in the above table the growth substances were applied every 4 days for 6, 9, and 16 times. It was intended that the latter treatment would be continuous for the duration of the test but due to the development of severe formative effects after 9 treatments the interval was extended from 4 to 7 days, and after 16 application the treatment was discontinued. When Duraset and IAA were used in the combination treatment, applications were separated by a 2-day interval (e.g., Duraset applied every 4 days followed 2 days later by IAA).

D. Data obtained.

Plant height was measured at 5-day intervals during the time that the treatments were being made and for 50 days following treatment.

The growth patterns of the individual plants were recorded as diagrams which showed the general form of the plants including the positions of the leaves, clusters, etc. on the stems. For each clusters, the total number of flowers, the number of fasciated flowers, the number of multiple ovaries, and the number of leaves in the cluster were noted. Photographs were taken at intervals to illustrate certain growth characteristics. The growth responses for the "during-

TABLE II

SCHEDULE OF APPLICATIONS OF DURASET (500 PPM) AND IAA (25 PPM)

Number of Applications		Dates of application of Duraset															
		3/11*	3/15	3/19	3/23	3/27	3/31**	4/4	4/8	4/12	4/19	4/26	5/3	5/10	5/17	5/24	5/31
Duraset	6x	D	D	D	D	D	D										
Duraset	9x	D	D	D	D	D	D	D	D	D							
Duraset	16x**	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
IAA+Duraset	6x	DI***	DI	DI	DI	DI	DI										
IAA+Duraset	9x	DI	DI	DI	DI	DI	DI	DI	DI	DI							
IAA+Duraset	16x**	DI	DI	DI	DI	DI	DI	DI	DI	DI	DI	DI	DI	DI	DI	DI	DI
IAA alone	6x	I	I	I	I	I	I										
IAA alone	9x	I	I	I	I	I	I	I	I	I							

* Plants were 25 days old on this date.

** The first 10 applications at 4-day interval; last 6 applications made at 7-days interval.

*** The first series of photographs were taken on April 30, 29 days after this date. Other photographs were taken May 14 and May 16.

**** IAA applied 2 days after application of Duraset.

treatment" period are contrasted with those for the "post-treatment" period.

RESULTS

1. General Responses of Plants to N-meta-tolylphthalamic Acid (Duraset) and Indole Acetic Acid (IAA)

Duraset at 500 ppm applied to young plants of all varieties caused them to wilt for a brief period. The foliage of all varieties assumed a deeper green color and some distortion in the leaflets was evident, especially when the treatment period was extended. Epinasty appeared in the terminal leaves and distortion of leaves was most severe when the plants were treated with both Duraset and IAA.

Due to the inhibition in the growth of the sympodial buds, the main stems of plants of all 4 varieties were terminated by the first cluster (in a few by the 2nd) during the time the plants were treated with Duraset. The growth of laterals also was inhibited. A wide range of aberrations in the growth of the stems, leaves, and flower clusters was associated with this delay in vegetative growth. These deviations in growth varied with variety and number of applications of the growth regulators. Thus, the plant growth substances affected the plants according to their natural degree of determinateness. In a general way, there was an increase in the degree of determinateness in the plants of each variety when Duraset was applied.

The Duraset treatments caused the clusters to initiate more total flowers, fasciated flowers and fruits, more leaves and longer thicker peduncles. The stems of treated plants showed some fasciation

and also some root primordia.

Flower fasciation was evidenced by an increase in parts (sepals, petals and anthers). The style and ovary were much flattened, the latter was rough and ribbed. Fasciation was especially severe in those flowers in a terminal position in the cluster. In some flowers 2 or 3 distinct pistils appeared. Fasciated peduncles were found in some clusters with flowers appearing in a mass at the enlarged terminal, suggesting a umbel-like inflorescence. As the cluster developed the peduncle became thickened in its terminal portion, great masses of flowers and in some cases, leaves were produced. Fasciation appeared in some plants as a widening of the stems, opposite leaves and dichotomous branching.

When the treatments were intensified peduncles sometimes failed to initiate pedicels, or flowers and pedicels were formed without the differentiation of the usual flower parts. The terminal meristems of these barren (rudimentary) pedicels and peduncles became active after treatment ceased and differentiated a flower or flowers. These were mostly distorted or fasciated and showed poorly developed and nonfunctioning pistils.

Plants sprayed with IAA alone grew more rapidly than the controls, they also showed some fasciation of flowers and leaves in clusters and root primordia on the stem.

When IAA was combined with Duraset at the lowest treatment level, the plants appeared to respond about like those treated with Duraset alone. However, vegetative growth was resumed faster and was more abundant after the treatments ceased. At the higher treatment levels the combined treatments showed rather severe formative

effects with leaflet distortion and abbreviation.

2. Okla 20 D

This is the most determinate variety used in the study, as indicated by the most frequent appearence of the clusters on the stem. As a result of the d_1 gene (Table I) the internodes are short and the leaflets thick, rugose and deep green in color (Figure 1).

Plants at all Duraset treatment levels were terminated by the first (or second) cluster at about the 6th leaf. The stems of plants sprayed 6 times terminated permanently with the first cluster, however, clusters subsequently appeared in the axils of most the leaves. These clusters were quite evident 29 days after the treatments were discontinued (Figure 2). The proportion of fasciated flowers was high. Sixteen days later (Figure 3) the plants bore multiflowered clusters with large strong peduncles but there was no renewal of vegetative growth. When the treatment period was extended to 9 and 16 applications some of the clusters were very rudimentary (reduced to peduncles and pedicels alone) due to the inhibition of flowers (Figure 4). The foliage showed considerable distortion and some leaflets were greatly abbreviated.

When IAA was combined with Duraset the results varied according to the number of times the growth substances were applied. When 6 applications were made the IAA appeared to neutralize to some extent the effects of the Duraset, and the plant showed almost normal vegetative growth (Figure 5). When the two growth substances were combined in 9 and 16 treatments each the reverse situation prevailed.

Figure 1. Untreated plant of Okla 20 D (dwarf). Photographed April 30, 1959. Note rugose foliage, short internodes, and close spacing of clusters on the main axis.

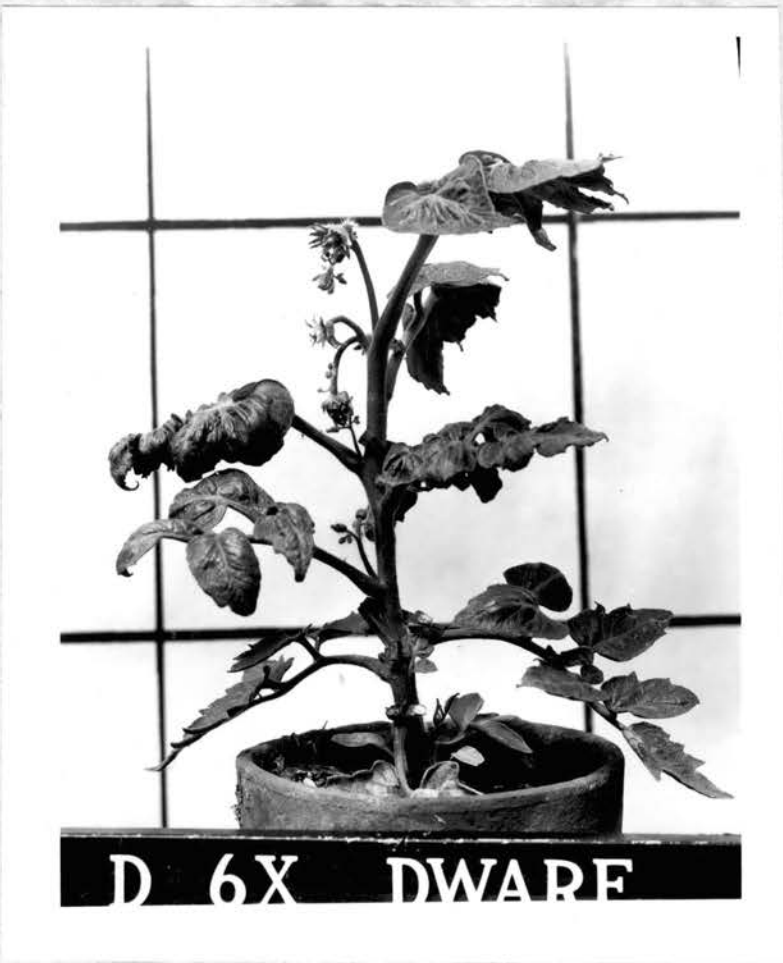

Figure 2. Plant of Okla 20 D treated 6 times with Duraset. Photographed April 30, 1959, 29 days after the last treatment. Note the older terminating cluster with large fasciated flowers, and the more recent clusters appearing in the leaf axils in place of lateral shoots.

Figure 3. Same plant as shown in Figure 2, but 15 days later. Note the long thick peduncles, abundance of flowers and absence of vegetative growth. A high percentage of flowers are fasciated, some with double or triple ovaries.

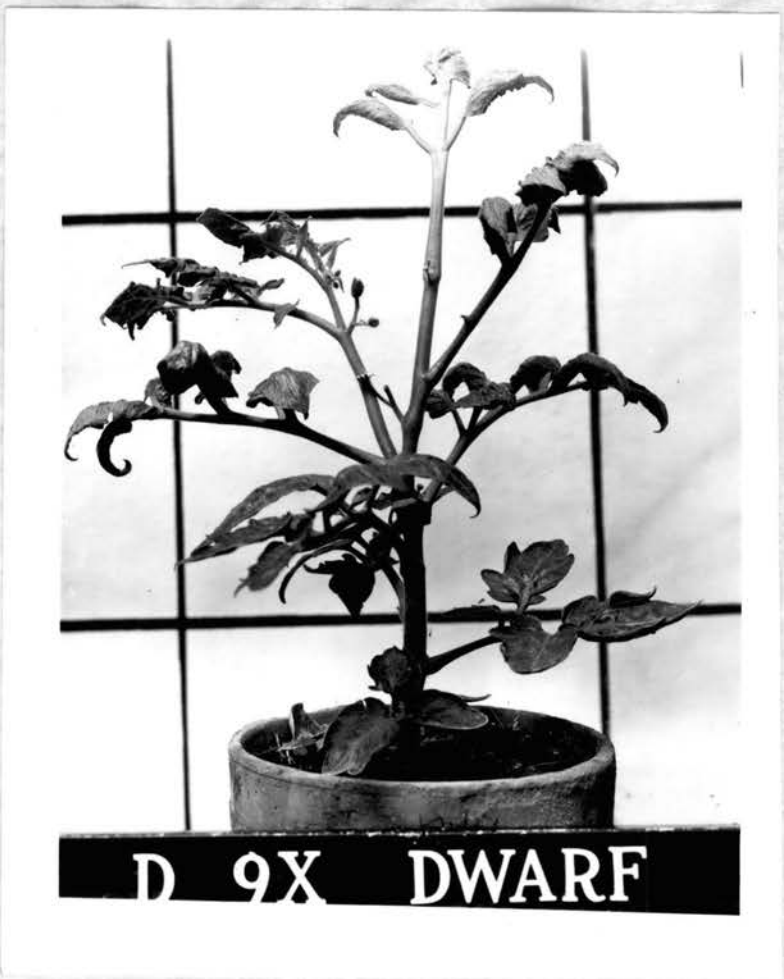

Figure 4. Nine applications of Duraset to plants of Okla 20 D. Photographed April 30, 15 days after the last treatment. Note the inhibition of flowers. Inflorescences have few flowers or are reduced to barren pedicels and peduncles. Some distortion and abbreviation in leaflets can be seen.

Figure 5. IAA combined with the Duraset in 6 applications on Okla 20 D. Photographed May 14, 43 days after treatments were discontinued. Vegetative growth was greatly enhanced and the plants showed almost normal growth of lateral stems.

The Duraset and IAA appeared to "cooperate" in producing severe formative effects in the plants with much distortion of the leaves and with abbreviated clusters. In these plants the maximum number of flowers per cluster and the greatest amount of fasciation in the flowers appeared in the cluster numbers which developed during the post-treatment period.

IAA alone did not affect this variety.

A summary of results for treatments on the Okla 20 D tomato is given in Table 3.

TABLE III

AVERAGE NUMBER OF FLOWERS PER CLUSTER, PERCENT OF FLOWERS FASCIATED AND PERCENT OF RUDIMENTARY FLOWERS IN VARIETY OKLA 20 D TREATED WITH DURASET ALONE AND DURASET PLUS IAA*

	Duraset 500 ppm											
Cluster	Ave. no. of flowers				% fasciation				% rudimentary			
No.***	control	6x	9x	16x	control	6x	9x	16x	control	6x	9x	16x
1****	6.4	18	3	2	3.8	51.5	44.5	0	0	0	29.2	66.6
2	6.8	17	8	3	5.2	43.7	41.7	20.0	0	0	25.2	60.0
3	6.0	13	7	3	4.6	34.8	36.4	25.0	0	0	0	60.0
4		11	4	4		38.5	25.0	40.0	0	0	0	58.1
5		10	1	5		34.4		16.7	0	6.5		26.6
6		8	1	7		26.0		14.3	0			18.2
7		8				22.6						

	Duraset 500 ppm plus IAA 25 ppm											
	Ave. no. of flowers				% fasciation				% rudimentary			
		6x	9x	16x		6x	9x	16x		6x	9x	16x
1		8	2	2		18.4	4.4	5		8.2	20	95
2		8	4	4		33.3	9.1	0		37.5	18.7	100
3		4	6	4		41.7	28.0	0		33.3	18.0	87.5
4		6	7	5		44.5	45.0	28.5				50.0
5		12	8	5		46.0	55.5					
6		16		7		47.0	60.0					
7		12				49.0	37.5					

* Averages for 3 treated plants and 6 control plants

** Percent of total flowers in cluster showing fasciation and rudimentary (inhibited) development.

*** According to age; cluster 1 being oldest.

**** Cluster No. 1 was initiated and developed while treatments were being applied.

3. Okla 35

This variety (Figure 6) is intermediate in growth habit. It is moderately vegetative but not as indeterminate as the variety Rutgers. In responses to the Duraset and IAA, however, it is quite similar to this variety.

Plants treated with Duraset alone became determinate, mostly at the first cluster, as did those of Okla 20 D. There was some increase in size of clusters and number of flowers. Some flowers also were fasciated as a result of treatment with 6 applications of Duraset. Nine and 16 Duraset treatments reduced the cluster size, since some pedicels and peduncles failed to initiate flowers. The plants showed formative effects in the leaflets in association with these more extended treatment periods. Sometime after the treatments ceased, laterals appeared in several leaf axils and vegetative growth was vigorously resumed (Figure 7). These new shoots contrasted sharply with the old leaves, pointing up the fact that vegetative activity had long been at a stand still in these plants. The influence of the Duraset treatments continued for some time in the post-treatment period, since larger clusters and fasciated flowers were noted in the new growth. Leaves were formed in some clusters and stems were fasciated (Figure 8).

When IAA was combined with Duraset for 6 applications the plants resumed vegetative growth after treatment was stopped with more vigor than did those treated with Duraset alone. Severe formative effects (leaf distortion and abbreviation) appeared in the 9 and 16 application series (Figure ( ). With these longer treatment periods there were more abnormal clusters and the flowers had extra large sepals and and petals. There also was a tendency for leaves to form in the clusters

Figure 6. Untreated plant of Okla 35. Photographed April 30. This variety is intermediate in growth habit and moderately vegetative.

Figure 7. Plant of Okla 35 treated 6 times with Duraset. Photographed May 16, 47 days following last treatment. Vegetative growth has been vigorously resumed and laterals have appeared in the leaf axils. Large numbers of flowers are in the cluster with many showing fasciation.

Figure 8. Okla 35 plant treated 6 times with Duraset. Photograph May 14, 45 days after treatment. Note fasciation of the stem, terminating cluster, flattened stem, opposite leaves and dichotomous branching in the post-treatment growth.

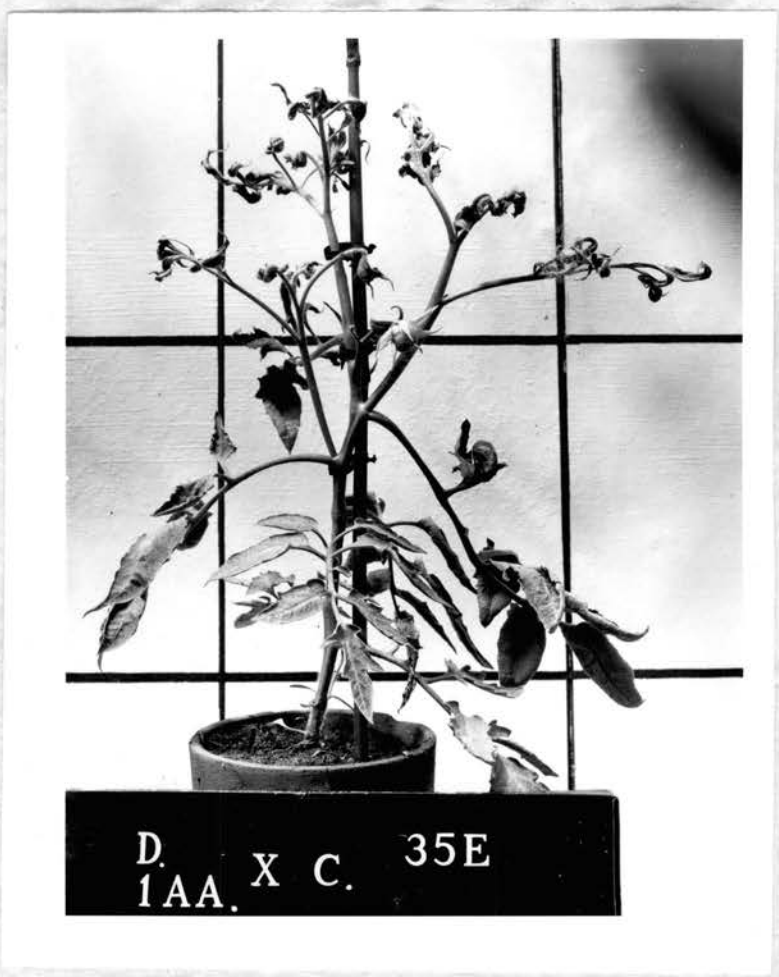

Figure 9. Plant of Okla 35 after 11 treatment with the combined Duraset - IAA. Photographed April 30. Note extreme formative effects with some leaves reduced almost to the midrib. (This plant is in the 16 treatment series)

and for root primordia to be initiated on the stems.

When IAA was applied alone with 6 and 9 applications the plants appeared to be quite similar to the control, except for some acceleration in growth rate. Leaves formed in some clusters along with a few fasciated flowers. At times there was stem fasciation and mild leaf distortion (Figure 10).

A summary of all treatments on the Okla 35 variety is given in Table 4.

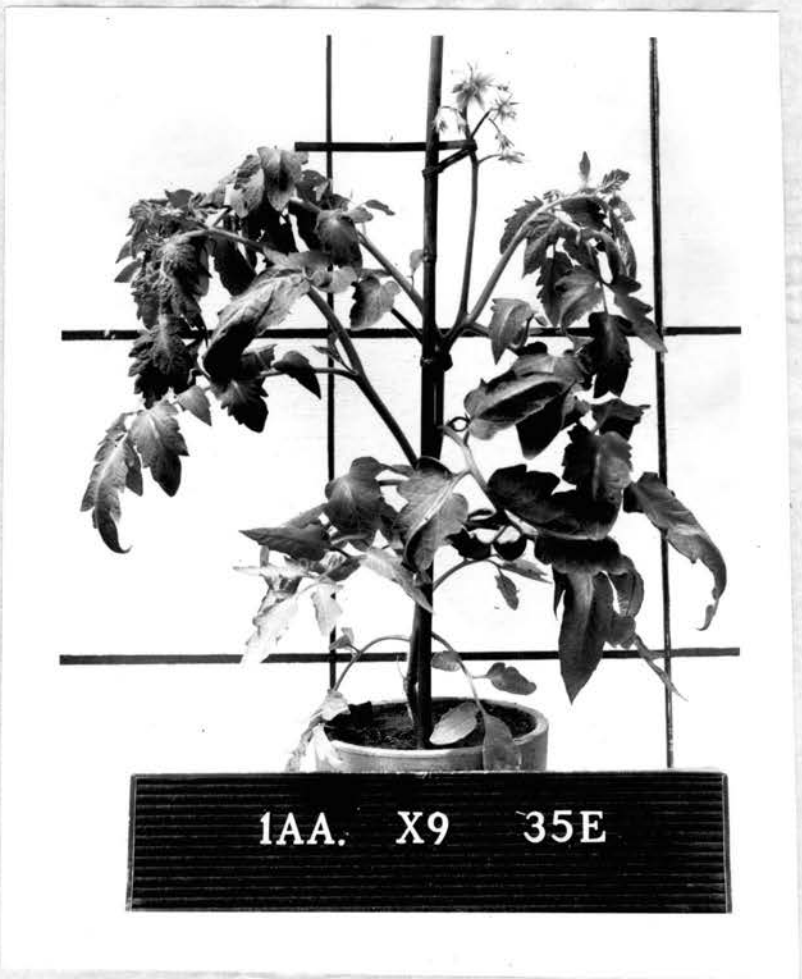

Figure 10. Plant of Okla 35 receiving 9 applications of IAA. Photographed April 30, 29 days after last application. Note fasciated flowers on the abnormally long peduncle and mild leaf distortion.

TABLE IV

AVERAGE NUMBER OF FLOWERS PER CLUSTER PERCENT OF FLOWERS FASCIATED AND PERCENT OF RUDIMENTARY FLOWERS IN VARIETY OKLA 35 TREATED WITH DURASET ALONE AND DURASET PLUS IAA*

Cluster No.***	Duraset 500 ppm: Ave. no. of flowers control	6x	9x	16x	% fasciation** control	6x	9x	16x	% rudimentary** control	6x	9x	16x
1****	6	14	7	4	0	33.3	30.8	19.1	0	0	15.4	73.8
2	6	13	7	5	0	17.0	27.0	26.6	0	0	5.0	40.0
3	6	5	9	5	0	6.7	22.6	37.5	0	0	0	37.5
4		4	8	7	0	7.7	21.3	14.3	0	0	0	33.3
5		5	12			7.2	15.0			0		
6		5	8			6.7	13.0			0		
7		6	5			5.9	0					

	Duraset 500 ppm plus IAA 25 ppm: Ave. no. of flowers 6x	9x	16x	% fasciation 6x	9x	16x	% rudimentary 6x	9x	16x
1	10	6	4	33.3	10.0	0	14.3	40.0	83.5
2	7	7	6	16.7	14.6	0	0	43.5	82.0
3.	6	7	10	13.7	18.2	0	0	54.5	76.0
4	6	12	10	5.9	18.2	13.8	0	41.0	71.0
5	6	10		0	23.2		0	53.0	56.5
6	3	9		0	30.4			0	

* Averages for 3 treated plants and 6 control plants

** Percent of total flowers in cluster showing fasciation and rudimentary (inhibited) development.

*** According to age; cluster 1 being oldest.

**** Cluster No. 1 was initiated and developed while treatments were being applied.

4. Rutgers:

Plants of this variety are indeterminate and quite vegetative (Figure 11). The clusters are separated by 3 or more leaves and the stem elongates indefinitely. The responses of this variety to the Duraset treatments were generally similar to those of Okla 35. The plants were terminated by the first (or second) cluster. The number of flowers in the cluster and the degree of fasciation were increased by increasing the treatments with Duraset. Figure 12 shows a plant receiving 6 applications of Duraset. This plant had a main stem with one lateral which showed fasciated flowers and leaves. The peduncle of the cluster on the lateral was fasciated, with 35 flowers were produced along with a few leaves (Figure 13). Twenty-nine days after the treatment ceased, the plants had made considerable recovery in vegetative growth. Laterals were developed in the axils of the terminating leaves, and elsewhere, and grew out beyond the terminating cluster. When the applications of Duraset were increased to 9 and 16 the plants showed formative effects, and some flower fasciation. With the latter there was a considerable increase in abortive pedicels and peduncles which failed to produce flowers.

The combination of IAA with Duraset at the 6-treatment level hastened vegetative recovery after the treatments ceased (Figure 14). The more severe or extended treatments of 9 and 16 applications resulted in extreme formative effects with much leaf distortion and abbreviation. A high proportion of the clusters were rudimentary and failed to initiate structures reconizable as organized flowers (Figure 15).

When IAA was applied alone and at 6 and 9 applications, a few fasciated and large flowers appeared. In general plants grew taller than the controls. Perceptible formative effects showed on some young

Figure 11. Untreated plant of Rutgers tomato. Photographed April 30. An indeterminate and very vegetative variety. The clusters are separated by 3 or more leaves and the stem elongates indefinitely.

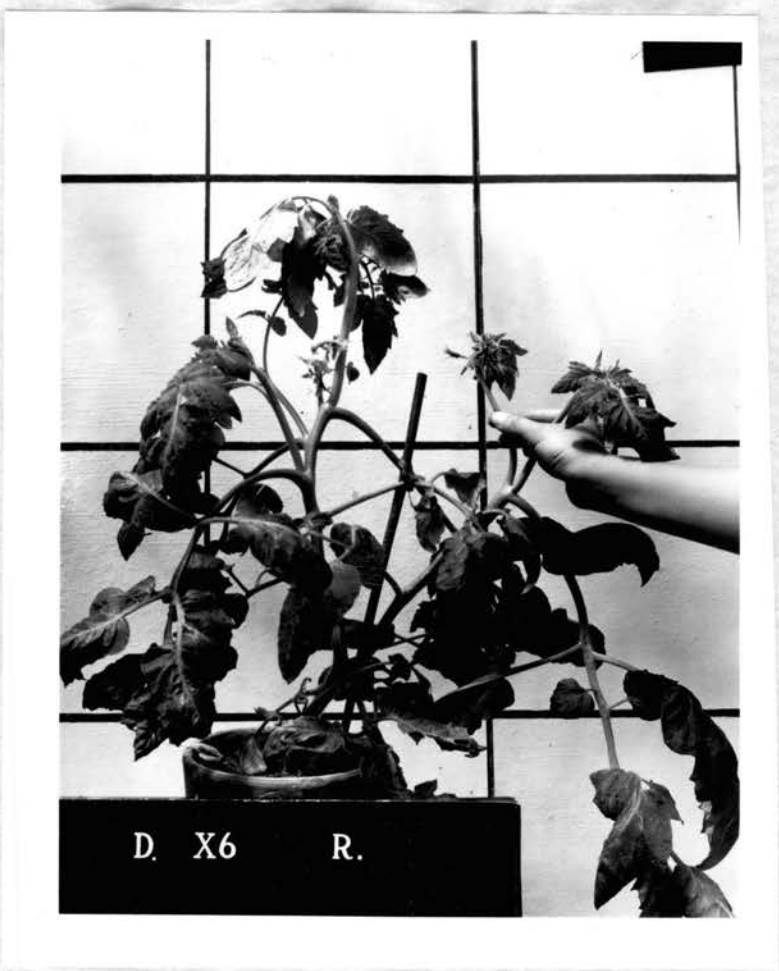

Figure 12. Rutgers plant treated 6 times with Duraset. Photographed April 30, 29 days after treatment ceased. Clusters on main stem (left) and lateral (right) terminated growth until vegetative growth was resumed in the post-treatment period. Cluster at right has many flowers (35), along with several leaves, crowded on the terminal of the fasciated peduncle.

Figure 13. Details of cluster at right in Figure 12 showing the large and thickened peduncle with 35 flowers, some fasciated with leaves, and without leaves.

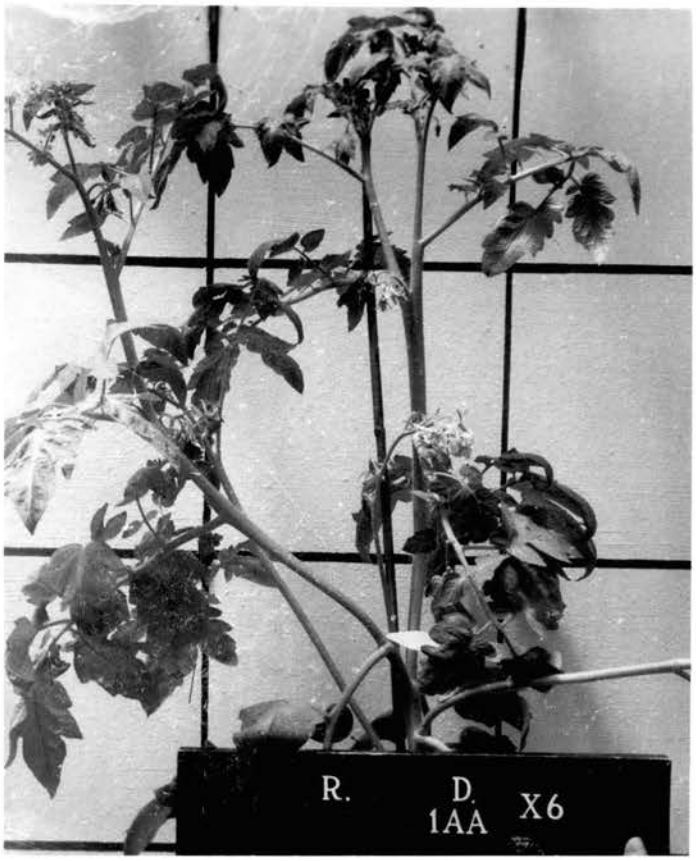

Figure 14. Rutgers tomato treated with a combination of IAA with Duraset for 6-treatments. Photographed May 14, 45 days after last treatment. Note vegetative recovery, multi-flowered clusters, and dichotomous branching in stem at right.

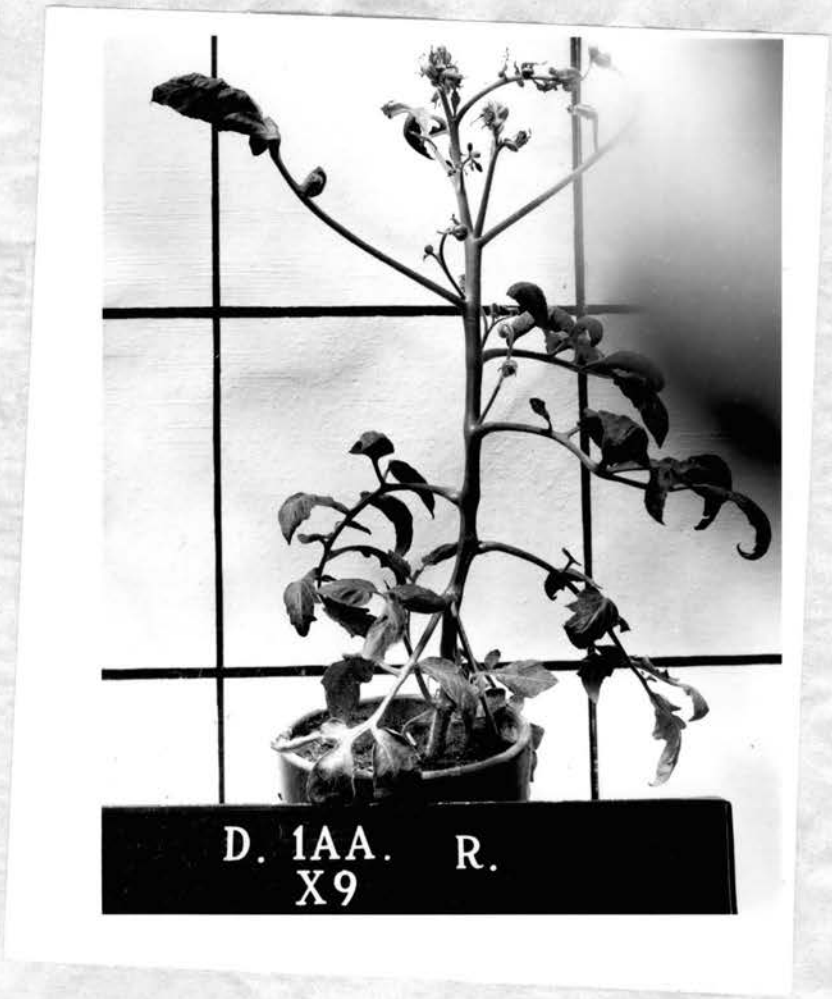

Figure 15. Rutgers plants sprayed 9 times with combined IAA and Duraset treatments. Photographed April 30, 17 days after the last treatment. Note extreme formative effects with leaves malformed and of different sizes and shapes.

leaves. Root primordia appeared later.

A summary of all treatments on Rutgers variety is given in Table 5.

TABLE V

AVERAGE NUMBER OF FLOWERS PER CLUSTER PERCENT OF FLOWERS FASCIATED AND PERCENT OF RUDIMENTARY FLOWERS IN VARIETY RUTGERS TREATED WITH DURASET ALONE AND DURASET PLUS IAA*

	Duraset 500 ppm											
Cluster	Ave. no. of flowers				% fasciation**				% rudimentary**			
No.***	control	6x	9x	16x	control	6x	9x	16x	control	6x	9x	16x
1****	7	27	7	4	0	25.0	13.6	0	0	0	14	100
2	8	17	10	7	0	18.5	12.9	0	0	0	0	72
3	7	15	10	11	0	12.3	0	2.9	0	0	0	29.4
4		5				9.6			0	0	0	
5		6				9.1						
6		8				7.1						
7		7				3.1						
	Duraset 500 ppm plus IAA 25 ppm											
	Ave. no. of flowers				% fasciation				% rudimentary			
	control	6x	9x	16x	control	6x	9x	16x	control	6x	9x	16x
1		16	7	4		26.0	0	0		0	48.0	100
2		14	12	2		26.1	22.2	0		0	16.7	100
3		8	15	1		24.0	20.4	0		0	29.6	98
4		6	10			0	20.0	0		0	23.2	
5		6	9			0	14.3	0		0	14.3	
6			2								0	

* Averages for 9 treated plants and 6 control plants

** Percent of total flowers in cluster showing fasciation and rudimentary (inhibited) development.

*** According to age; cluster 1 being oldest.

**** Cluster No. 1 was initiated and developed while treatments were being applied.

5. Okla 55

This variety is partially determinate with fairly good vegetative development. It is of special interest because of the lf and j genes, and the production of flowers and fruits on jointless pedicels in clusters which show a few leaves. The peduncle of the inflorescence has a stem-like character (Figure 16).

Treatments given this variety were limited to Duraset alone which was applied 6, 9, and 16 times. A special feature of the study with this variety was to see if there was any reduction in the leafyness of the clusters in plants induced to be extremely determinate by the Duraset treatment.

As reported for the other varieties, plants of Okla 55 were induced to terminate with the first cluster by the Duraset treatment. Vegetative growth was checked during the period the plants were being treated. The average number of flowers in the first cluster was more then doubled by 6 applications, remained about the some for 9 applications, and was reduced by the 16-application treatment (Table 6). The reduction in number of flowers in the latter case was due to abortive or rudimentary clusters in which flower formation was inhibited. Flower fasciation and peduncle fasciation was present.

Vegetative growth resumed vigorously after the treatments ceased. This was especially true of the clusters themselves. This is illustrated in a plant of the 6-application series, 30 days after treatment ceased and shortly after vegetative activity was initiated (Figure 17). A fasciated peduncle was terminated by a mass of fasciated, almost sessile, flowers and rudimentary leaves. Figure 18 shows the plant 16 days later, after there had been much development in the terminal cluster and other leafy clusters had developed from the leaf axils.

Figure 16. Untreated Okla 55 tomato plant. Photographed April 30. Partially determinate with fairly good vegetative growth. Jointless pedicels and leaves are found in the cluster. The first cluster extends outward to the left from the internode above the 4th leaf. The first 3 flowers of this cluster did not set fruit but were persistent because of the jointless pedicel. A vegetative shoot extends from the terminal of this cluster.

TABLE VI

AVERAGE NUMBER OF FLOWERS PER CLUSTER, PERCENT OF FLOWERS FASCIATED AND PERCENT OF RUDIMENTARY FLOWERS IN VARIETY OKLA 55 TREATED WITH DURASET ALONE AND DURASET PLUS IAA*

	Duraset 500 ppm											
Cluster	Ave. no. of flowers				% fasciation**				% rudimentary**			
No.***	control	6x	9x	16x	control	6x	9x	16x	control	6x	9x	16x
1****	3.3	8.1	3.6	1.9	0	22.3	18.7	0	0	0	17.0	85.6
2	3.5	7.8	3.5	1.9	0	20.1	18.1	0	0	0	9.0	60.3
3	3.2	6.9	3.8	1.5	0	18.6	17.8	0	0	0	8.1	50.1
4	3.4		2.9		0	17.7	17.6	14.7	0	0	0	8.6
5						17.4	15.0	12.1	0	0		
6						18.0	11.1					

* Averages for 3 treated plants and 6 control plants

** Percent of total flowers in cluster showing fasciation and rudimentary (inhibited) development.

*** According to age; cluster 1 being oldest.

**** Cluster No.1 was initiated and developed while treatments were being applied.

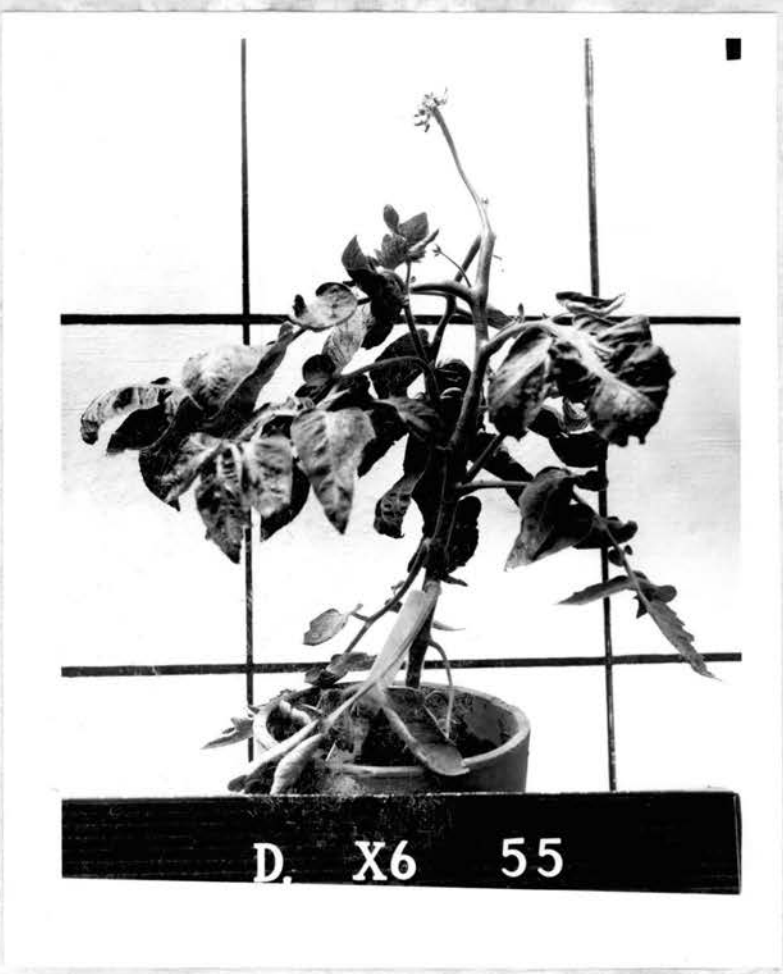

Figure 17. Okla 55 tomato sprayed 6 times with Duraset. Photographed April 30, 29 days after treatments ceased. The plant was terminated by the first cluster at the 7th leaf. This cluster has a fasciated terminal where almost sessile flowers (some fasciated) and rudimentary leaves are formed.

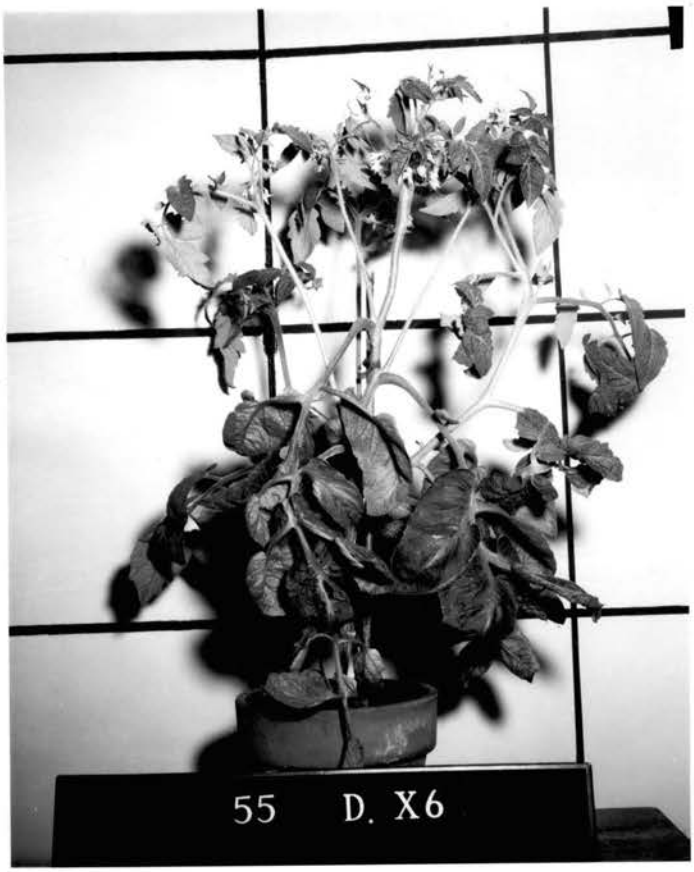

Figure 18. The same plant as shown in Figure 17, 16 days later (May 16), after considerable new growth has taken place. The terminating cluster has elongated and thickened at the apex. Three new leafy inflorescences are emerging from the axils of the leaves in the upper part of the plant.

Fasciation in the peduncle of the terminating cluster is indicated by its thickened terminal region which is shown in detail in Figure 19. Some of the original flowers are much fasciated and nearly sessile while secondary clusters (or stems terminating in clusters) have developed in the axils of the cluster leaves. Some elongation of the central axis or peduncle is also apparent.

Figure 20 illustrates a typical plant for the 9-application series, 18 days following the last treatment and after limited vegetative activity has been initiated. The fasciated terminal cluster is shown with large fasciated flowers and epinastic leaves. Some the clusters of this type became very vegetative and the peduncle grew out like a stem (Figure 21). There was considerable elongation and secondary clusters formation. Terminal laterals developed from axils of the cluster-leaves.

When the Duraset applications were continued for an extended period (16), the plants were characterized by rather severe formative effects with considerable leaf distortion (Figure 22) and in some cases reduced to unbranched and flowerless peduncles (Figure 23). After the effects of the treatments wore off these peduncles initiated a flower or flowers (as reported previously for other varieties), which were fasciated and malformed in various ways particularly with reference to carpel developement.

Root primordia appeared in abundance on the stems and peduncles on some plants of this variety. These became evident after the treatments were discontinued and were associated with the rapid renewal of vegetative growth (Figure 24).

Figure 19. Details of the terminal cluster of the same plant as in Figure 17 and 18. Photographed May 14, but 15 day later. This cluster shows much renewed growth. The peduncle has elongated and thickened. Secondary clusters appear as laterals in axils of the leaves that were originally present in the cluster.

Figure 20. Okla 55 plant sprayed 9 times with Duraset. Photographed April 30, 17 days after last treatment. A leafy cluster terminates the stem. Epinasty is present in the leaves. Almost sessile and fasciated flowers and small laterals have developed from the inflorescence.

Figure 21. Okla 55 tomato plant sprayed 9 times with Duraset. Photographed May 16, 17 days after last treatment. The terminating peduncle became very vegetative and grew out, like a stem, with considerable elongation. Secondary flower clusters terminated the laterals springing from the axils of the leaves in this cluster. Wooden label points to the base of the peduncle of this terminal cluster which is thickened (fasciated).

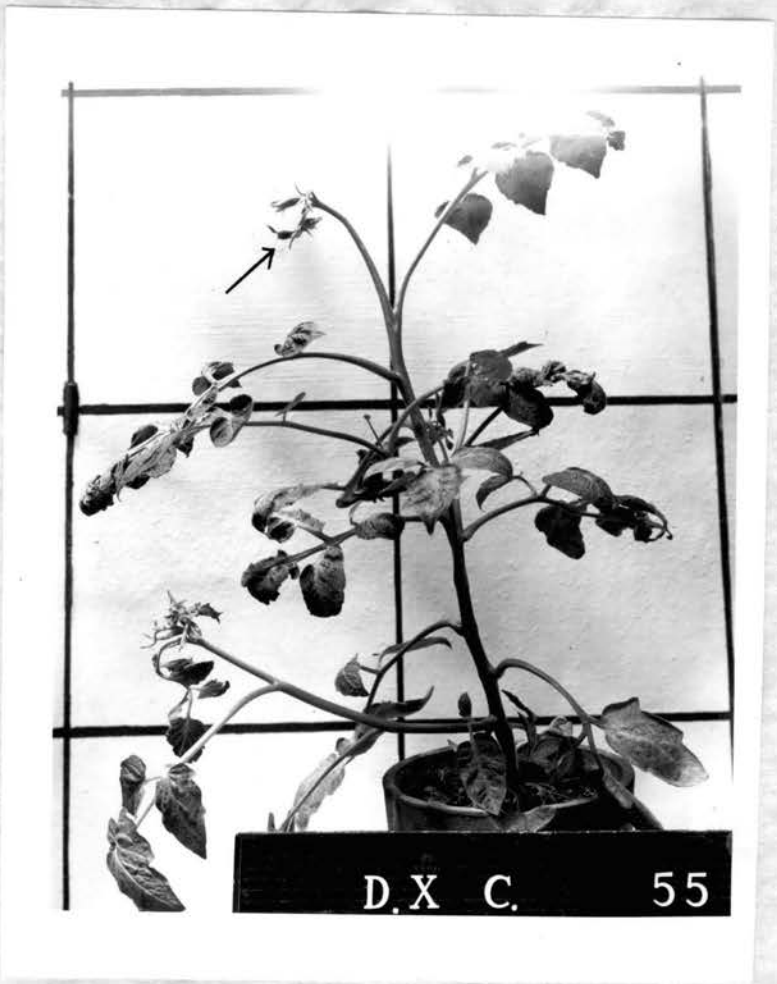

Figure 22. Okla 55 tomato plant after 11 treatments with Duraset. Photographed April 30. One small leaf (arrow) grew out of the flower in place of a sepal. The cluster produced three large flowers on the terminating peduncle. (This plant is in the 16-treatment series)

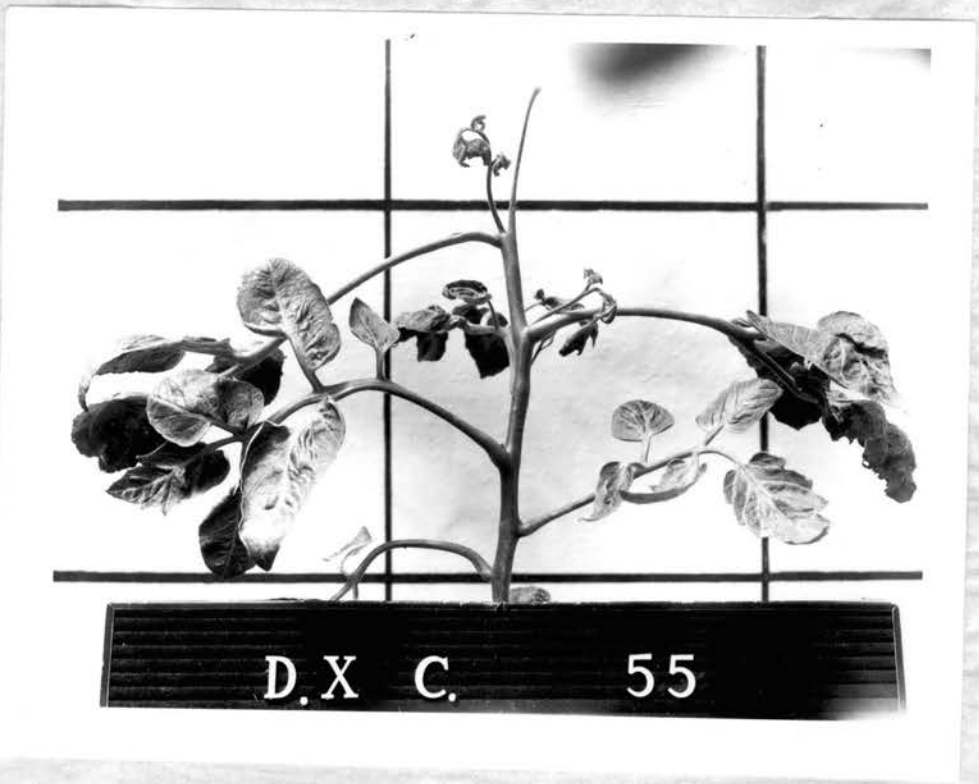

Figure 23. Okla 55 plant after 11 treatments with Duraset. Photographed April 30. The terminal cluster has a single peduncle. The shoots shown in the axils of the two upper most leaves indicate the resumption of vegetative growth in the post-treatment period. (This plant is in the 16-treatment series)

Figure 24. Plant of Okla 55 tomato after 15 treatments with Duraset. Photographed May 25. Note the root primordia found in the middle-section of the plant. Root primordia are also found on the fasciated peduncle of the terminal cluster (to the left of the cane support). (This plant is in the 16-treatments series)

The increase in determinateness induced in plants of Okla 55 variety by Duraset treatment was not accompanied by a decrease in the leafyness of the clusters. Leaf count was complicated by a renewal of growth in the clusters after the treatments were discontinued. Therefore, the leaf data are given (Table 7) for leaves originally in the clusters and for those arising from the new growth. The original number of leaves increased when the plants were treated with Duraset with additional leaves appearing on the new growth. Inflorescences treated 6, 9, and 16 times, all showed an increase in leaves. The increase in leaf number in the clusters agrees closely with changes in numbers of flowers as shown in Table 6.

TABLE VII

NUMBER OF LEAVES IN THE CLUSTER AND NUMBER OF FLOWERS ON THE TERMINATING CLUSTER IN THE OKLA 55 VARIETY

No. of applications of Duraset (500 ppm)**	Ave. no. of lvs./cl.*				Ave. no. of flowers/cl.*			
	old	new	total	%,new	old	new	total	%,new**
untreated	1.7	0	1.7	0	3.5	0	3.5	0
6 application	3.5	2.4	5.9	40.6	8.1	4.6	12.7	36.2
9 application	1.9	2.4	4.3	55.8	3.6	2.7	6.3	42.8
16 application	2.1	2.0	4.1	48.7	1.9	1.5	3.4	44.1

* Average of 10 plants.
** Percent of total flowers in clusters showing renew.
*** Average of first 3 clusters for 10 plants.

6. Varietal Comparisons:

A. Flowers per cluster As indicated by the data in Table 8, the Okla 20 D variety showed a three-fold increase in number of flowers in the first clusters (those differentiated during the treatment period) when 6 applications of Duraset were made. With 9 applications the flower number was reduced one-half that of the controls and reduced still more when Duraset was applied 16 times. The other 3 varieties showed this increase in flower number at 6 applications, the normal number for 9 applications and a substantial reduction for the more extended treatments of 16 applications. Applied alone IAA had little or no affect on flower number. When it was combined with Duraset the number of flowers was reduced below that for corresponding Duraset alone treatments. It is apparent that the effects of the growth substances carried over into the new growth and to the clusters originating after the treatments ceased. This is indicated by the flower numbers given as averages for clusters 2-4 and for clusters 5 to 7.

TABLE VIII

AVERAGE NUMBER OF FLOWERS PER CLUSTER IN RELATION TO NUMBER OF APPLICATIONS OF DURASET ALONE IN COMBINATION WITH IAA, AND IAA ALONE

Variety	Cluster Number	Control	Duraset 500 ppm 6x	Duraset 500 ppm 9x	Duraset 500 ppm 16x	Combined Duraset + IAA 6x	Combined Duraset + IAA 9x	Combined Duraset + IAA 16x	IAA 25 ppm 6x	IAA 25 ppm 9x
Okla 20 D	1st	6.4	18.3	3.0	1.7	8.2	2.0	1.5	6.0	6.9
	Ave.2,3,4 cl.		13.3	6.4	3.2	5.9	4.7	4.2		
	Ave.5,6,7 cl.		8.5	0.9	2.0	13.3	7.3	5.3		
Okla 35	1st	6.2	14.0	6.7	4.0	10.3	6.0	3.7	7.0	5.7
	Ave.2,3,4 cl.		7.4	7.4	5.8	6.3	8.7	5.8		
	Ave.5,6,7 cl.		5.1	8.4	5.6	4.5	6.3	4.6		
Rutgers	1st	7.3	27.0	7.3	4.0	15.7	7.2	3.5	6.0	6.0
	Ave.2,3,4 cl.		12.3	9.4	8.8	9.4	4.1	4.1		
	Ave.5,6,7 cl.		6.5	6.5	6.5	4.8	1.8	2.4		
Okla 55	Original*	3.3	8.1	3.6	1.9					
	New*		3.6	2.7	1.5					
	Total		11.7	6.3	3.4					

* Original indicates flowers first formed and before second growth was "new" flowers originated in the secondary.

Auxins have a dual action and may stimulate or inhibit a growth function. This dualism was noted for several growth processes in this study and is illustrated in the trends in flowers per cluster in relation to the various treatment levels in Figure 25. In this figure the vertical lines representing the various treatments are drawn in position on a standardized curve (12). Applications of Duraset alone or in combination with IAA promoted flower production. As the treatment level was increased there was an inhibitory effect and flower production declined. These trends show the degree to which IAA is additive to Duraset.

The most determinate Okla 20 D and the indeterminate Rutgers were selected as the two extremes with reference to type and also with reference to responses in flower numbers. The trends in flower number for the intermediate type varieties (Okla 35 and Okla 55) were intermediate, falling in between those for the extreme types.

The trends shown in the figure indicate that compared to the flower number in other varieties the determinate Okla 20 D was promoted (increased) less at the low treatment levels and that flower inhibition appeared sooner in this variety as the treatment level increased.

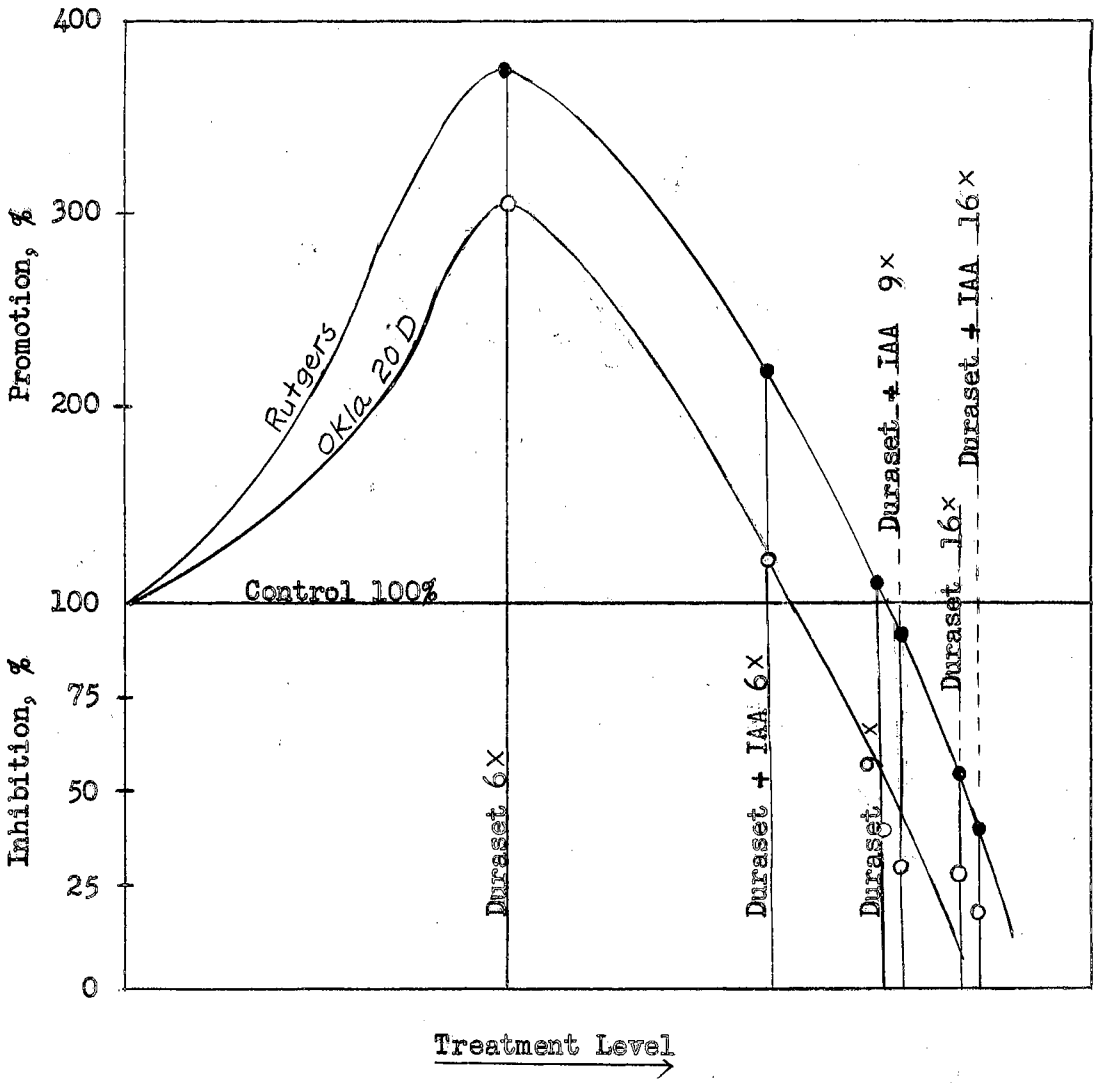

Figure 25. Range in flowering responses of first clusters to growth substances for indeterminate Rutgers and the very determinate Okla 20 D. The number of flowers per cluster for treated plants is expressed as percent of that of controls.

B. Fasciation The data for flower fasciation are presented for first clusters (during treatment), in contrast with those developed on the new growth that followed the period of treatment; e.g., clusters 2 to 7, in Table 9. Flower fasciation was most extensive in the Okla 20 D variety, and at the maximum was about 50%. It should be pointed out that this most determinate variety naturally shows some fasciated (4.5%) flowers. The other varieties ranked in decreasing order Okla 35, Okla 55 and Rutgers, as they naturally rank in the determinateness scale. As an average for all varieties fasciation was highest in the first cluster when 6 applications of Duraset were made. The addition of IAA decreased the percentage fasciation from the Duraset treatment alone.

The effect of the treatments carried over into the post-treatment period as indicated by clusters 2 to 7 which are listed according to age. In the 6 and 9 application series of Duraset the percent fasciation decreased gradually with time as the clusters were successively formed on the plant. For Okla 20 D the optimum conditions for fasciation was obtained at 16 applications with the 4th cluster while a similar situation existed when IAA was added to the 6 and 9 applications series. The variety Okla 35 showed similar trends.

When IAA was applied alone for 6 and 9 times, the variety Okla 35, as well as Okla 20 D, showed a low percent of fasciated flowers on all clusters.

TABLE IX

PERCENT FASCIATION* OF FLOWERS IN EACH CLUSTER FOR VARIETIES** OKLA 20 D, OKLA 35, RUTGERS AND OKLA 55 TOMATOES AND IN RELATION TO TREATMENT WITH DURASET AND IAA

Cluster No.	Duraset 500 ppm											
	6 applications				9 application				16 application			
	Okla 20 D	Okla 35	Rut-gers	Okla 55	Okla 20 D	Okla 35	Rut-gers	Okla 55	Okla 20 D	Okla 35	Rut-gers	Okla 55
1st	51.5	33.3	25.0	22.3	44.5	30.8	13.6	18.7	0	19.1	0	0
Ave.2,3,4	39.0	10.4	13.5	18.8	34.4	23.8	12.9	17.8	28.3	26.2	2.9	14.7
Ave.4,5,6	27.6	6.6	6.4	17.7	0	14.0	0	13.5	15.5	0	0	12.1
	Duraset 500 ppm combined with IAA 25 ppm											
	6 application				9 application				16 application			
	Okla 20 D	Okla 35	Rut-gers	Okla 55	Okla 20 D	Okla 35	Rut-gers	Okla 55	Okla 20 D	Okla 35	Rut-gers	Okla 55
1st	18.4	33.3	26.0		4.4	10.0	0		5.0	0	0	
Ave.2,3,4	39.4	12.1	25.5		27.5	17.0	20.7		28.0	13.8	0	
Ave.5,6,7	47.3	0	0		51.0	26.8	14.3		0	0	0	
	IAA 25 ppm											
	6 application				9 application				16 application			
	Okla 20 D	Okla 35	Rut-gers	Okla 55	Okla 20 D	Okla 35	Rut-gers	Okla 55	Okla 20 D	Okla 35	Rut-gers	Okla 55
1st	4.7	3.5	0		4.3	0	0		3.8	0	0	
Ave.2,3,4	4.3	0	0		4.2	4.2	0		4.9	0	0	
Ave.5,6,7	0	0	0		0	0	0		0	0	0	

* Percent of total flowers in cluster showing fasciation.

** Okla 20 D, Okla 35, Rutgers total for three plants, control for six plants, Okla 55 total for ten plants

*** According to age, cluster number, was first to appear and developed during the treatment period.

C. Fasciated Stems and Leaves in the Cluster As indicated in Table 10 the four varieties responded differently to Duraset in so far as these characteristics are concerned. Treated plants of Okla 20 D showed some fasciation of the stems but did not have any leafy clusters. The three varieties, Okla 20 D, Okla 35 and Rutgers, ranked in order for fasciation of stem and leafyness of clusters according to their natural position in the determinateness scale.

Rutgers showed increased fasciation in the stem and increased leafy clusters, when Duraset and IAA were combined.

When IAA alone was applied some fasciation of stems was found and leafy clusters appeared only on plant of the indeterminate Rutgers variety.

TABLE X

FASCIATION IN THE STEMS AND LEAVES IN THE CLUSTERS* IN THE NEW VEGETATIVE GROWTH FOLLOWING CEASATIONS OF TREATMENTS ON OKLA 20 D, OKLA 35, AND RUTGERS VARIETIES

	Okla 20 D			Okla 35			Rutgers		
	Lvs. in cl.		Fas	Lvs. in cl.		Fas.	Lvs. in cl.		Fas.
	no. cl.	no. lvs.	in Stems	no. cl.	no. lvs.	in Stems	no. cl.	no. lvs.	in Stems
Control	0	0	0	0	0	0	0	0	0
Duraset alone	0	0	4	4	7	14	17	22	18
Duraset + IAA	0	0	13	3	3	28	13	24	42
IAA alone	0	0	4	0	0	5	2	2	7

* Total for 27 plants (combined three series treatments, e.g. 6,9,16), control total for 18 plants.

D. Flower Inhibition At the higher treatment levels Duraset had an inhibitory effect on flower initiation. This appeared first, as a reduction in number of flowers in the cluster and then, in the appearance of abortive or flowerless pedicels and peduncles (Table 11).

Flower inhibition was found in clusters on plants of all varieties receiving 9 applications of Duraset. The inhibition was greatly increased at the 16-application level and continued into the clusters initiated on the new growth during the post-treatment period. There was a decline in the inhibitory effect with the passing of time as indicated by the data for clusters 2 to 6.

As previously indicated the terminal meristems were retained in these abortive pedicels and peduncles. In the absence of any inhibitory effect they were capable of differentiating floral parts with the resulting flowers showing some degree of abnormal structure (fasciation) and least development with reference to the carpels. Control plants and those treated with IAA alone did not show abortive pedicels or peduncles.

TABLE XI

PERCENT ABORTIVE FLOWERS FOR CLUSTER OF 4 DIFFERENT VARIETIES IN RELATION TO TREATMENT WITH DURASET ALONE, AND COMBINED WITH IAA*

Cluster No.	Duraset 500 ppm											
	6 application				9 application				16 application			
	Okla** 20 D	Okla** 35	Rut-** gers	Okla*** 55	Okla 20 D	Okla 35	Rut- gers	Okla 55	Okla 20 D	Okla 35	Rut- gers	Okla 55
1	0	0	0	0	29.2	15.4	14	17.0	66.6	73.8	100	85.6
2	0	0	0	0	25.5	5	0	9.0	60.0	40.0	72.0	60.3
3	0	0	0	0	0	0	0	8.1	60.0	37.5	29.4	50.1
4	0	0	0	0	0	0	0	0	58.1	33.3		8.6
5	6.5	0	0	0					26.6			
6									18.2			

	Duraset 500 ppm combined with IAA 25 ppm											
	6 APPLICATION				9 APPLICATION				16 application			
	Okla 20 D	Okla 35	Rut- gers	Okla 55	Okla 20 D	Okla 35	Rut- gers	Okla 55	Okla 20 D	Okla 35	Rut- gers	Okla 55
1	82.0	14.3	0		20	40	48		95	83.5	100	
2	37.5	0	0		18.7	43.5	16.7		100	82	98	
3	33.3	0	0		18	54.5	29.6		87.5	76		
4	0	0	0		0	41.0	23.2		50	71		
5	0	0	0		0	33	14.3			56.5		
6	0	0	0		0	0	0					

* Percent of total potential for flowers in the cluster showing abortion.
** Total for three plants.
*** Total for tem plants.

E. Root Primordia As indicated by the data in Table 12, Okla 55 was the only variety that showed root primordia in response to treatment with Duraset alone. The number of primordia increased as the treatment intensity increased thorugh 6, 9, and 16 applications. The primordia appeared on peduncles as well as on stems of this variety.

Plants of the other varieties developed root primordia only when given the combined Duraset-IAA treatment, with Rutgers plants produced the most primordia especially at the 16-application level.

TABLE XII

AVERAGE WEIGHT INDEX* FOR ABUNDANCE OF ROOT PRIMORDIA ACCORDING TO NUMBER OF APPLICATIONS OF DURASET ALONE AND COMBINED WITH IAA

Treatments	Duraset alone	Duraset combined with IAA**		
	Okla 55	Okla 20 D	Okla 35	Rutgers
Control	1.0	1.0	1.0	1.0
6	1.9	1.0	1.0	1.0
9	2.3	1.3	1.7	2.0
16	3.5	1.3	1.7	4.0

* Index calculated on basis of 1.0= no root primordia, 2= low number of root primordia, 3= medium number of root primordia, 4= high number root primordia. See Figure 25 for example of high number of primordia.

**Root primordia appeared on plants of these varieties only when IAA was applied with Duraset except for a few primordia appearing on plants treated with IAA alone.

F. Plant Height As indicated by Figure 26, the height of the plants of the very determinate Okla 20 D were reduced most by treatment with Duraset. There was little or no vegetative recovery in these plants after the treatments ceased. The indeterminate Rutgers variety made the greatest vegetative recovery. Six applications of IAA resulted in heights greater than the controls while heights for plants receiving 9 applications were about equal to that of the controls.

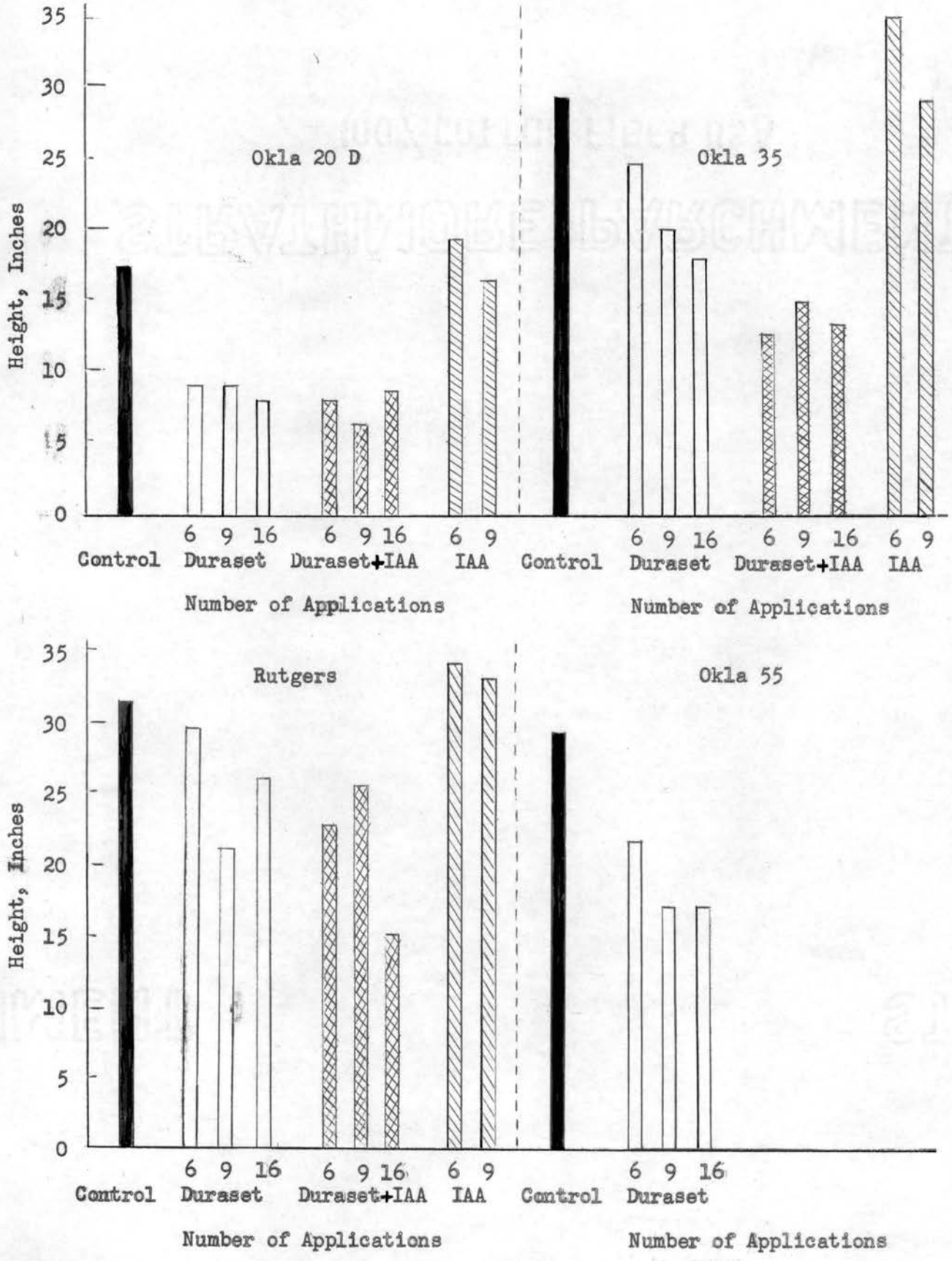

Figure 26 Final plant heights obtained on June 1, 1959

DISCUSSION AND CONCLUSIONS

The tomato varieties chosen for this study show rather wide differences in the correlative relationships between vegetative and reproductive activities and, therefore, differences in determinateness, as indicated by the frequency with which the inflorescences are initiated on the stem. These differences arise through the action of certain genes and modifiers which evidently control indirectly the formation of a hormone or hormones in the plant. According to the results of this study variations in the growth habits found in the plants of the tomato varieties relate to variations in their auxin systems and therefore differences in response to growth substances are to expected.

The growth substance, Duraset (n-meta-tolylphthalamic) which is classed as an auxin synergist, modifies the action of the "growth-response" genes probably through it's interaction with the auxin-type plant hormones. That Duraset induces changes in the auxin systems is further substantiated by responses which are usually related to auxin such as fasciation of flowers, peduncles, and stems, by the formation of leaves in the clusters, and by the initiation of root primordia on the stems.

Plants of all varieties generally became determinate with the first cluster and vegetative activity mostly ceased while the plants were being reatreatted

were being treated with Duraset. When IAA (indole-acetic acid) was combined with the Duraset for 6 treatments, the renewal of vegetative growth in the post-treatment period was hastened. However, when 9 and 16 applications were applied the plants developed severe formative effects with much leaf distortion and abbreviation.

The treatments with IAA alone resulted in some formative effects, including fasciation in flowers and stems, development of leaves in clusters, and the formation of root primordia on stems.

The renewal of vegetative activity in several varieties, after treatments with Duraset and IAA were discontinued and the nature of this growth, are of considerable interest. Duraset is known to hydrolyze readily in plant tissue and is, therefore, directly effective for a very short interval of time. Plants of the very determinate Okla 20 D failed to renew vegetative growth after the Duraset treatments ceased, but in the other three varieties vegetative growth was very vigorously renewed with laterals appearing in the axils of leaves that were quite mature. Some of these new lateral stems showed fasciated nodes (wide stem, opposite leaves and Y-branching). The clusters appearing on these new stems also showed increased numbers of flowers and some fasciation in flowers and peduncles. In fact, the maximum number of flowers and extreme degree of fasciation were attained for some varieties and treatments in the second to fourth clusters which were a part of the new growth.

These growth response (following treatment) are suggestive of a high auxin level. This leads to the supposition that during the treatment period the auxins were tied up by unstable chemical combinations with the Duraset, or were bound in some way, and released in abundance when the treatments ceased.

The relationship between Duraset and the auxins in the plant is probably quite complex. It is not clearly understood at this time. Our present knowledge of auxins does not provide a ready explanation for all the growth responses noted in the this study. It appears logical to assume that the tomato plant has a complex of auxins which varies to some extent with variety. Duraset has a different effect of reaction with these variety complexes.

Another possibility is that Duraset reacts only with a single or with certain reactive groups in the auxin molecule to modify its influence on growth processes (13). Thus, fasciation of flowers (a high auxin response) appears in a plant in a highly reproductive condition that is incapable of vegetative growth.

It has previously been demonstrated that the different growth activities in plants have different optima with reference to auxin concentration (13). Inhibition of the growth process then results at a supra-optimal level. This is clearly indicated in the results of this study.

High auxin concentrations reduces or prevents flowering in some plants and it is generally conceded that a medium or low auxin level is most effective in promoting flowering. A special flowering hormone (florigen) may exist in some plants.

The highest degree of reproductive activity was found in plants of Okla 20 D receiving 6 applications of Duraset. This is represented by both an increase in the number of flowers in the cluster as well as in number of clusters. Many of the clusters arise in the axils of the leaves in place of lateral shoots. The replacement of lateral in the leaf axils by flower clusters in response to treatment with

Duraset was previoustly reported (5) for a sibling of Okla 20 D (20-1-1) and also was noted in this study in Okla 55.

At the higher treatment levels, and with IAA combined with Duraset, flower initiation was inhibited to some extent and number of flowers per cluster returned to the level of that of the control plant or was markedly reduced. As previously pointed out, the optimum hormone balance for reproduction was not attained immediately in plants receiving these high level treatments. Thus, the most flowers were produced in clusters developing later, during the post-treatment period.

Fasciation of the flower was indicated by an increase in floral parts, including the pistils. In most cases the pistil was single but the style was flattened and the ovary was elongated and ribbed. Flowers in a terminal position in the inflorescence were most frequently fasciated. Ordinarily fasciation would be classed as a high auxin response and yet in this study it appeared to be associated with or running parallel to numbers of flowers per cluster.

Fasciation in stems and peduncles again might be related to a favorable high auxin level. It was most evident in the post-treatment period when the plants were growing vigorously. Fasciated peduncles appeared in several varieties but were most generally present in the Okla 55 plant when growth was renewed in the cluster during the post-treatment period.

Leaves appeared in the clusters of treated plants of all varieties except Okla 20 D. These were favored by treatment with IAA and to some extent by Duraset. Their presence might be taken as an indication of a high auxin level.

The optimum auxin level for root formation is low compared to that for vegetative parts. However, during the post-treatment period

the hormone balance in the treated plants of Rutgers and Okla 55 especially, became favorable to the initiation of root primordia. These were initiated in abundance well up on the stems instead of in the older tissues at the base of the plant as is normal. In Okla 55 they were initiated on the peduncles as well.

The growth responses in the clusters of Okla 55 induced by Duraset treatment were of special interest. Some of the terminating first clusters, developed during the treatment period, were made up largely of fasciated flowers on a fasciated peduncle. Thus, the flowers were almost sessile and placed close together with the leaves at the terminal of these peduncles. In the post-treatment period the terminal portion of these peduncles elongated and broadened. Shoots or secondary clusters grew out from the axils of the cluster leaves. In some, the peduncles grew upward with all the characteristics of a stem and appeared as a continuation of the main axis of the plant. On the basis of these growth reponses and because of the initiation of root primordia on these, it must be concluded that the peduncles of the clusters of Okla 55 are most stem-like. Perhaps they are stems bearing a solitary flowers. The leaves in these clusters probably served in the production of auxin and this created a balance favorable to vegetative growth.

SUMMARY

1. The growth patterns of tomato plants were changed by treatment with n-meta-tolyiphthalamic acid (Duraset) when applied alone or in combination with indoleacetic acid (IAA).
2. Plants of all varieties (indeterminate to determinate) become extremely determinate while under treatment with Duraset. Vegetative activity was largely inhibited during the treatment period.
3. Plants of the indeterminate and the intermediate types actively renewed vegetative growth in the post-treatment period, while the plants of the determinate 20 D made little vegetative recovery and axillary inflorescences replaced lateral stems.
4. Many growth anomalies appeared in the treated plants, such as fasciation in flowers, peduncles and stems, leaves in the clusters, leaflet distortion, and root primordia on the stems. All of these relate in some way to auxin activity.
5. These aberations in growth varied according to variety, the number of Duraset treatments and with time in the life of the plant.
6. These aberrant growth responses continued into the post-treatment period and at a time that the Duraset was not actively present in the plant.
7. The number of flowers per cluster was increased by Duraset treatment to a maximum of approximately 400 percent.
8. As illustrated by the number of flowers, the responses to the

growth substances were carried through the promotional phase into the inhibitional phase as the treatment intensity increased.

9. Indoleacetic acid had an additive effect when applied in combination with Duraset.

10. The results of this study was suggested that genetic differences in growth habit in the tomato are the result of different auxin complexes.

11. The peduncle in leafy cluster in the Okla 55 variety is most stem-like and is readily capable of initiating vegetative growth. The presence of a stem-like auxin system in this unusual peduncle is indicated.

LITERATURE CITED

1. Bonner, J. F., 1950. Plant Biochemistry. Academic Press Inc.

2. Bonner, J. F., and Galston, A. W., 1952. Principle of Plant Physiology. W. H. Freemon and Co., San Francis Co.

3. Crane M. B., 1915. Heredity Types of Inflorescences and Fruits in Tomato. Jour. of Genetics, 5:1-11.

4. Clark, H. E. and Kerns, K. R., 1942. Control of Flowering with Phytohormones. Sci., 95:536-537.

5. Cordner, H. B. and Hedger, G., 1959. Determinateness in the Tomato in Relation to Variety and to Application of N-meta-tolylphthalamic Acid of High Concentration. Proc. Amer. Soc. Hort. Sci., 73:323-333.

6. Hoffmann, O. L. and Smith, A. E., 1949. A New Group of Plant Growth Regulators Sci., 109:588-590

7. Jones, H. A. and Rosa, J. T., 1928. Truck Crop Plants. McGraw-Hill Book Co., Inc.

8. Kramer, M. and Went, F. A., 1949. The Nature of the Auxin in Tomato tip. Plant Physiol., 24:207-221.

9. Loomis, W. E., 1949. Growth and Differentiation in Plants. Iowa State College Press.

10. Leopold, A. C. and Guernsey, F. S., 1953. Modification of Floral Initiation with Auxins and Temperatures. Amer. Jour. Bot., 40: 603-607

11. Leopold, A. C. and Thimann, K. V., 1949. The Effect of Auxin on Initiation. Amer. Jour. Bot., 36:342-347.

12. Leopold, A. C., 1955. Auxins and Plant Growth. Univ. of Calif. Press, Berdeley.

13. Morre, J. F., 1957. N-1-naphthyl Phthalamic Acid N-m-tolylphthalamic Acid and Other Growth Regulators Applied as Whole Spray to Field-Grown Tomatoes. Proc. Amer. Sco. Hort. Sci., 70:350-356.

14. Morrison, G., 1938. Tomato Varieties. Mich. Agr. Exp. Stat. Spec. Bull., 290.

15. Mann, L. K. and Minges, P. A., 1949. Experiments on Setting Fruit with Growth Regulating Substances on Field Grown Tomato in California. Hilgardia, 19:309-337

16. Rick, C. M. and Sawant, A. C., 1955. Report of the Tomato Genetic Cooperative. Dept. of Veg. Crop Univ. of Calif., Jan., 5:26-27.

17. Skoog, F., 1949. Growth Substances in High Plants. Biochem. Ann. Rev., 16:529-557.

18. Skoog, F., Schneider, C. L. and Molan, P., 1942. Interactions of a Auxin in Growth and Inhibition. Amer. Jour. Bot., 29:569-576.

19. Thimann, K. V. and Bonner, W. D., 1948. The Action of Triiodobenzoic Acid on Growth. Plant Physiol., 23:158-161.

20. Teubner, F. G. and Wittwer, S. H., 1955. Effect of N-m-tolylphthalamic Acid on Tomato Flower Formation. Sci., 122:74-75.

21. Teubner, F. G. and Wittwer, S. H., 1957. Effect of N-arylphthalamic Acid on Tomato Flower Formation. Proc. Amer. Soc. Hort. Sci., 69:345-351.

22. Wittwer, S. H. and Teubner, F. C., 1957. The effect of Temperature and Nitrogen Nutriention Flower Formation in the Tomato. Amer. Jour. Bot. 44:125.

23. Wittwer, S. H. and Teubner, F. C., 1956 New Practices for Increasing the Fruit of Green-house Grown Tomatoes. Mich. Agr. Exper. Stat. Quart. Bull., 39:198-207.

24. Young, P. A. and MacArthur, J. W., 1947. Horticultural Characters of Tomato. Texas Agr. Exper. Stat. Bull., 698.

25. Yeager, A. F., 1927. Determinate Growth in the Tomato. Jour. Hered., 18:262-265.

26. Warmke, H. E. and Warmke, G. L., 1950. The Role of Auxin in the Differentiation of Root and Shoot Primordia from Root Cutting of Taraxacum and Cichorium. Amer. Jour. Bot., 37:272-279.

27. Zielinski, Q. B., 1945. Fasciation in Horticulture Plants with Special Reference to the Tomato. Proc. Amer. Soc. Hort. Sci., 46:263-268.

28. Zimmerman, P. W. and Hitchcock, A. E., 1949. Triiodobenzoic Acid Influence on Flower Formations of Tomato. Contrib. Boyce Thompson Inst., 15:353-362.

29. Zimmerman, P. W. and Hitchcock, A. E., 1942. Flowering Habit and Correlation of Organs Modified by Triiodobenzoic Acid. Contr. Boyce Thompson Inst., 12:492-296.

30. Zimmerman, P. W., 1943. The Formative Influence and Comparative Effectiveness of Various Plant Hormone-like Compound. Torreya, 43:98-115.

31. Zimmerman, P. W., 1948. Plant Growth Substances. Encyclopedia of Chem. Tech., 10:723-736.

32. Zimmerman, P. W., 1951. Formative Effects of Hormone Like Growth Regulator. Plant Growth Substances. Univ. of Wesc. Press, Madison. In Skoog (Ed.).

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