# THE EFFECTS OF INDOLEBUTYRIC ACID AND IRRADIATION ON TOMATO FRUIT SET AND YIELD

by

Charles Daniel Taper

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ABSTRACT

During the winters of 1946 to 1947 and 1947 to 1948 one hundred and twenty-eight tomato plants of the varieties Vetomold 121 and Ailsa Craig, growing in a greenhouse at the University of British Columbia, were subjected to irradiation from 200 watt fluorescent lamps, and treated with organic acids, applied to foliar and floral parts, in an attempt to increase fruit set and yield.

The plants were grown in soil in 10 inch pots placed in randomized positions. During the first winter they were treated in groups of eight; and, during the second, in groups of six. Control groups were maintained.

Sixty-seven days of irradiation from 200 watt fluorescent lamps, used to increase the normal photoperiod by six hours, produced, in Vetomold 121, prounced damage to foliage and an inhibition of flowering.

Pre-irradiation of seedlings of Vetomold 121 for four hours daily, following the greening of the cotyledons, resulted in a significant increase in set of 29.6 per cent for first clusters. A combination of this treatment and a water spray, on flowers, of indolebutyric acid, 5000 p.p.m., was, for first clusters, significantly the most effective treatment applied to the variety.

The initiation of flowering in tomatoes, it was found, is

governed by the length of the photoperiod; and is not influenced by food relationships within the plant.

Foliar sprays of indolebutyric acid 50, 100, 250 and 500 p.p.m., applied to Vetomold 121, prior to flowering, had no effect.

Indolebutyric acid 100 p.p.m. and 200 p.p.m. in water were ineffective in influencing fruit set.

"Fix", "Seed-Less-Set", and indolebutyric acid 5000, 3000 and 500 p.p.m., applied in water, significantly improved fruit set 20.9 to 37.1 per cent on first clusters of the varieties. Hormodin No. 1, in talc, used on the second clusters of Vetomold 121, increased set by 22.8 per cent. No treatment was better than any other in influencing set, but indolebutyric acid produced fruits of better shape than the commercial preparations "Fix" and "Seed-Less-Set". No treatment caused plant injury.

Total yields were significantly increased by effective treatments; but average fruit sizes were not increased.

There was no difference due to variety, year, or time of planting.

A delayed spray appeared to be the most convenient method of application; i.e., one application made to each cluster when most of the flowers are open, with earlier flowers on the point of dropping.

Parthenocarpic fruits were sweeter than seeded fruits.

Applications of effective concentrations of indolebutyric acid resulted in the production of bands of uniformly sized fruits maturing at nearly the same time.

Fruits from flowers treated with acid ripened five to seven days earlier than fruits developed from untreated flowers.

Where acid treatments were effective the formation of abscission layers was retarded and, as a result, there was no fruit drop.

Of the materials and concentrations tested, indolebutyric acid 500 p.p.m. in water, applied as a delayed spray to floral parts, appeared to be the most valuable.

## ACKNOWLEDGMENTS

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# FOREWARD

The following investigation was conducted under the direction of the Plant Nutrition Section of the Department of Horticulture of the University of British Columbia during the sessions 1946 to 1947, and 1947 to 1948.

The object of the experiment was to determine the effects of irradiation and indolebutyric acid on tomato fruit set and yield.

This information, it was hoped, would suggest a means of increasing the percentage of flowers developing into fruits, thus aiding the growers of commercial crops of tomatoes in greenhouses in the Vancouver area of British Columbia. It was felt that any such information would be of particular value during the winter months; for it is then that fruit set is least satisfactory.

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## INTRODUCTION

### Statement of the Problem

In the northern United States, and in Canada, one of the problems connected with the production of greenhouse tomatoes, during the winter, is the low percentage of fruit set. Possibly this is the major difficulty encountered. It has been found that the tomato, unlike many plants, enters the flowering stage of the reproductive phase under conditions varying widely from the optimum; but, although pollen is formed, many flowers do not develop into fruits; the reproductive phase not continuing to completion. This low set appears to be due, more than to any other single cause, to a too brief photoperiod during the short winter days.

It is interesting to note, however, in connection with photoperiodism and radiation, that tomatoes can be injured, and finally killed, in any day-length over 19 hours (1).

### General Explanation of the Purpose of the Present Experiment

The main purpose of the investigation reported here, stated briefly, was an attempt to discover a satisfactory method of inducing the setting of fruits in greater quantities than fruit set as a result of self-pollination in the tomato varieties Vetomold 121, and Ailsa Craig, grown experimentally, during winter months, under greenhouse conditions, and daylight conditions, as they display themselves in the Vancouver area of British Columbia.

The chemical $\gamma$-(indole-3)-n-butyric acid and two commercial preparations known as "Fix", and "Seed-Less-Set" were applied to foliage and flowers of the Vetomold 121 and Ailsa Craig varieties of tomato to see if the desired result could be obtained. In addition, plants of the Vetomold 121 variety, not treated with a chemical growth regulator, had their day length increased by artificial lighting. Fruit set in these plants was compared with that in the chemically treated plants; and set in both was compared with set in untreated control plants growing in normal daylight.

Work of the First Year

During the winter of 1946 an experiment, terminated April 3, 1947, was conducted, at the University of British Columbia, with the purpose of increasing fruit set in the greenhouse grown variety of tomato Vetomold 121. The attainment of the object in view was attempted in two ways:

(1) By increasing the natural day-length through the use of a 200 watt fluorescent lamp; and by simulating this increase.

(2) By applying indolebutyric acid in varying concentrations in water sprays and talc dust to ovaries and flowers.

A study of experiments, covering the period from 1928 on, seemed to indicate that certain naphthoxy compounds were often more effective in increasing fruit set, and in inducing the formation of parthenocarpic fruits, than was indolebutyric acid. Naphthoxy and phenoxy compounds showed more activity in effecting growth responses; but the responses were often undesirable. Foliar damage, and puffy, hollow parthenocarpic fruits, due to a too great stimulation, and a too rapid growth in pericarpal tissues of the ovary, were common. Indolebutyric acid, on the contrary, when applied in concentrations of sufficient strength, proved a mild, but effective, greenhouse growth regulator when used to induce parthenocarpic fruiting.

Thus, it was decided, in attempting to adapt the hormone treatment of plant reproductive parts to our local Vancouver conditions, to use the organic chemical indolebutyric acid.

Irradiation of seedlings in the flat stage for four hours daily, for twenty-two days, resulted in an increase in fruit set on first clusters only. This was further increased by an additional treatment of indolebutyric acid. The total increase due to preirradiation alone was not as large as that effected by the growth regulator used alone; so that, practically, there was small advantage in seedling irradiation unless accompanied by an acid treatment.

Seedlings in a subgrouping were subjected to a simulated long day; i.e., a long dark period was broken into two shorter periods by means of artificial illumination. The response was as though the day had been long. The breaking of the dark period into shorter units achieved the same effect as a longer, and continuous application of light. A reversal of response appeared to be caused in a chain of reactions occurring in the dark period.

This points to a financial saving when lamps are used to alter normal day lengths in greenhouses.

Another group of plants, given six hours daily irradiation, under the fluorescent lamp, at first developed flowers which proved vegetative, and then ceased flowering. At no time, while undergoing irradiation, did they show fruit set. Ultimately, the entire foliar system of these plants turned yellow, withered, and displayed a large degree of physiological damage. This, probably, was due to the quality of the artificial light used. Upon being removed to a normal daylight area, new growth, both basal and terminal, arising from these plants, showed normal health.

A spray of water and indolebutyric acid, 5000 p.p.m. applied to flowers, and Hormodin No. 1 powder, a commercial preparation of indolebutyric acid, applied to ovaries of flowers whose stamens had been removed, significantly increased fruit set. One was not superior to the other in effecting increased fruit set; but spray 5000 p.p.m. was more convenient of application. This latter concentration, in a few instances, seemed to cause temporary epinasty from which there was a rapid and complete recovery. A concentration of indolebutyric acid 100 p.p.m. was completely ineffective in influencing fruit set in the variety.

Ten and one-half hours appeared to be the lower limit of the photoperiodic range necessary to induce flowering in Vetomold 121. The majority of plants flowered on reaching the length of day of ten hours and twenty-nine minutes; but none flowered where the day was shorter than this.

Work of the Second Year

The sttempt, made during 1946 to 1947, to apply, to local greenhouse conditions, the present knowledge of organic acids, as inducers of increased fruit set in winter tomatoes, having shown indolebutyric acid as being effective when applied as a flower spray, but not having indicated the best concentration, the decision was made to conduct a continuation of the winter greenhouse experiment.

The use of methods for applying hormones other than in sprays was not considered; the inconveniences involved being too great, and any resultant advantages not being important enough to warrant their use.

Pre-irradiation tests included in the first part of the experiment were not again repeated, their effects having been well demonstrated the first year. Other light treatments were felt to be worthy of investigation on their own accounts; so they were not attempted during 1947 to 1948.

A study of the current literature on the topic of growth regulators seemed to uphold the wisdom of having determined upon the use of indolebutyric acid for the first year. Therefore, it was decided to use it again.

The first year of the experiment having indicated a suitable material, it was hoped that the second year would determine the most effective concentration or concentrations.

During the second year two varieties of greenhouse tomatoes, were grown, Vetomold 121 and Ailsa Craig, and some observations were made with regard to yields. It was felt that the second half of the work would be more valuable if it dealt with fewer aspects of the problem under investigation. Notwithstanding, the effects of the two factors, variety and season were studied; though the main purpose was to determine the concentration of indolebutyric acid most suitable for increasing tomato fruit set on the first # blossom clusters.

Justification for the Present Experiment

The immense value of discovering some efficient, certain, and economical method of increasing fruit set in greenhouse tomatoes, during the winter months, is a matter of obvious import.

In the Vancouver area of British Columbia the problem seems to be of particular moment. On an average, the annual rainfall of this district is 57 inches per annum. By far the greater amount of this precepitation comes during the winter months; and the attendant number of hours of cloud, fog, and overcast is proportionately great. These may be adverse conditions in that they may lower the viability and stimulating qualities of pollen, or inactivate it by increasing its moisture content; but it is doubtful if light intensity is enough reduced to prevent a sufficient production of carbohydrates for growth, fruiting and maturation; though we know, that to get fruiting, after an initially rapid vegetative growth, there should be, along with

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ample nitrogen and water, an excess of carbohydrates over and above the amounts utilized with the nitrogen (2).

Alice P. Withrow says:

"This low set is due to faulty pollination caused in turn by the low carbohydrate content of the plant occurring during the cloudy, short days of our northern winter. It is logical.."(3)

Freeman S. Howlett (4), who is an authority on the subject, is cited as support for this statement; but it would appear that the assumption may be due to a misinterpretation of Howlett, who, perhaps, was referring to deficiencies resulting from other causes. One must bear in mind that noon daylight, during the summer, can be reduced to one-twelfth its value before any decrease in the rate of photosynthesis occurs (1a). Ordinarily, there is much more light available in nature than plants can absorb in photosynthesis, so long as other factors, such as carbon dioxide supply, remain the same.

In this region, nutritional abnormality has not been noted in winter growth; and it would appear that, at fruiting time, there is, where cultural practices have been normal, an excess of carbohydrates sufficient to provide for the production of fruit buds and of fruit. It is a matter of stimulating the plant to utilize materials present within it. This being so, there appears to be no nutritional reason why pollen or pollination should be faulty; though possibly pollen viability may be impaired under poor light conditions. Possibly the minimum photoperiod necessary to flowering may not suffice to produce pollen containing those stimulating substances necessary to fertilization; the result being poor set in midwinter. It may be that periods of lowered light intensity, during which it is possible that light quality may be varied, may have some diminishing effect on that amount of fruit set which may normally be predicted even during short days. It is possible, too, that certain kinds of glass may vary light quality adversly. Whether there are such factors or not, it still remains that winter is a short-day period of the year; and artificially increasing day-length, then, would seem a logical undertaking from which only beneficial effects should result.

If sufficient photosynthesis takes place in winter to provide for the production of fruit, it seems not unreasonable to hope that, other than an optimum photoperiod, some satisfactory means of stimulating fruit set may be found. Tomatoes do flower during short-day seasons of the year, even though fruit set is poor. Thus, the reproductive phase, the period of final maturation, does commence, though it may not be carried to a satisfactory conclusion. This knowledge provides one with a starting point; and the concept of a chemical stimulus, applied to the flower, readily suggests itself.

It is, perhaps, possible that a hormone spray may induce fruit setting if applied to the roots or foliage, of a plant previous to flowering. This method has been used to stimulate rooting in cuttings (5); but treated foliage frequently displayed a marked epinasty. Fruit spurs on apple trees have been treated to influence the initiation of fruit buds (6). Thus a further method of approach to the problem of fruit set in the tomato is suggested; a way which may warrant a thorough, separate investigation at some future time.

Local temperature conditions are very favorable to greenhouse operation; the amount of fuel required to maintain proper heat being about one third that required at Winnipeg, thus making operating costs measurably lower. If problems, such as this particular one of fruit set, can be overcome, conditions, in general, warrant an expansion of the industry, which, on the whole, is a very profitable one, and is in a generally healthy economic state. If the greatest difficulty for tomato growers, that of unsatisfactory winter fruit set, can be satisfactorily solved, the greenhouse industry might benefit, very largely, in a financial way.

Relation to the Broad Field

The present experiment is related, generally, to work being done in fruit set. In the future, other chemicals and means may, possibly, be used to induce fruit setting in tomatoes. It may be asked if the problem affects other crops. If so, any information gained here may be of more extensive value. More light may be thrown upon the subject of parthenocarpy in plants. The fascinating question of parthenogenesis may be touched. More broadly, there is yet much to be learned regarding nutrition; the utilization of nutrients in the full development to maturity of a plant; and such factors as radiation, day length, plant hormones, and all elements which exert an influence on such utilization. It is here that this one problem enters the whole, wide field of plant physiology.

## Intrinsic and Practical Value

A justification for performing the present experiment has already been developed; but, to be of benefit to the greenhouse industry, the discovery of a good method of increasing fruit set in greenhouse tomato plants during the winter, is not, in itself, enough. An increase in the number of fruits set, and in the total quantity of such fruits, must be great enough to warrant the use of the method producing them; i.e., the method and equipment should be inexpensive and economical of time and labour. Chemicals should be readily obtainable at low cost; and they should be capable of being easily and quickly applied by means of simple apparatus.

HISTORICAL DATA

The fruit of the tomato is recognized as being one of the more nutritious and valuable foods; particularly because of its high vitamin C content. Hence, it can readily be seen that it would not only be a boon to the populace at large, but, in a more restricted sense, an important aid to the commercial operation of greenhouses if this problem of set could be attacked and solved in an efficient and economical way. Since the year 1936 many experiments have been conducted in attempts to overcome the difficulty.

The tomato, though originally a short-day plant, has been developed into one preferring a long day. Therefore, an increase over winter day-length should bring the plant nearer to optimum conditions. For this reason, one of the first ways which suggests itself, when one ponders a solution to the problem of set in the tomato, is that of attempting to increase the length of day by means of artificial lighting during winter months. This has been done in many commercial greenhouses as a routine practice. Forty watt internal reflector lamps, and lights of even lower intensity, appear to have given results which, though not scientifically recorded and analyzed, have warranted costs. Experimenters have used lamps of much greater intensity (3).

Since the discovery of the relationships between plants and various organic acids, plant hormones, and plant vitamins in the role of growth regulators, promoters and accelerators, another method of approaching the problem of set has led to a great number of new experiments being done. These various substances were first used to promote rooting in woody cuttings from plants difficult to propogate vegetatively. Later, an attempt was made to improve results by spraying the plants before removing the cuttings (5). Finally, an effort was made to increase growth in plants, particularly in the size of fruit, by spraying, or dusting the accelerating substances as a step in a cultural method. Results obtained from these experiments, together with results obtained from experiments in stimulating parthenogenesis in animal organisms (7), seemed to indicate that chemical stimulation might lead to the production of fruits in plants when no fertilization had taken place. Since then, a great many attempts have been made to induce the setting of parthenocarpic fruits in tomato plants by spraying the flowers with growth regulators. Some substances have been shown to have a retarding effect on growth in general (8). Some have been shown to cause injury under certain conditions, or in particular concentrations. With other chemicals, certain experimenters have obtained no results; while, with the same chemicals, others have been consistently successful in obtaining increased set of fruit, and larger, though seedless fruits, or a larger quantity of good quality, smaller fruits. Perhaps the foremost amongst these latter investigators is Freeman S. Howlett, of the Ohio Agricultural Experimental Station, Wooster, Ohio. However, despite all the attempts to solve the problem of set in the tomato plant, results have not always proven conclusive.

Not until this year, 1948, has the work progressed much beyond the experimental stage. It appears that, even now, some profitable work could still be done in determining the results from treatment in different months and at different periods of growth,

To date, indolebutyric acid has shown the most consistently good results in inducing the production of parthenocarpic fruits on tomato plants. Other substances, such as indoleacetic acid, naphthaleneacetic acid, and indolepropionic acid have given fairly good results. Beta naphthoxyacetic acid is very effective; but damaging to plant tissues. These compounds have been expensive. There are, now, the less-costly, halogenated phenoxy acids. Some of these have been found to improve tomato fruit set when the acid is applied to flowers in relatively low concentrations. One, 2-4 dichlorophenoxy propionic acid has been used quite successfully. Others, which may be suggested, are 2-4-5 trichlorophenoxyacetic acid, its sodium salt, sodium trichlorophenoxyacetate, and 4 chlorophenoxy acetic acid. Two-4 dichlorophenoxy acid must be used in extremely dilute concentrations, because it is known to cause injury. Orthochlorophenoxyacetic acid is effective, but there are indications that outer tissues may develop at a more rapid rate than placental tissues, the result being a hollow, collapsed fruit. Many growth regulators produce similar effects when used in high concentrations. In such cases the fruits often feel puffy, or spongy to the touch.

These organic acids have been sprayed or applied to flowers in varying concentrations. Carriers used have been ethyl alcohol or carbowax. These have been dissolved in water to make sprays; or mixed with lanolin paste, or talc dust, to make preparations suitable for dry applications. Prepared in the latter way, hormones are somewhat difficult of application to flowers.

The conception of animal hormones was accepted as long ago as 1914; and as early as 1927 it was known that some substance, or substances, within plants, could stimulate growth (9). In 1928, Went, of Holland, isolated plant hormones; but, in general, these growth substances were completely unknown. Experiments soon provided more knowledge of their nature. It was learned that they could influence plant growth if applied to the outer surfaces of stems, roots or foliage. The Sitka gall midget does this very thing in nature, manufacturing a hormone, similar, chemically, to those produced within a plant, and applying this powerful substance to twig ends, inducing an extreme growth resembliing a pine cone, green in colour.

In 1929 a long paper on the subject of hormones was published by a German scientist, Arthur Pesek (10).

By 1936, Felix G. Gustafson, an American, had induced the production of seedless tomato fruits by the application, to the stigma and cut surface of the styles of mature flowers, of various substances in lanolin pastes. One material used was indolebutyric acid. In concentrations of 0.3 per cent the latter was found to be somewhat more effective than any other chemical used (11).

By 1938 the hormones auxin a and auxin b were well known. Beta-indolyl-acetic acid had been discovered to have growth stimulating properties similar to those of the auxins, and was called heteroauxin. This substance was discussed in many scientific papers of the period. H. Herbst, of Germany, published a paper, in 1939, which showed that in greenhouses, or in locations where pollen cannot be transferred by air currents, the application of heteroauxin to tomato flowers induced the production of small, parthenocarpic fruits. He found that Beta-indolyl-acetic acid 0.1 per cent, in water solution, on foliage and fruit of the tomato, increased the yield 5 to 20 per cent by weight, but made the fruit spotted and unmarketable (12).

In 1939, Gustafson found that, in the John Baer variety of tomato, fruit setting as a result of the chemical treatment of the flowers, was as great as by pollination. Parthenocarpic fruits were smaller than seeded fruits, except where the soil was very rich (11a).

Freeman S. Howlett, in the United States, has , probably, undertaken the greatest number of experiments concerning the practicability of chemical applications to flowers in inducing increased fruit set in the tomato plant. In an experiment concerning the practicability of certain chemicals as a means of inducing fruit set in the tomato plant, 1939 to 1940, he found that indolebutyric acid was more effective than indoleacetic acid, at concentrations 0.5, 0.1 and 0.02 per cent, in lanolin paste, in causing the development of flowers into fruit and in producing larger fruits (13). With the varieties Globe and Marhew, indolebutyric was best at 0.25 per cent and poorest at 0.02 per cent. K indoleacetic and K naphthalenacetate gave fairly good effects at 0.05 per cent concentrations. Fruits induced by indolebutyric acid tended to be larger than those produced following self-pollination. Locules were well filled. Quality was as good as fruit produced naturally.

The location of the experiment described above was not mentioned in the reference, but it was probably at the Wooster, Ohio Agricultural Experimental station.

In 1941, Howlett, at the Ohio Agricultural Experimental Station, deprived tomato flowers of pollen, and induced fruit set by means of 0.3 per cent indolebutyric acid in lanolin paste. He concluded that indolebutyric acid left little to be desired in achieving his purpose (13a).

In 1942, Howlett found indolebutyric acid to give its best results with the earlier flower clusters for, as day-length increased, natural set became correspondingly greater (13b). In 1945, he repeated his experiments , using the same acid in a spray (13c).

T. Swarbricke, Long Ashton Research Station, 1942, found 0.01 per cent solutions of naphthaleneacetic acid, and naphthoxyacetic acid on tomato plants resulted in a check to their development, and in marked epinasty on the parts touched (14).

T. W. Brets found volatolized growth promoting substances caused distortion of tomato plants and fruits grown in greenhouses (15).

A successful experimenter with acids is P. W. Zimmerman of the Boyce Thompson Institute for Plant Research, Yonkers, New York (16).

In a professional paper, "Substances Effective for increasing Fruit Set and inducing Seedless Tomatoes", published in the "Proceedings of the American Society for Horticultural Science", in 1944, P. W. Zimmerman, and A. E. Hitchcock gave a report on some of the work done up to the year 1944, at the Boyce Thompson Institute Laboratories, to locate effective chemicals for inducing parthenocarpy. The paper is, also, an admirable summarization of the greater part of all similar experiments previously completed.

These men found that Beta naphthoxyacetic acid, and some of the substituted phenoxy and benzoic acids may have pronounced formative influences on all plant tissues, causing injury, epinasty, and modification of habit. A plant's general condition is a factor which leads to results varying with each experiment, so that the choice of these materials for inducing parthenocarpy is, at best, doubtful. They refer to such substances as being active. Indolebutyric acid they found to be a mild and inactive regulator.

They found, from a concentration standpoint, that the most effective chemical known for stimulating ovary growth was 2, 4-dichlorophenoxyacetic acid, but, that, unfortunately it was the one most likely to cause inhibition of growth and modification of leaves. Above 5 mg/l it affected areas of the plant other than flower parts. They thought 5 mg/l, however, nearly optimum for stimulating growth of the ovary. It would, therefore, appear that it can, in some cases, be used safely. With a vigorous grower; such as Vetomold, unduly sensitive, because of its succulence, to any chemical treatment, the use of this acid may be ruled out as entailing a too great risk.

These experimenters found the percentage of fruit set on treated plants to be from one to 19 per cent greater than that on pollinated, but untreated, controls. The quality of parthenocarpic fruit depended to some degree upon the sensitivity of a variety to growth substances. The persistence of floral parts was a characteristic response on the part of treated plants. Entirely seedless fruit was difficult to procure where pollination occurred; but the more rapid development, and larger size of fruits from treated flowers was evidence of a stimulative effect.

Aerosol and vapour methods of dispensing growth promoters exposed the entire plant to chemical activity. They thought compounds active for parthenocarpy might be found which would not greatly inhibit plant growth. The aerosol method would then become more important. An entire greenhouse of 10,000 cubic feet capacity might be treated at one time; which would be a very great convenience indeed.

For inexperienced growers, and those working with only a few plants, Zimmerman and Hitchcock felt that water solutions, applied with an atomizer, were to be recommended, and that the spray should be applied to the back of the buds and the flowers, and to the open side of the flowers.

Zimmerman found the physiological activity of hormones to be related to chemical structure (16a).

Alice P. Withrow, Purdue University Agricultural Experimental Station, Lafayette, Indiana, (2), compared fruit set in tomato plants, treated with artificial irradiation, with set in plants on which the flowers had been treated with indolebutyric acid. This experiment has a special significance for the present investigation, and will be referred to again.

In 1944, A. Pollard, M. E. Kieser, and Joan Steedman reported that the food value of parthenocarpic tomatoes was as high as that of seeded fruits. Seedless fruits were sweeter, and lower in ascorbic acid content, but not significantly so (17).

In 1945 Howlett published a further report (13d), showing that he had found Beta naphthoxy acetic acid, and 2-4-dichlorophenoxyacetic acid to increase tomato size, but that the treatments resulted in cavities filled with an undesirable gelatinous pulp, and in an abnormal growth of leaves. He further reported that indolebutyric acid had been adopted by commercial growers of greenhouse tomatoes in Ohio, for the treatment of spring crops. A 0.2 per cent application in water spray was resulting in fruit sets of up to 90 per cent from all flowers formed. In view of the fact that experiments in the application of growth regulators to tomato flowers were widely conducted in 1946 and 1947, one can but conclude that these growers were themselves experimenting, though on a large scale. The results reported were, apparently, not made from accurately kept records. Further, in view of the fact that this acid was selling to experimenters at that time, in the pure state, for as much as five dollars a gram, this information is of great interest indeed. Unless the price of the material was greatly reduced to commercial growers__which is probable__the cost of treatment would hardly have been warranted, even by the greatly increased crops.

During the year 1946, M. C. Strong found one application of 2, 4-dichlorophenoxyacetic acid (2, 4-d) 10 p.p.m., when sprayed on flower clusters, to increase tomato size and decrease the time of bloom to maturity by one to two weeks. Some parthenocarpic fruits were hollow; many of these being unmarketable (18).

Also, in 1946, F. S. Howlett and R. B. Withrow reported indolebutyric acid to be generally non-injurious when applied to the flowers of tomatoes. Howlett stated that 2000 p.p.m. was an effective concentration, increasing fruit size. Aqueous solutions were especially good, and saved time, but fruits so stimulated may show an increased susceptibility to blossom end rot (13e and 13f).

A more recent paper is one supplied by H. K. Kemp, of Australia, in 1947. He found Beta naphthoxyacetic acid, 100 p.p.m., applied to tomato flowers, to increase growth without fruit distortion. The chemicals 2, 4-dichlorophenoxyacetic acid, 10 p.p.m., and 2, 4, 6 trichlorophenoxyacetic acid, 50 p.p.m., induced parthenocarpy with distorted growth (19).

Some of the more recent literature dealing with growth regulators may be found in the Yearbook of Agriculture, U. S. D. A., 1943-1947, published in 1947. John W. Mitchell discusses growth regulators and greenhouse tomatoes. He states that, because there are few insects or air currents in greenhouses in winter, one must pollinate tomato flowers by shaking; but that hand pollinated flowers often fail to set a high percentage of fruit, especially in cloudy weather. Often this is due to the failure of the flower to produce a pollen of a vigorous kind, similar to that developed by field plants in the summer. Vigorous pollen serves to fertilize so that seeds develop, and, also, apparently, contains substances which stimulate the development of the ovary into fruit. The place of these substances may be taken by growth regulators, artificially applied. Flowers should be sprayed, when fully open, with a 0.2 per cent water solution, or emulsion, of indolebutyric acid. This is the most widely used and safest means of attaining the desired result. If an emulsion is used, it should contain lanolin 1 to 2 per cent. If entirely seedless fruit is desired, it is necessary to cut off the stamens at the time of treatment. The aerosol bomb method of application is still in the experimental stage.

Indolebutyric acid is a relatively mild, greenhouse regulator. Naphthoxyacetic acid holds some promise when mixed with indolebutyric acid. Most other active compounds, naphthoxy and phenoxy, cause the pericarp of the fruit to grow faster than inner parts, leading to the formation of hollow fruits.

Sterile fruits often surpass others in size and quality. However, most fruits from treated flowers will show evidence of pollination by the development of seeds (20).

Also in the U. S. D. A. Yearbook for 1947 is a discussion of day length and flowering by H. A. Borthwick (21). This topic, of course, also relates to the present investigation. Borthwick summarizes the latest information regarding photoperiodism.

Borthwick states that Garner and Allard have found the photoperiod to have an effect on functions of the plant other than flowering. Thus, a plant may have several photoperiods, one for each function. For instance, a certain photoperiod may determine the time of flowering in the potato, while a different one will provide optimum light conditions for full tuber development. For any photoperiod there may be a difference in response from two different organs.

It is obvious that, for field plantings, a variety should be chosen whose day-length requirements are satisfied by those prevailing in the locality in question. One-half hour of difference in day-length may be responsible for as many as fifteen days difference in the flowering date. Thus, rather small differences in day-length may have important results.

The size of a plant and its general maturity do not determine the time of flowering. The lower limit of its flowering photoperiodic range does. A very young and small plant may flower if it is subjected to its flowering photoperiod. However, the longer a plant has grown vegetatively, and the bigger and more vigorous it is, the more flowers and heavier yield there will be. A short-day plant, seeded in April, will not flower until the fall, when days commence to shorten. Such a plant will have had time to become large through vegetative growth.

Borthwick states, that J. E. Knott, of the University of California, found plants to receive the stimulus of photoperiod through the leaves. He discovered this by exposing the leaves of spinach to long photoperiods, while the stem growing point and very young leaves in the centre of the rosette received short photoperiods. These plants produced seed stalks as did controls receiving long days. Others receiving long photoperiods on growing points, and short one on the leaves, remained vegetative, as did the short-day control plants.

The effects of photoperiod may be expressed by parts of plants not subjected to it. Sometimes flower production, as a result of a favourable photoperiod, remains localized on the treated part, but not always. Often, flower buds form on untreated parts if leaves are removed from them; for these leaves seem to interfere with the translocation of the flower-inducing stimulus from a treated to an untreated area.

The stimulus, apparently, moves from leaves to growing points, the areas in which hormones are most often found. (It is to be noted that some investigators have thought that the stimulus originates in growing points.) There is a strong indication that a chemical growth regulator is involved.

Short-day plants flower not because the photoperiod is short; but because of the long period of uninterrupted dark. If the dark period is broken, say, into two short ones, by an artificial light interruption of less even than one minute, the effect becomes that of a long-day and flowering is retarded. If the dark period is long, one minute interruptions bring long-day plants into flower. Reversal of response in each type seems to be caused by a break in a chain of reactions occurring in the dark period. Hence the term "photoperiodic effect" may be somewhat of a misnomer.

The effect created in the case of long-day plants, by brief interruptions in the dark period,is thus the same as that created by extending the photoperiod with artificial light added to one end of the day; an ordinary greenhouse procedure. A saving in costs is here indicated.

A long period of light, followed by a long period of dark, will not prevent a short-day plant from flowering. Thus, the long period of dark is required, not the short period of light.

Similarly, long-day plants will flower with short periods of light if the uninterrupted periods of dark are, also, short. A short day does not prevent flowering, a long night does.

Photoperiods, of course, have a photosynthetic function. Light intensity must be such, during photoperiods, that active photosynthesis will take place.

The photoperiodic mechanism is fundamentally the same for both long and short-day plants. Responses depend upon reactions during the dark period . The leaves of long-day plants grafted to short-day plants may cause the latter to behave like long-day plants. The wave lengths of light required to inhibit flowering of short-day plants, by the interruption of long periods of dark, are the same as those required to bring about flowering of long-day plants under similar conditions.

It has been found that a flower-inhibiting substance is not produced in the leaves of short-day plants growing in long photoperiods ( pp.279 ). It is merely that leaves of short-day plants fail to supply a flower-inducing substance, or enough of it, if the dark period is short, and not long. Leaves of long-day plants may fail to supply a flower-inducing substance when the dark period is long. The reason for this is obscure.

There is no evidence as to the chemical nature of flower-inducing substances produced in a plant (pp.279).

Apparently the quality of light is an important factor in photoperiodic effect.

One leaf, if subjected to a flowering photoperiod, gives, apparently, enough leaf surface to provide a stimulus.

If the nature of the substance manufactured in the plant could be determined it might be applied externally and photoperiod ignored, in so far as the date of flowering is concerned.

All these experiments, and those of a similar nature, typify the kind of work done to date. It is quite possible that obscure publications, particularly in Germany, may record earlier work. It is quite possible that, in the same country, as early as 1930, and perhaps earlier, experiments without publication of results may have been conducted in attempts to induce parthenocarpic fruiting. However, one need not be concerned here with such work.

PHYSIOLOGICAL FACTORS BASIC TO THE PROBLEM

It may not be out of place to give, here, a consideration to some of the physiological conditions of growth in plants.

The actual foods of a plant are carbohydrates, fats, proteins, and the vitamins or accessory foods. Out of carbon dioxide, water, and a little of various salts, plants construct their own tissues. Under the anabolic phase of metabolism, we may consider the synthesis of carbohydrates (photosynthesis); the synthesis of fats and oils, and proteins; and, finally, the conversion of these foods into protoplasm (assimilation).

The catabolic phase is digestion, respiration, and fermentation or anaerobic respiration, such as takes place in seeds.

The essential activity of a plant is in the top, where, in green parts, chlorophyll absorbs energy for the activities of life from ether waves forming certain portions of the spectrum of visible light, solar or artificial. A series of reactions takes place whereby plants build carbohydrates from what are commonly thought of aas the products of combustion; i.e., carbon dioxide from the air, and water obtained through the roots, from the soil. Chlorophyll, and substances in the structure of the plastids containing it, are intermediarily essential in the synthesis. Chlorophyll, as well as absorbing light, probably take a chemiczl part in the process. Enzymes, organic catalysts, are the activators. Chlorophyll is continuously destroyed by light; but cannot be manufactured in its absence. Carbon, hydrogen, oxygen, and nitrogen, with magnesium, are constituents of the chlorophyll molecule. Iron is not; but it seems to be necessary to chlorophyll formation; and it perhaps stimulates respiration (1a). Wiltstatter has shown magnesium to be the only metal constituent of chlorophyll. Iron may be necessary to its utilization.

Carbon dioxide and water are found in the flues of furnaces and in the rspired breaths of animals. Being products of combustion, they cannot provide the primary energy used in building foods. The energy, that is used, is the same energy that is required to activate the receiving apparatus of a radio set. Thus, plants are a form of solar engine.

In most plants, the first stable product of photosynthesis is the soluble sugar glucose. Oxygen is a by-product. Usually the sugar is immediately changed to starch in the leaf, for starch is insoluble in water, and does not obstruct the osmotic properties of cells; neither does it retard the photosynthetic processes through the accumulation of end products. At night the starch is converted back to sugar, and is removed from the leaf, through the veins, to other parts of the plant. Leaf cells are thus free of starch in the morning, and can hegin photosynthesis again, and continue the process of storing light energy in the foods manufactured; the energy being stored in the form of insoluble polysaccharides; i.e., starch, glycogen, inulin, cellulose, hemicelluloses.

All interactions occurring within the plant, following photosynthesis, are activated by enzymes. Hence, temperature is an important factor in plant function. The activity of enzymes is slowed by lowered temperatures. The average production of carbohydrates, in many common plants, is somewhere in the neighborhood of 1g. per square meter of leaf surface per hour (1b).

Carbohydrates, formed by photosynthesis, serve not only as sources of carbon, hydrogen and oxygen to combine with nitrogen, and smaller amounts of other materials, in the synthesis of proteins, but as the plant's sources of energy released during respiration.

> "Starch, cellulose, and other carbohydrates are made directly out of the original glucose resulting from photosynthesis. Some of the glucose is converted into glycerin and fatty acids from which fats are made. By the addition to glucose of such minerals as nitrates, phosphates, and sulphates, amino acids are made. These, in turn, are linked together to form proteins, always found in abundance where there is active cell division and growth. Out of the proteins may be made enzymes, secretions, other complex organic compounds, and protoplasm itself. The making of the living substance protoplasm is called assimilation. Assimilation is the ultimate goal of all anabolic processes. It is really in assimilation that the nonliving substances become living". (1c).

Because of protoplasm a plant is capable of self-reproduction which, in a final analysis, is a process of flowering, fruit setting and fruiting, which is maturation.

Secondary reactions, the oxidation of the products of synthesis into protoplasm, take place in the dark. In this secondary activity the plant works like a heat engine, by oxidation of the substances synthesized by sunlight. Oxygen respiration involves the utilization of free oxygen, at least in the final stages of the process, and results in complete oxidation to carbon dioxide and water. The really important feature is that energy is released by it.

Most of the energy liberated does not appear as heat; but is used in carrying on the work of the cells. Synthesized substances are used as fuel in an engine, and release the usual products of combustion, carbon dioxide and water. In the dark, the plant works more like an animal, living on substances made by a plant--in this case itself--during sunshine hours. Most growth takes place in the dark -- ten times as much as in daylight. Growth signifies hydrolysis, digestion, and starch back to sugar. Soluble nitrogen is most abundant in the dark; and proteins are thus most abundant where there is active growth and cell division.

Respiration is oxidation of digested foods. It is a process to which light is not necessary, though light stinulates it, indirectly, by providing respirable material. Digestion, or hydrolysis of foods into soluble substances, which supply growth, may, also, be said to supply the energy for growth (22). In the process there is a loss of sugars. Carbohydrates are easily digested, and are, therefore, used most in respiration. They are the most available source of stored up radiant energy; and are a sort of storage battery ready to break down and combine with oxygen to release energy in a form protoplasm can employ.

Cytochrome, a substance common to all living cells, appears to have a fundamental part in the utilization of oxygen by protoplasm, and has similarities with chlorophyll.

It has long been claimed that the requirements of a plant are not for light, but for the products of light. With regard to a plant's obvious needs for carbohydrates, this is very apparent. It may seem, after reading through the present work, especially those portions emphasizing optimum photoperiod requirements, that an attempt has been made to reverse this statement. A little thought will show that this is not the case. If a certain photoperiod is required to bring a plant to maturity, to activate and utilize the carbohydrates available, and the activation is considered to be due to a factor, factors, hormones, or growth inducing agents formed in most abundance where there is an optimum photoperiod, then these may, also, be said to be products of light; and though, in one particular sense, it is light itself which is needed, yet, in the final analysis, it is the products of that light which are required.

It is known that light controls plant growth and structure (22a). In view of the most recent information, this can hardly be denied. What one desires to know is how light, and variations in its supply, produce such profound effects.

Tincker (23) adopted the very simple technique of running plants, growing in pots, into and out of a dark shed for only six, nine, or other similar periods of daylight per diem. Under these conditions a bean plant, normally growing to a height of two feet, altered profoundly in growth and turned into a rosett of leaves. The root fattened out like a small carrot, and proved edible. A new vegetable dish had been discovered.

Light, though necessary to growth, paradoxically checks growth. Stems in full light are shorter, though dry weight is greater, than is the case when plants are grown in partial shade (22b). Also, although chlorophyll, necessary to all continuous growth, cannot be formed in the absence of light, chlorophyll is continuously destroyed by light.

Since light controls the growth, and, hence, the structure of plants, variation in supply should affect plant structure profoundly. Tincker's experiment with the bean, already described, bears out this statement. Blakeslee, East, and Clausen in America, Maximov in Russia, and Tincker in England have obtained interesting results by submitting plants to daylight periods of abnormal lengths. A greenhouse technique for bringing about variations in the lengths of days (24) has been worked out in great detail.

There are many factors vovering growth and the production of tissues; but the relative value of any one in a particular process can only be determined by keeping the others constant.

In general, only about 1 per cent of the total energy incident on a leaf is used in photosynthesis (1d and 22c). This is due to the fact that rays of only certain parts of the light spectrum are absorbed by chlorophyll. and the photosynthesis is limited by the quantity of chlorophyll, temperature and enzyme activity, humidity, atmospheric pressure, nutrient supply, soil water content, available carbon dioxide, and possibly other factors (22d). An increase in carbon dioxide, in the atmosphere means an increased diffusion gradient of this gas towards the leaf. Careful experiments have shown that plants can use greatly increased percentages of carbon dioxide if they are available. Increasing carbon dioxide increases the yields of many crops 30 to 300 per cent (1e). The vaporization of water in transpiration, and radiation to the atmosphere, dissipates excess energy falling upon the leaf. Most plants carry on photosynthesis at a maximum rate, for usual conditions, in a light intensity much below that of normal daylight. More light may be used, of course, if changes occur in determining factors.

For any particular set of conditions, duration of daylight determines the total amounts of carbohydrates made. It is thought that the development of flower buds is conditioned by the carbohydrate supply in store at the time of their formation. Withrow has thought that this, also, influences fruit set (3). She has, also, thought that an initial increase of carbohydrates, brought about during the early days of growth through increased photosynthesis, due to irradiation from artificial light, will increase fruit setting by improving pollination. Whether it is possible for sufficient carbohydrates to be stored during initial growth to influence any sort of growth function later on is extremely debatable. It is known that, at the fruiting phase, there should be an excess of carbohydrates over an ample supply of nitrogen; but Alice P. Withrow's own experiment shows, that, providing a reasonable balance be maintained between carbohydrates and nitrogen, sufficient carbohydrates are manufactured to provide for fruit production even with shorter days and lowered light intensity. The fact that plants grown in normal winter daylight, when stimulated by hormone sprays to set fruit, produced greater crops than initially irradiated plants, shows that there were sufficient carbohydrates present under normal conditions to provide for fruiting and that, though carbohydrates were low, the chemical caused the utilization to such an extent that these plants produced more fruit than plants with a greater carbohydrate content.

Even in winter the tomato puts forth numerous, sturdy fruit buds which seldom fail to flower. Knowing these things, it would appear contradictory to explain faulty fruit setting on nutritional grounds, providing the carbohydrate and nitrogenous compounds are in a proper relationship for the phase which the plant has reached. Undeniably there is, during short days, at this point, a failure in the reproductive phase. Tomatoes appear to flower under most conditions. The difficulty is failure of the maturation process to continue during the short days of winter. Withrow's plants, given an initial irradiation treatment, set more fruit than untreated plants growing in normal winter daylight, but not so much as plants whose flowers had been sprayed with indolebutyric acid. Hence, the failure to set fruit satisfactorily, in winter, may not be due to a lowered storage of carbohydrates in stems, but to the failure of some other factor, or factors which are necessary to the utilization of the carbohydrates which are present. This does not mean that an increased yield could not be obtained if carbohydrates were increased by longer duration of light, or an increased amount of carbon dioxide in the atmosphere; always providing the utilization factor is present; and always providing the balance with nitrogen is maintained at a proper ratio.

Such conditions can lead to larger yields in any season. The point one wishes to emphasize is only that, always, there must be some factor present to make possible the utilization, to make available, for the reproductive phase, the carbohydrates in the plant. It may only be that the factor brings about increased fruit set by increasing the viability of pollen; the carbohydrates, perhaps, being used in fruit production in any case once the fruit is set. Little is yet known regarding this.

Many plants will not flower, or flowering will not set fruit excepting under or near to their optimum light conditions. These conditions differ with each plant. Extensive information is now available as to various day-length requirements. The same, or better, effects can often be obtained by spraying flowers with various stimulating substances. In view of this information regarding photoperiodism, it has been concluded that the utilization factor, already mentioned, is light, itself, of a definite duration for each plant, or a substance or substances formed, or induced to form because of light provided by day-lengths within fixed limits. Many investigators believe terminal buds to be the loci for the stimulus of photoperiodism. Cajlachjan, the Russian investigator, considers leaves to be the receptive areas. Thus, flowering and fruiting seem to depend upon an optimum photoperiod. The nearer the day approaches this the better carbohydrates are utilized for reproduction and, it may well be, the better all foods are utilized for the same processes. In other words, the greater the amounts utilized of the materials which are necessary to reproduction and maturation. Though excess carbohydrates over nitrogen are necessary for the reproductive phase, no amount of increase in carbohydrates, in themselves, can cause fruit to set without the utilization or stimulating factor (s). The cosmos is a short-day plant. During long-day periods, the cosmos should be able to develop sufficient carbohydrates for any functional purpose; but it will not flower then, no matter what the carbohydrate nitrogen ratio. If the growing tips of the cosmos are covered with black caps, so as to shorten the day, the treated buds will flower. With just the tips covered, plants should still manufacture as much, or almost as much carbohydrates as plants with uncovered buds, providing these latter plants are subjected to the same photoperiod. If increased carbohydrates are needed in the covered buds to make them flower, there is nothing to prevent translocation of these materials from other parts of the plant, which, being still subjected to a long day, theoretically should, and probably do have them in abundance. The fact that the whole plant will flower when deprived of the excess, by a short day, indicates that, in this plant at least, a shortage of carbohydrates does not interfere with satisfactory fertilization. In fact, the conditions developing excess carbohydrates prevent flowering in the cosmos.

These facts delineate two things: First, that the effect of day-length is localized and, secondly, that the effect is caused by light, and not by food relationships within the plant. All of this appears to be a refutation of the hypothesis that a low carbohydrate content is responsible for poor fruit set in the tomato. It may be noted again that Withrow has shown in her own experiment that, where there is poor fruit set, the plant may be, at the same time, capable of flowering, and capable of producing fruit if stimulated by hormones. If the plant can flower, and produce parthenocarpic fruit, why is there a failure in the fertilization process? The failure appears to be due to one factor, a too short photoperiod.

Flowering implies vastly increased respiration. Light is not directly necessary to respiration, for it takes place in the dark as well as in the light. By deduction then, light, itself is not the utilization factor we have spoken of. Hormones are found in the meristematic regions. They are found in greatest amounts when the plant is subjected to its optimum photoperiod. Hormones stimulate respiration locally. Hence, it is logical, in our present state of knowledge, to believe that these hormones are formed, or gather, as a result of optimum photoperiods, and they are the stimulators of plant maturation which we have been seeking.

In the case of phototropism, the growth substances appear to be repelled by light, for they are found on the side of the stem away from the light. Does light stimulate their production in this case? It is not purposed, in the present paper, to attempt an explanation of problems of this nature; but referring to the point serves to emphasize the fact that the problem of photoperiodism and fruit set is, after all, complex in the extreme; and it behooves anyone to think well before categorically challenging the conclusions of others.

Alice P. Withrow's experiment seems to show that hormones may be stored. Her irradiated plants, subjected to a long day, in the early stages of their growth, later produced more fruits than plants subjected to normal winter day-length ; but there was a gradual falling off of the initial increase in fruit setting, showing that, though the irradiation was not maintained, the effect was prolonged, though gradually diminishing. The effect was explained as being due to an increased storage of carbohydrates resulting from a longer duration of photosynthesis. By now, it should be apparent that there is little likelihood of this being the true explanation. Where hormone production is continuously maintained a falling off in fruit setting may be due to an exhaustion of stored carbohydrates or an exhaustion of previously stored hormones. In this latitude there is always a falling off as the changing seasons carry a plant past its optimum photoperiod.

Various toxic chemicals, in small dosages, applied to a plant, act to stimulate respiration. Hence, one may apply various organic acids, or hormones synthesized in the laboratory, or hormones extracted from plants, and get the same effects as result from the manufacture of hormones within a plant.

It has been found that there is an increase in soluble organic materials in plants at the point of application of growth promoting substances (6). This is also true in the case of growing tips subjected to optimum light duration; and growth promoting substances have been isolated there.

In the case of the artificial application known hormones may be applied, and certain organic acids which may, or may not be hormones themselves; i.e., in the sense that they stimulate tissue changes directly. These organic acids, if they are not hormones, may only cause hormones, manufactured in the plant, to migrate to the point of application. These are matters whibh still require study. However, there seems little doubt that the reproductive phase in a plant is not so much influenced by total photosynthesis, and food relationships within a plant, as it is by some factor or factors, activating the utilization of foods for certain, definite purposes; and the factor, or factors seem to be related to optimum day-length. Experiment has shown that substances present in growth regions, and, present in the greatest abundance during optimum daylight conditions, may be used to produce growth effects when applied artificially.

Growth, particularly reproductive growth, implies increased respiration (25). The rate of respiration is affected by the amount of available carbohydrates, temperature, oxygen, and water. Weak concentrations of toxic chemicals, such as ether, chloroform, and paraldehyde, may speed up the rate of respiration for a time, and bring plants into flower earlier. Injury and disease also increase respiration, taking sugars to injured portions for purposes of repair. Increased temperatures within opening flowers may be as much as 30 degrees Centigrade (1f). Thus, it may be, that when the reproductive phase is reached, anything increasing respiration may be a factor in causing the process to continue to completion. Respiration in the plant is enzymatic in nature. This is a thing to be remembered. How is it tied in with the effects of growth regulators such as hormones? Are the latter organic catylists also?

Vitamins, synthesized by the plant, seem, also, to be important to the health and growth of the plant. Probably they are always present, unless the plant is temporarily out of its environment, as it is when it has just been transplanted. Their artificial feeding may be expected to give best results under such conditions. The same, of course, may be said of hormones.

Temperature is one of the more important factors in plant growth. Each plant has an optimum for each phase of its growth, usually requiring a higher temperature for the maturation phase. Temperature influences the activity of enzymes.

The relation of amounts of carbohydrates and nitrogen is one of the very important things to be considered in plant growth. The relative proportions of carbohydrates, fats and oils, and proteins may be maintained in a particular ratio by varying the amount of soluble nitrogen compounds fed the plant; so that nitrogen is brought into line with the amount of carbohydrates being formed by photosynthesis.

Let C+ be excess or abundant carbohydrates, N+ be excess or abundant nitrogen, C ample carbohydrates, N ample nitrogen, c restricted carbohydrate supplies, and n restricted nitrogen supplies, then, normally, the results are:

$\frac{c}{N+}$ Poor growth. Small amount of fruit. Nitrogen not all utilized with carbohydrates in the synthesis of higher organic compounds.

$\frac{C}{N}$ Rank growth. Small amount of fruit. Just enough of carbohydrates so that hitrogen is fully utilized.

$\frac{C+}{N}$ Fair growth. Good fruiting.

$\frac{C+}{n}$ Poor growth. Small anount of fruit. (2).

That light is a potent influence on plant structure is seen in the fact that plants grown for a time in the absence of carbon dioxide, but in the presence of light, do not become eticlated (1g). In addition to an optimum day-length there is an optimum light intensity for a plant, seen in the fact that some plants prefer full light, while others prefer shade. These optimum light conditions seem necessary to normal tissue differentiation; particularly so in the case of reproductive tissues. Fruit setting appears to be at a maximum in a light intensity exceeding that required for maximum photosynthesis. It is possible that certain organic acids, applied to the outer surfaces of flowers, may not only induce the setting of parthenocarpic fruits, but may induce maximum fruit setting, even during a wide departure from optimum light conditions. To obtain ideal light conditions by artificial illumination, an alternative method, may be found most difficult.

It is possible that even under an optimum day-length a plant may fail to flower if the light intensity is too weak. The failure here may be due to both failure of the utilization stimulus and to insufficient photosynthesis. In both long and short-day plants vegetative growth is greatest under the long day. The difference is that, in the plant preferring the long day, reproductive activity is also great.

Activation of any process in a plant by day-length, or artificially applied chemicals, may continue after the stimulus has been removed. This may be why the irradiated plants in Alice P. Withrow's experiment gave increased fruit production after the irradiation was discontinued. There appears to have been a gradually diminishing effect.

> "The reaction or response of a plant to a stimulus may not begin until some time after the stimulus is applied and may continue after the stimulus is removed." (1h).

Finally, the actual growth of plants results from the simultaneous operation of all factors, internal as well as external. It is therefore, not always possible to separate the influence of a single factor from that of the other factors.

DISCUSSION OF A RELEVANT EXPERIMENT

The work of several experimenters has already been briefly reviewed in this paper. A paper entitled "Comparative Effects of Radiation and Indolebutyric Acid Emulsion on Tomato Fruit Production", and written by Alice P. Withrow of Purdue University Agricultural Experimental Station, Lafayette, Indiana, (3), describes a greenhouse experiment which is closely paralleled, in many respects, by the present investigation. Because of this, and because the results of the Lafayette experiment and the present experiment follow the same general pattern, it is interesting to attempt an interpretation of the results of the former from a physiological viewpoint.

Alice P. Withrow worked with three groups of tomato plants of two varieties, Long Calyx, and Michigan State Forcing, sown December 15,1943. While in seed flats, one group was irradiated for twenty-one days from the time of the unfolding and greening of the cotyledons. Irradiation was for four hours daily from a 300 watt internal reflector lamp.

On January 14, all plants were transplanted to ground beds. The three groups were:

(a) Control plants grown by regular greenhouse methods, and vibrated daily, after flowering, to aid pollination.

(b) The plants given initial irradiation and, subsequently, the same treatment as the control plants.

(c) Plants whose flowers were treated four times a week with a growth regulator, indolebutyric acid, 2000 p.p.m. from a nasal atomizer. Although no precautions were taken to prevent pollination, these plants were not vibrated to aid it.

The irradiated plants showed an increased fruit set on the first five clusters for Long Calyx, and on the first four clusters for Michigan State Forcing. Beyond this the production was less than for comparable clusters of the control plants. The net result was, that Long Calyx showed a 10 per cent total gain in the number, and 9 per cent in the total weight of fruits over the controls; and Michigan State Forcing a 3 per cent gain in each of these. The average weight per fruit was about the same as for the control plants.

It is possible, in the case of these irradiated plants, that the light treatment, given when the plants were small, brought about a storage of hormones which later, on first flower clusters, stimulated an excess of fruit set over that in controls. Perhaps the decrease in fruit set on later clusters, as compared with controls, was due to a more rapid initial utilization of available carbohydrates in the irradiated plants, with a subsequent exhaustion of stored hormones, and a greater initial exhaustion of carbohydrates. The fact that the irradiated plants showed a small net gain may be due to a better total utilization of carbohydrates. Even if the small amount of increased carbohydrates in the tiny plants irradiated in the flats, did influence later fruit setting, it is doubtful if the increased carbohydrates would be sufficient to explain the net gain in weight of fruits. The explanation is more likely to hinge upon a storage of stimulating substances within the plant during the period of initial irradiation.

Irradiated plants were out of production earlier than control plants, due to the fruiting phase proceeding at a faster rate. Fruits matured more rapidly.

Pre-irradiation did not ensure adequate pollination, as many blossoms failed to set fruit.

From observations made during the present experiment, seedlings during initial irradiation grow more rapidly than control plants. Probably extra carbohydrates, made by additional photosynthesis, are utilized immediately in growth, and not stored to influence fruit set, as intimated in Withrow's introduction. In any case, there is no accumulation for the formation of fruit buds in a plant until vegetative growth slows down or, even, has ceased.

Where plants were treated with the growth regulating substance, there was, on Long Calyx, a net increase of 18 per cent in number of fruits set, and 15 per cent in weight over controls. Increases for Michigan State Forcing were about half this. The initial increase on Long Calyx, on the early clusters, where increase was greatest, was not followed by a decrease to a lower level than controls, as was the case with the irradiated plants; although, later, as the season advanced, weight production came to equal that of control plants; not because of a drop in production in the treated plants, but because of an increase in production in control plants as the days became longer, and approached more nearly the optimum requirements of the tomato. Thus, as Withrow has logically suggested, it appears, from this experiment, that the use of growth promoting substances, on the flower of the tomato, may not be worthwhile on the later flower clusters, as the production was not increased over that of controls when the weather became brighter and the days longer. Thus, it is shown that the artificial application is only effective where the plant is out of its optimum reproductive environment during the short winter days. Later, as longer days bring about the production of growth stimulating substances within the plant, the continued application of growth promoting substances, artificially, does not increase the effect of those manufactured naturally inside the plant; but, on the contrary, has no effect whatsoever.

The average weight of fruits from plants sprayed with the growth regulator was observed to be less than that for the control plants, though about the same number of fruits were set as on control plants. This seems to imply that, while plants growing naturally had the benefit of a certain amount of carbohydrate storage before fruiting, this was lacking in plants which had already been producing fruit during the short days. Nevertheless, the net increase displayed by artificially treated plants shows that the procedure is worthwhile.

Beyond mentioning that the plants treated with the growth regulator often had fruits with a green placental pulp, there was no other reference made to the edibility of fruit.

Plants treated with a growth regulator showed a greater net increase in production over controls, particularly in first clusters, than did initially irradiated plants, showing that increased carbohydrates were not needed for increased fruit production, and therefore that there was very little likelihood that they were needed for increased fruit set. Plants treated with the growth regulator could have had no more carbohydrates as a result of photosynthesis than could plants used as controls.

It is most probable that if an experiment were to be conducted so that sugars were introduced into a plant artificially in the absence of long day photosynthesis; i.e., during short days, there would still be no fruit setting, even with the increased amounts of carbohydrates, it being almost indisputable that the main factor in fruit setting is the accumulation of growth substances due to a long day, or to the application of such substances artificially.

Also, if Withrow's experiment were conducted so that plants irradiated in the flat grew in an atmosphere of lessened carbon dioxide supply, so that there would be less carbohydrates than in the control plants, it is probable that the irradiated plants would still show an increased fruit set and production over controls.

A major conclusion to be drawn is that the effects of artificially applied treatments differ greatly with varieties; but that treatment with a growth regulator during short days does result in important increases in fruit set in the tomato plant of the two varieties grown in the experiment.

MATERIALS AND METHODS OF THE FIRST YEAR

On October 30, 1946, tomato seed of the variety Vetomold 121 was sown in sterile, washed, river sand on moisture retaining burlap sacking in two flats, 12 by 18 by 3 inches in size. The use of this coarse sand, of particle size 2.0 to 0.2 millimetres, would, it was hoped, lessen damping off in seedlings. The seed was placed in shallow, lath made rows 1.5 inches apart, and lightly covered with sifted sand. The sand was watered until it was thoroughly moist, covered with newspapers, to exclude light; and the labelled flats placed in the semi-tropical room, of the university greenhouse, on sand covered propogating benches receiving a bottom heat of 70 degrees Fahrenheit from hot water pipes. The sand in the flats was watered whenever it showed signs of drying out. This was every second day.

On November 5, 1946, the first cotyledons appeared; and the newspapers were removed. Though mice were present, they were kept under control by the use of ordinary traps; so that there was no rodent damage to seedlings at any time.

On November 8, flat B was placed in the plant nutrition room, where the temperature was maintained between 60 and 64 degrees Fahrenheit. A 200 watt fluorescent lamp, regulated automatically by an electric clock, was suspended two feet above the tops of the seedlings, which were irradiated for twenty-two days for four hours daily, the periods being 4:00 a.m. to 6:00 a.m., and 6:30 p.m. to 8:30 p.m. The cost of providing the light was four cents per K. W. H.

According to Hill, Overholts and Popp, when plants receive alternations of light and darkness in periods of six hours or less, they respond as though kept under a long day ( 1h ). To test this out, four seedlings in flat B were covered with black paper caps daily, excepting on Sundays, from 8:15 a.m. until fifteen minutes past noon, or for a period of four hours each day for six days in the week. This, with the hours of artificial lighting already stated, fulfills the conditions above. It was anticipated, that if the statement should prove to be correct, these covered plants, though undoubtedly producing less carbohydrates as a result of photosynthesis, should respond with a percentage of fruit setting as great as in the uncovered plants. #

This group, of four plants, was labelled Pa; the letter P signifying the large group receiving a pre-treatment if irradiation; and the letter 'a' signifying the covered test group within it.

The daily capping of the group Pa was stopped at the same time as the irradiation of all the plants in flat B; i.e., after twenty-two days.

Flat A, on November 8, was placed under the normal greenhouse daylight conditions of the horticultural research room, which was kept at a temperature of 52 to 54 degrees Fahrenheit during the coldest months. As the season advanced, this minimum degree of warmth was greatly increased, until, at flowering time, it was often over 80 degrees.

From November 7, until the time when the seedlings were

\# It is now thought (1948) that a long day can be simulated by dividing or interrupting a long dark period with one minute of artificial illumination, H. A. Borthwick ( 21 ).

were transplanted into soil, they were fed with a nutrient solution applied sufficiently often to keep damp the surface of the sand in the flats.

The solution used was Hoagland's and Arnold's, 1928. The six major elements were provided from molal stock solutions (1 M or 1 GMW of solute per litre of solution) made up in distilled water, using each of the following in chemically pure form:

Potassium phosphate, ( $KH_2 PO_4$ );
potassium nitrate, ( $KNO_3$ );
calcium nitrate, ( $Ca(NO_3)_2 . 4H_2O$ );
magnesium sulphate, ($MgSo_4 . 7H_2O$ ).

The essential element iron (Fe) was provided from a stock solution of a 1per cent concentration of iron tartrate.

The table below shows, succinctly, the proportion of each stock solution applied to the plants in one litre of nutrient solution:

| STOCK SOLUTION | | FOR USE IN 1 L. OF NUTRIENT SOLUTION |
|---|---|---|
| (1.) | 1M. $KH_2PO_4$ | 1 c.c. |
| (2.) | $KNO_3$ | 5 c.c. |
| (3.) | $Ca(NO_3)2.4H_2O$ | 5 c.c. |
| (4.) | $MgSO_4.7H_2O$ | 2 c.c. |
| (5.) | Iron Solution | 1 c.c. |

In addition, to provide the micro elements, boron, magnanese, zinc and copper, were mixed together in a pint of distilled water, one-fourth teaspoonful of each of the following substances being the sources of the elements:

Boracic Acid, $H_3BO_3$;

manganese sulphate $MnSO_4, 4H_2O$;

zinc sulphate, $ZnSO_4.7H_2O$;

copper sulphate, $CuSO_4.5H_2O$.

This mixture was used at the rate of ten drops per litre of Hoagland's solution.

All stock solutions were stored in glassware in a dark cupboard.

Such solutions are best applied when they have an acidity of approximately pH6. In practice, the nutrient solutions are mixed in distilled water without adjustment. However, the tomato prefers a soil solution of pH 6 or 6.5; so that, if it is grown to maturity in sterile sand, alkaline solutions may be adjusted by the addition of a few drops of acetic, or of sulphuric acid. Under alkaline conditions, iron goes out of solution, resulting in the tomato, in chlorosis. Available iron may be supplied by spraying foliage with a solution of iron sulphate.

Solution plants have well controlled conditions, and are largely free of disease, insect pests, and weeds.

All seedlings were thinned out to a spacing of 2 times 2 inches on November 18.

Irradiation of the seedlings in flat B was terminated November 30, 1946. On this date, twenty-five days after the appearance of the first cotyledons, fifty-six plants were selected and transplanted into 2 inch, earthern pots containing a sandy, composted soil based on rotted grass cuttings. Until the time of transplanting into 10 inch pots, these plants were watered with the solutions used in the flat stage. Twenty plants, as uniform in size as possible, were taken from the irradiated group. Included were the four plants of group Pa, which had been subjected to simulated long day conditions of light. Thirty-six uniform, untreated plants were selected from flat A.

Sixteen of the plants from flat A were placed in the plant nutrition room with 200 watt fluorescent lamps suspended 24 inches above their tops. Irradiation was given for six hours daily; three hours in the morning, ending at sunrise; and three hours in the evening commencing at sunset. The times of sunset and sunrise were determined from local newspapers. The effect was a greatly increased photoperiod.

The remaining forty plants were placed, on a long bench, under the normal daylight conditions of the somewhat cooler horticultural research room.

It has been thought that a hormone spray on foliage, prior to flowering, might induce fruit setting, providing a concentration could be found which would be sufficiently dilute to avoid the danger of causing epinasty, yet strong enough to be effective. To date, no success has been attained. Nevertheless, the four plants in group S were set aside for such a test.

All plants were labelled. The tabulation below is self-explanatory.

| Group | No. of Plants | Treatment |
|---|---|---|
| N | 8 | (Control Group) Normal Daylight |
| NT | 8 | Normal Daylight and Indolebutyric Acid |
| P | 8 | Pre-irradiation, No Hormone Treatment |
| PT | 8 | Pre-Irradiation and Indolebutyric Acid |
| Pa | 4 | Pre-Irradiation and Simulated Long Day |
| S | 4 | Normal Daylight and Foliar Sprays |
| L | 8 | Photoperiod increased by Six Hours Daily Irradiation. No Pre-Irradiation |
| LT | 8 | As above, and Indolebutyric Acid |
| Total | 56 | |

On January 7, 1947, all plants were transplanted to 10 inch, earthenware pots. Labelling and room locations were not changed.

The soil used was similar to that in the first transplanting. Using a colorimetric determination for pH, and rapid soil testing methods, the condition of the soil was found to be CN3 P4 K3; i.e., the pH was between 5 and 6, available nitrates were in medium supply, phosphorous was low, and potash medium. The supply of calcium, also, was found to be medium.

The requirements of the tomato are C N2 P2 K3; i.e., pH 5 to 6, and a high proportion of each nutrient.

Well rotted animal manure was sieved through a ½ inch riddle. One pound of the material was added to each pot. One-half, a coarse portion, was mixed with soil near the bottom of the pot. In this position it was a reservoir of moisture, and was available for plant feeding at fruiting time, when roots had reached this depth. A fine portion of the manure, along with a tablespoonful of Urbanite 6-7-6, a product of the Fertilizer Division of Canadian Industries, Limited, was thoroughly mixed in the upper layer of soil for immediate feeding.

The tomatoes were planted at a somewhat greater depth than that at which they had been growing in the small pots, and unfertilized soil heaped around them to prevent injury from the commercial mix. They were pressed firmly into the soil, and a cupful of warm water poured around them.

Biologically, the soil analysis was borne out at each stage of the plant's development. Just sufficient nutrients had been added to correct the original deficiencies. As the added nutrients were slowly available throughout the season, no further soil treatment was found necessary. However, iron tartrate solution was applied once each month as a precautionary measure, as iron is commonly deficient.

Two weeks later a stake was pushed into the soil of each pot and, as increased growth made it necessary, the plant was tied to this.

To minimize variations in light and heat intensity, due to placement, the plants of all groups were randomized over the site, rather than kept in separate rows.

Cultural treatment, in general, was as uniform as possible. Watering was done in such a fashion as to prevent the soil around the roots becoming entirely dry at any time.

All plants were trained to single stems.

On January 28, the four plants of group S were sprayed on foliage and stems, until wet but not dripping, with varying concentrations of indolebutyric acid in distilled water. The acid was first dissolved in 95 per cent ethyl alcohol. The concentrations applied were:

50 p.p.m. on plant S1,

100 p.p.m. on plant S2,

250 p.p.m. on plant S3,

500 p.p.m. on plant S4.

On January 30, when their photoperiod had just commenced to rise above fifteen hours, the plants of groups L and LT formed first cluster flower buds, some of which started to open. As the day length rose towards sixteen hours, these opening buds closed, but remained persistent. None of the flowers opened fully. After February 7, when the photoperiod had reached fifteen hours, thirty minutes, no more buds formed, and the plants continued vegetative growth only.* It was thought that the photoperiod had perhaps become excessive for flowering, so that, on February 21, when the normal day had reached ten hours,

* It is now believed (1948) that these effects were due to the quality of the fluorescant light supplied. The number of days of exposure to this light seems, also, to have been a factor.

twenty-nine minutes, and the extended day sixteen hours and twenty-nine minutes, all plants of L grouping (L, and LT) were moved to the horticultural research room, and placed on the same bench as the plants of other groupings.

Also, February 21, 1947, was the date on which the first flowers of cluster 1 opened in the N, NT, P, PT, Pa, and S groups. With the beginning of flowering, those plants receiving no chemical treatment were vibrated, daily, by tapping supporting stakes with a cane. The purpose of this was to aid pollination so that poor fruit set would be indicative only of unsatisfactory fertilization, rather than lack of pollination.

The first three clusters only were treated. The treatment used was indolebutyric acid in every case. Dissolved in 95 per cent ethyl alcohol, and made up in distilled water, the organic acid $\gamma$-(indole-3)-n-butyric acid, applied with a nasal atomizer, was used in the concentrations 50, 100, 250, and 500 p.p.m. as a foliar spray on the plants of group S; in the concentration 0.5 per cent (5000 p.p.m. ) as a blossom spray on the first clusters of the groups NT and PT; and in a concentration of 0.01 per cent ( 100 p.p.m. ) on the third clusters of the same groups. The L, LT groups had no first clusters, and were not treated on the third cluster because the treatment here was mainly a test of concentration effectiveness, and it was felt that two groups would supply the necessary information as clearly as three groups.

The 0.5 per cent concentration of indolebutyric acid was applied to entire clusters as a delayed spray; i.e., one application only was made to each cluster; and this was applied after most of the flowers of the cluster were fully open, with the earlier flowers on the point of dropping. Buds and flowers alike were sprayed until thoroughly wet; the intention being to get some of the acid low down on the style, or directly on the ovary, wherever this was possible.

The flowers of the second clusters of groups NT, PT, and LT were emasculated just as each was on the point of opening, and a dilute concentration of indolebutyric acid in talc dust applied directly to the ovary with a camel's hair brush. The preparation used was a commercial one known as Hormodin No 1. It is made by Merck and Co., Rahway, N. J.

Emasculation was performed in one, simple operation by removing the ring of stamens with a pair of small tweezers. Ordinarily, petals and pistil come off at the same time.

No groups other than those named were given hormone treatments.

Accepting the criterion that a fruit has reached the green-ripe stage, and is ready for picking when a white spot shows clearly on the blossom end, twenty such fruits, as they reached the designated stage,* were picked from first clusters of group N. A similar number of fruits, at the same stage of development, were taken from the first clusters of group NT. In order to gain some comprehension of the effect of organic acid sprays on the weights of mature fruits,

* These were the first twenty fruits, in each group, to reach the designated stage of maturity.

and on final yield, these two groups of green-mature fruits were compared as to average weights.

Records were carefully kept, and the following details noted as they were observable: The dates of flowering for clusters; the number of flowers in each cluster; the treatment; the dates of treatments; the number of fruits set on each cluster ( taken when the ovary of a flower had noticeable increased in size); the dates of harvesting; the number of fruits harvested from each cluster; the total weight of fruit on each cluster; the diameters of fruits from second clusters; the appearance and quality of the fruits; and the percentage of parthenocarpic fruits set.

The weights of green-ripe fruits were taken as they were picked.

All remaining fruits excepting those of cluster 3 of group L, were harvested April 3, 1947. The weight was recorded for the total number of fruits on each cluster, excepting for the fruits of the second cluster of group LT. These were harvested to ascertain the percentage of seedless fruits formed in the group. Diameter readings were taken for the fruits of cluster 2. The measurements were taken with callipers at the widest part of each fruit at right angles to the stem-blossom axis. Measurements were transferred to a metric scale, and the readings recorded in centimetres.

All fruits were cut open to ascertain the numbers which were parthenocarpic.

Thus, on April 3, 1947, the first part of the experiment was terminated.

MATERIALS AND METHODS OF THE SECOND YEAR

On October 27, 1947 , tomato seed of the variety Vetomold 121 was sown in a flat of sterile, washed river sand. The method of planting was similar to that followed in 1946. The first seedlings appeared on November 3, 1947.

A sowing of the same variety and one of Ailsa Craig, were made on November 12, 1947. In these flats the first cotyledons appeared November 17, 1947.

Plants in all the flats were thinned out, to a spacing of 2 times 2 inches, as soon as they showed signs of being crowded. In the flat stage nutrients were supplied by sprinkling with the solution used in 1946.

On December 1, 1947, seventy-two plants of uniform size, twenty-four from each of the three flats, were selected and transplanted into 2 inch, earthen pots containing a sandy, composted soil. These plants were, also, fed with Hoagland's and Arnold's solution.

Plants from the first sowing of Vetomold 121 were labelled V 121 A. Those from the second sowing of Vetomold were labelled V 121 B. Plants of the Ailsa Craig group were marked AC. Each of these groups was divided into four subgroups. These were labelled as follows:

| | | |
|---|---|---|
| V 121 AC | V 121BC | ACC |
| V 121 Aa | V 121 Ba | ACa |
| V 121 Ab | V 121 Bb | ACb |
| V 121 Ac | V 121 Bc | Ac |

Plants in the C subgroups were controls. They were not treated with hormones. The subgroupings a, b, and c were treated with hormone sprays applied to the floral parts.

The seventy-two plants were placed in randomized positions upon a table in the horticultural research room. Temperatures were, in general, about as they were during the previous year.

On January 5, 1948, all plants were transplanted to soil in 10 inch, earthen pots. Plant positions and labellings were unchanged.

The source and composition of the soil were similar to those of 1946; and the condition was found to agree remarkably well with that determined previously. Acidity and nutrient levels were C N3 P4 K3. The pH was found to be 6, slightly higher than in 1946, but a satisfactory level of acidity for tomato growth. Calcium was present in medium amounts.

As before, one pound of animal manure and a tablespoonful of Urbanite 6-7-6 was mixed into the soil of each pot; the commercial fertilizer being placed in the top layer of soil for early feeding.

As growth made it necessary, pots were staked with bamboo canes, the plants tied to these supports with raffia, and each tomato trained to a single stem.

Water was applied moderately at intervals so that the soil, at no time, became completely dry. In order to prevent leaching of nutrients, no excess of watering was done.

Despite, differences of more than two weeks in sowing times, and the greater size of plants in the V 121 A group, every plant, in every group, opened its first flowers on February 23, 1948.

After flowering, all control plants were vibrated, daily, to aid pollination, so that, as before, poor fruit set would be indicative only of unsatisfactory fertilization, and not of lack of pollination. The plants treated with hormones were not shaken, but no precautions were taken to avoid pollination brought about by any other means.

During the year 1947, indolebutyric acid 5000 p.p.m., or 0.5 per cent, was found to be effective in that it greatly increased fruit set on first flower clusters. However, this concentration caused a minor amount of leaf damage. This may have been due to an over-vegetative condition in the plants used. A foliar test, made in 1948, with this concentration of indolebutyric acid, produced no epinasty in either the variety Vetomold 121 or Ailsa Craig. Nevertheless, it was decided to use the acid in a reduced concentration range for the second part of the investigation. A 0.02 per cent solution has been shown, by Howlett, to be in the neighborhood of the least strength producing any considerable positive results , although it does not approach the usefulness of higher concentrations. Therefore, a strength of 200 p.p.m. was chosen for the lower limit of the spray concentration range.

During 1948, in addition to water sprays of indolebutyric acid, the commercial preparations "Fix", and "Seed-Less-Set" were also applied as water-sprays to floral parts in an attempt to increase fruit set.

The chemical $\gamma$-(indole-3)-n-butyric acid, dissolved in 95 per cent ethyl alcohol, was made up in distilled water to concentrations of 3000 p.p.m., 500 p.p.m., and 200 p.p.m. "Fix" was prepared by dissolving 5 tablets in a quart of water. "Seed-Less-Set" was made up so that one quart of a water solution contained one ounce of the material.

Controls were not treated with hormones. All other groups were treated, on first clusters only, with one of the hormone sprays applied with a nasal atomizer. Each treated cluster received a single delayed spray applied in a fine mist. As previously stated, a delayed spray is applied when most of the flowers in the cluster are open, and earlier flowers are starting to drop. In this way it is possible to treat the maximum number of buds which have enlarged to a point where a growth regulater will influence their development into parthenocarpic fruits.

All groups having flowered on the same date, February 23, 1948, it was possible to spray all treated subgroups on February 28, 1948. The table below shows the material and concentration applied to each subgroup.

| Group | No of Plants | Treatment |
|---|---|---|
| V 121 Aa | 6 | Indolebutyric acid 0.3 per cent |
| b | 6 | Indolebutyric acid 0.05 per cent |
| c | 6 | Indolebutyric acid 0.02 per cent |
| V 121 Ba | 6 | "Fix" |
| b | 6 | Indolebutyric acid 0.05 per cent |
| c | 6 | "Seed-Less-Set" |

| | | |
|---|---|---|
| ACa | 6 | Indolebutyric acid 0.3 per cent |
| b | 6 | Indolebutyric acid 0.05 per cent |
| c | 6 | Indolebutyric acid 0.02 per cent |

One gram of indolebutyric acid was used in 1947-1948.

Records were kept of the number of flowers and the number of fruits set in each of the first clusters.

First cluster fruits were permitted to mature and were harvested as individual tomatoes ripened. Harvesting commenced April 14, 1948 and was completed May 6 , 1948. Total yields and average fruit weights were compared.

No stress was placed upon parthenocarpy, as the attainment of this was not the object in view; but fruits were examined to determine quality.

These observations completed the experimental phase of the work.

## PRESENTATION OF RESULTS FOR THE FIRST YEAR

### The Effect of an Excess of Fluorescent Light on the Initiation of Flowering in Tomato Plants:-

On January 30, when their photoperiod had just commenced to rise above fifteen hours, plants of the L groups had formed flower buds. Some of these buds started to open; but, as the photoperiod rose towards sixteen hours, due to seasonal lengthening of the natural days, these buds closed again without having opened fully. After February 7, when the photoperiod had reached fifteen hours, thirty minutes, no more buds formed, but old buds persisted until the termination of the experiment on April 3, 1947.

On February 21, when the normal day had reached ten hours, twenty-nine minutes, and the extended day sixteen hours and twenty-nine minutes, all plants of the L groupings ( L, and LT ) were moved to the horticultural research room. Flower buds of the first cluster already formed, did not open, but persisted until the termination of the experiment. However, on March 7, the second clusters of L and LT, flowered. This was four days later than the second clusters of other groups. The third clusters of both groups flowered March 12, which was the date of flowering of all other groups.

It should be noted that while control plants, subjected to a normal length of day, throughout the entire season, flowered when the photoperiod had reached ten hours and twenty-nine minutes, L and LT did not flower until they had been exposed for two weeks to the same day length as the control group. They flowered when the day had become eleven hours, twenty-two minutes.

At the time of the termination of the experiment, April 3, 1947, all plants of the L groupings presented a most remarkable appearance. Leaves and stems drooped downward, almost paralleling the main stems. The foliage displayed a pronounced yellow colour; yet no disease was apparent. The effect did not seem traceable to nitrogen deficiency, for, near the tops of stems, young leaves, which had developed after the plants had been moved to the horticultural research room, were of a deep healthy green. # Suckers arising from the bases of stems were also healthy.

The Comparative Effects of Pre-Irradiation and Flower Spray of Indolebutyric Acid, 5000 P. P. M. in Water, on Tomato Fruit Set and Yield:-

The treatments here were for the first clusters of groups NT, P and PT. The data are presented in Table 1 and Table 6. These show that both treatments were effective, but indolebutyric acid the more so.

Treated clusters developed uniformly sized bands of fruit, as treated flowers tended to develop fruit together. This was not the case with untreated flowers.

Flower buds sprayed at a very early stage sometimes withered away. Flower parts persisted where fruit had set.

Slight epinasty was occasionally noted twenty-four hours

# The damage was due, probably, to the quality of artificial illumination supplied.

after the spray had touched foliage; but there was a rapid recovery in all cases. Variety may have been a factor, as indolebutyric acid is considered as harmless to foliage.

The Comparative Effects of Irradiation and the Application, to Emasculated Flowers, of Hormodin No 1 Powder on Tomato Fruit Set and Yield:-

Here the second clusters of groups NT, P, PT, L and LT were involved. The data are set forth in Table 2.

There was a lack of uniformity in the development of treated flowers into fruit, because all were not treated at one time.

The percentage of parthenocarpic fruit was higher than for other acid treatments, because of emasculation. Pre-irradiation was without effect.

The Comparative Effects of Irradiation and a Flower Spray of Indolebutyric Acid, 100 P. P. M. in Water, on Tomato Fruit Set and Yield:-

The treatments, on third clusters, were for the groups NT, P and PT. The data are presented in Table 3.

No seedless fruits were found in the clusters, showing 100 p. p. m. of indolebutyric acid to be ineffective for inducing parthenocarpy. Pre-irradiation was without effect.

The Effect of a Simulated Long Day on Fruit Setting in Tomato Plants:-

Pa, the group, which, during the pre-irradiation of the P groupings, was given, by capping, a photoperiod intended to simulate that of other P groupings in total length but which actually totalled fewer hours of light, flowered on the same dates as other P groupings. The yield and degree of fruit setting attained by the Pa group are set forth in Table 4.

The Effects of Dilute Concentrations of Indolebutyric Acid Applied in Foliar Sprays to Tomatoes Prior to Flowering:-

The data here are derived from the S group and are set forth in Table 5. There was no increase in fruit set.

At no time was visible damage of any kind observed on the plants as a result of the folior sprays in the concentrations used.

Some General Observations From All Treatments:-

By the use of diagrams, kept with the records, it was possible to follow the history of individual flowers.

Sometimes very young flower buds, completely enclosed, and about ¼ inch in length, failed to develop, and withered away following the application of the effective spray of 5000 p.p.m. of indolebutyric acid. These last formed buds usually failed to develop in unsprayed clusters as well, because of the competition for nutrients from fruit already set.

Fruit development where flowers had been treated with an effective concentration of the hormone was much more rapid than that of fruit set from untreated flowers. At the fifth day, diameter size was often two to three times as great.

Sometimes treated ovaries developed before the petals of the flowers had opened. Frequently the set fruit burst through the side of the floral envelope.

Treated flowers frequently opened following treatment, and fertilization took place.

Occasionally ovaries developed into parthenocarpic fruits when sprayed after the petals had fallen.

The single delayed spray, applied to first clusters, brought about the development of uniformly sized bands of fruits.

Fruits developed from sprayed blossoms were more difficult to remove from the plant than fruits developed from untreated flowers.

Young, sprayed blossoms sometimes developed smaller fruits than opened blossoms, when sprayed with an effective concentration of the organic acid.

In general, parthenocarpic fruits were as well-shaped as seeded fruits, excepting in seven fruits which showed decided proturberances where styles had been stimulated to development at the blossom end. There were more malformed natural fruits, because the first fruit set on an untreated cluster, having, at first, no competition for nutrients, often grew so rapidly as to become cat-faced in shape. This was not found with seedless fruits.

In seedless fruits, pericarpal tissue tended to develop more rapidly than placental tissues. Small parthenocarpic fruits often displayed hollow locules. However, these seemed to fill with a gelatinous material as fruits matured, for older fruits were usually well filled. Seedless fruits were sweeter in flavour than normal fruits.

Some fruits contained both seeded locules, and seedless locules.

Treated, unopened flower buds tended to develop into parthenocarpic fruits more often than flowers treated when open.

There was a limited incidence of blossom end rot in both treated and untreated groups.

PRESENTATION OF RESULTS FOR THE SECOND YEAR

Although, during 1947, indolebutyric acid, 5000 p.p.m. on first clusters increased fruit set over first cluster controls 14 per cent more than Hormodin No 1 on second clusters increased set over that in second cluster controls, this was not due to a difference in materials and concentrations. A study of Tables 1 and 2 shows that the difference was due to an increase in natural fruit set on control second clusters, which decreased any lead in set due to the use of hormones. Thus, as days lengthened, fruit set in controls improved so that any possible advantage to be derived from the use of growth regulators became less in each succeeding cluster. Thus, on third clusters, when untreated clusters showed as much set as those treated with indolebutyric acid 100 p.p.m. in water, true results could have been obscured by the improvement in natural set, and not due to the acid being ineffective. The only real justifications for claiming 100 p.p.m. as ineffective lies in the facts that the natural increase was slight and that there was no parthenocarpy.

Hormodin No 1, applied to ovaries of emasculated second cluster flowers produced more parthenocarpy than any other treatment, and was effective, though natural fruit set had greatly increased.

From the facts enumerated above it appears that it is possible to make a true comparison of the effects produced by different concentrations only when all are applied to the same cluster of plants at, or near, the same stage of growth. Obviously effects are most marked on first clusters. Therefore, in 1947-1948 the effects from spraying first clusters only were considered. This limited influencing factors, and made possible a more conclusive decision as to causes.

No epinasty was noted during the year; and no blossom end rot.

The use of organic acids, where effective, resulted in bands of uniformly sized fruits of high quality. Indolebutyric acid used in a 0.02 per cent concentration did not significantly increase fruit set over that of controls. All other spray applications produced significant increases in fruit set. No effective spray proved significantly better than any other. There was no significant difference due to time of sowing, the year or the variety.

The total yields from sprayed clusters were significantly greater than those from untreated clusters due to increased fruit set.

This year there was no increase in the average weight of mature fruits due to treatments. Fruits from treated plants averaged nine to the pound as did fruits from controls.

The tables of results for 1947-1948 follow Table 6. These show that fruits from treated clusters had their ripening periods decreased 5 to 7 days. These fruits were, in general, of good quality and appearance, excepting that those resulting from treatments of "Fix", and to a lesser extent "Seed-Less-Set", frequently had unsightly protuberances at their blossom ends due to a development of styles.

Parthenocarpic fruits were, again, much sweeter than normal ones.

Fruits from Treated and Untreated Tomato Flower Clusters

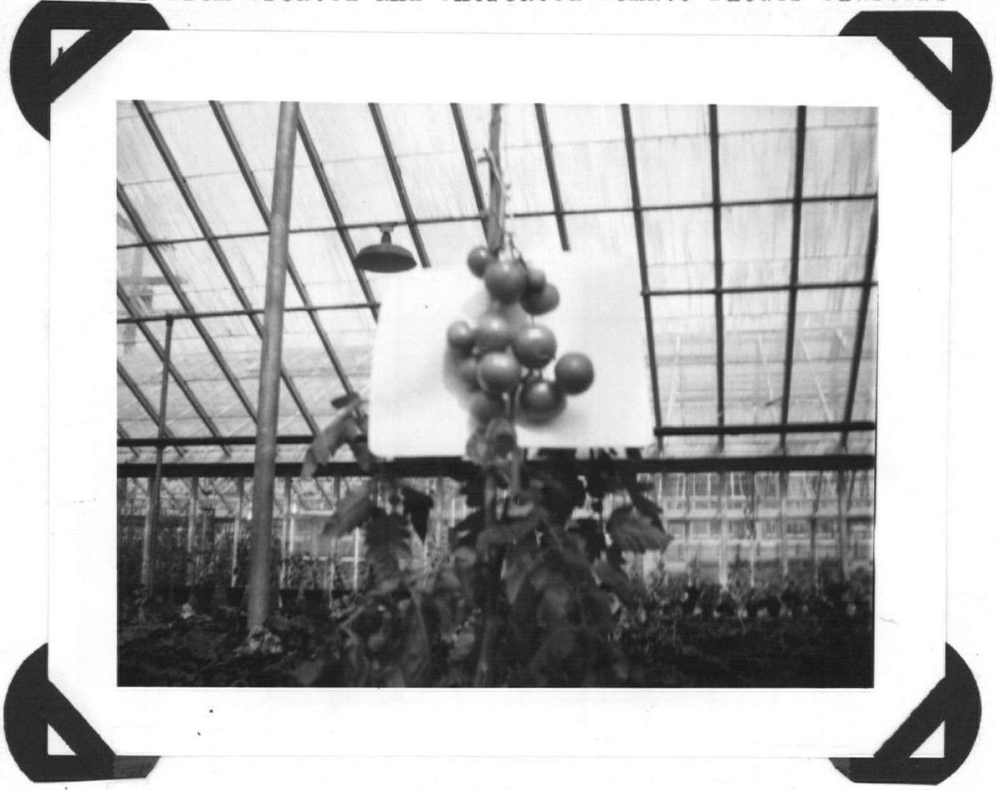

Fig. 1. A plant of the Vetomold 121 variety of tomato. The irregularly sized fruits in the upper cluster developed from untreated flowers. The uniformly sized fruits of the lower cluster developed from flowers treated with indolebutyric acid 500 p.p.m.

Fig. 2. As under figure 1.

Table 1
The Comparative Effects of Pre-Irradiation and a Flower Spray of Indolebutyric Acid, 5000 P.P.M. in Water, on Tomato Fruit Set and Yield

Cluster:..........1
Date of Flowering:# Feb. 21, 1947
Treatment:........Indolebutyric acid 5000 p.p.m.
Date Treated:......Feb. 26,
Date Harvested:## .April 3,1947

| Serial Nos. of Plants | Buds on Cluster, Group### N | NT | P | PT | No. of Fruits Set, Group N | NT | P | PT | Total Across | Seedless Fruits, Group NT | PT | Yield _ Immature Fruits (Grams), Group N | | P | PT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 7 | 16 | 15 | 5 | 7 | 15 | 14 | 41 | | | 111 | 255 | 292 | 401 | |
| 2 | 8 | 8 | 13 | 11 | 5 | 8 | 13 | 11 | 37 | | | 163 | 270.1 | 305.5 | 371 | |
| 3 | 8 | 8 | 7 | 14 | 4 | 5 | 7 | 13 | 29 | | | 153 | 247 | 312 | 440 | |
| 4 | 12 | 7 | 8 | 7 | 5 | 7 | 7 | 7 | 26 | | | 225 | 290 | 300.4 | 449.5 | |
| 5 | 9 | 11 | 8 | 7 | 4 | 11 | 4 | 7 | 26 | | | 211 | 281 | 311 | 398.3 | |
| 6 | 8 | 7 | 8 | 8 | 5 | 7 | 8 | 8 | 28 | | | 174 | 241.5 | 302.2 | 335.1 | |
| 7 | 7 | 8 | 8 | 14 | 6 | 8 | 7 | 13 | 34 | | | 214 | 263.5 | 313.[illegible] | 371 | |
| 8 | 8 | 8 | 14 | 16 | 6 | 8 | 11 | 14 | 39 | | | 230 | 280 | 311.4 | 295 | Grand Total |
| Group Total | 68 | 64 | 82 | 92 | 40 | 61 | 72 | 87 | 260 Grand Total | 20 | 29 | 1481 | 2128.1 | 2447.5 | 3060.9 | 9117 |
| Percentage Set | | | | | 58.8 | 95.3 | 87.8 | 94.6 | | | | | | | | |
| Percentage Parthenocarpy | | | | | | | | | | 32.78 | 33.33 | | | | | |
| Av. Wt. of Fruits (Grams) | | | | | | | | | | | | 37.0 | 34.9 | 34 | 35.2 | |

# Date of Opening of First Flower

## Final Harvest (Does not refer to pickings of mature fruits)

### Control Group

Table 2...The Comparative Effects of Irradiation and Hormodin No. 1 Powder on Tomato Fruit Set and Yield

Cluster..............2
Dates of Flowering.....March 3,1947 (N and P Groups); March 7,1947 (L Groups)
Treatment............Hormodin No. 1 Powder
Date Treated..... ....From March 3 and 7 as Flowers Opened
Date Harvested........April 3,1947

| Serial Nos. of Plants | Buds on Cluster Group | | | | | | No. Fruits Set Group | | | | | | Total Across | Seedless | | | Yields of Immature Fruits as Indicated by Total Diameter Readings in Cms Per Plant | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | NT | P | PT | L | LT | N | NT | P | PT | L | LT | | NT | PT | LT | N | NT | P | PT | L | LT | Total Across | |
| 1 | 13 | 14 | 8 | 8 | 8 | 7 | 8 | 12 | 9 | 8 | 4 | 6 | 45 | | | | 16.7 | 29.5 | 14.0 | 15.4 | 9.2 | 15 | 99.8 | |
| 2 | 7 | 7 | 8 | 8 | 8 | 7 | 5 | 7 | 6 | 8 | 5 | 7 | 38 | | | | 10.4 | 19.3 | 11.6 | 22.0 | 11.0 | 16.0 | 90.3 | |
| 3 | 9 | 8 | 8 | 7 | 7 | 7 | 7 | 8 | 8 | 7 | 5 | 7 | 42 | | | | 14.7 | 21.5 | 15.7 | 16.2 | 10.1 | 17.5 | 95.7 | |
| 4 | 7 | 7 | 13 | 15 | 7 | 8 | 7 | 7 | 7 | 13 | 5 | 8 | 47 | | | | 14.6 | 19.2 | 14.3 | 34.0 | 11.2 | 20.0 | 113.3 | |
| 5 | 8 | 7 | 8 | 8 | 7 | 7 | 5 | 7 | 5 | 8 | 5 | 7 | 37 | | | | 10.6 | 18.6 | 10.4 | 18.0 | 8.8 | 16.0 | 82.4 | |
| 6 | 9 | 10 | 13 | 8 | 7 | 11 | 10 | 6 | 8 | 8 | 5 | 7 | 44 | | | | 16.9 | 24.5 | 10.0 | 18.1 | 8.0 | 18.0 | 95.5 | |
| 7 | 8 | 9 | 7 | 8 | 8 | 7 | 5 | 9 | 6 | 8 | 6 | 7 | 41 | | | | 10.5 | 24.0 | 11.0 | 21.3 | 11.0 | 17.0 | 94.8 | |
| 8 | 9 | 8 | 8 | 8 | 11 | 7 | 7 | 8 | 5 | 8 | 5 | 7 | 40 | | | | 14.7 | 10.9 | 12.0 | 18.0 | 9.1 | 20.1 | 84.8 | |
| Group Total | 70 | 70 | 73 | 70 | 63 | 61 | 52 | 68 | 50 | 68 | 40 | 56 | 334 | 57 | 55 | 45 | 109.1 | 167.5 | 99.0 | 163.0 | 78.4 | 139.6 | 756.6 | Grand Total |
| Percentage Fruit Set | | | | | | | 74.3 | 97.1 | 68.5 | 97.1 | 63.5 | 91.8 | | 97.1 | 97.1 | 91.8 | | | | | | | | |
| Percentage Parthenocarpy | | | | | | | | | | | | | | 86.4 | 84.6 | 80.4 | | | | | | | | |
| Av. Diameters (Cms.) | | | | | | | | | | | | | | | | | 2.1 | 2.4 | 1.98 | 2.4 | 1.8 | 2.5 | | |
| Total Yields by Weight (Grams) | | | | | | | | | | | | | | | | | 270 | 307 | 294 | 323 | | | | |

Table 3...The Comparative Effects of Irradiation and a Flower Spray of Indolebutyric Acid, 100 P.P.M. in Water, on Tomato Fruit Set and Yield.

Cluster:..............................3
Date of Flowering:....................March 12, 1947
Treatment:............................Indolebutyric Acid 100 P.P.M.
Date Treated:.........................March 17, 1947
Harvested:............................April 3,1947

| Serial Nos. of Plant | Buds on Cluster Group N | NT | P | PT | No. of Fruits Set N | NT | P | PT | Total Across | Parthenocarpy N | NT | P | PT | Yield Immature Fruits (Grams) N | NT | P | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 8 | 8 | 8 | 8 | 6 | 5 | 6 | 25 | | | | | 30.1 | 25.4 | 20.5 | 22.0 |
| 2 | 9 | 8 | 9 | 8 | 6 | 5 | 5 | 5 | 21 | | | | | 21.6 | 19.6 | 19.0 | 18.4 |
| 3 | 8 | 8 | 9 | 10 | 8 | 6 | 8 | 5 | 27 | | | | | 37.0 | 24.4 | 31.4 | 20.0 |
| 4 | 8 | 8 | 8 | 8 | 7 | 6 | 6 | 8 | 27 | | | | | 27.2 | 23.6 | 24.0 | 30.4 |
| 5 | 11 | 10 | 8 | 7 | 5 | 7 | 6 | 7 | 25 | | | | | 20.6 | 28.6 | 23.8 | 26.0 |
| 6 | 8 | 8 | 8 | 7 | 6 | 7 | 6 | 5 | 24 | | | | | 20.3 | 28.1 | 23.5 | 17.7 |
| 7 | 8 | 8 | 8 | 10 | 5 | 7 | 8 | 7 | 27 | | | | | 18.4 | 27.6 | 32.8 | 28.0 |
| 8 | 7 | 8 | 9 | 10 | 6 | 5 | 5 | 8 | 24 | | | | | 23.6 | 20.2 | 19.8 | 32.4 |
| Group Total | 67 | 66 | 67 | 68 | 51 | 49 | 49 | 51 | 200 GRAND TOTAL | | | | | 198.8 | 197.5 | 194.8 | 194.9 | 786.0 GRAND TOTAL |
| Percentage Set | | | | | 76.1 | 74.2 | 73.1 | 75 | | | | | | | | | |
| Parthenocarpic | | | | | | | | | | 0 | 0 | 0 | 0 | | | | |
| Av. Fruit Wt. (Grams) | | | | | | | | | | | | | | 3.9 | 4.03 | 3.97 | 3.82 |

Table 4.- ( Figures are averages for four plants.)

Pa

| Plants | Cluster 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|
| | Fruits Set (Percentage) | Yield (Grans) | Set | Yield | Set | Yield |
| | 86.2 | 1211 | 67 | 149 | 69 | 87.8 |

Table 5.- (Figures are averages for four plants.)

S

| Cluster 1 | | 2 | | 3 | |
|---|---|---|---|---|---|
| Fruits Set (Percentage) | Yield (Grams) | Set | Yield | Set | Yield |
| 61 | 737.4 | 71 | 132 | 76.4 | 103 |

Table 6.-

Weights of Mature Fruits (Grams)
(First cluster)

| | N | | NT | |
|---|---|---|---|---|
| 1 | 44 | | 65 | |
| 2 | 48 | | 57 | |
| 3 | 53 | | 45 | |
| 4 | 47 | | 65 | |
| 5 | 55 | | 67 | |
| 6 | 61 | | 55 | |
| 7 | 48 | | 55 | |
| 8 | 50 | | 48 | |
| 9 | 50 | | 45 | |
| 10 | 45 | Fruits from treated plants | 62 | |
| 11 | 44 | | 55 | |
| 12 | 51 | Totals 0.6 per cent more by weight | 50 | |
| 13 | 51 | | 48 | |
| 14 | 45 | than fruit from the control group, | 51 | |
| 15 | 52 | | 50 | |
| 16 | 56 | indicating a0.6 per cent greater average | 47 | |
| 17 | 64 | | 54 | |
| 18 | 84 | weight at maturity. E. D. is 2.7 which | 53 | |
| 19 | 45 | falls short of statistical significance | 41 | |
| 20 | 51 | | 63 | |
| | 1044 | Mean 52.2 | 1076 | Mean 53.8 |

Table 7... The Comparative Effects, on Tomato Fruit Set, of Indolebutyric Acid 3000,500, and 200 P.P.M. in Water, and the Commercial Preparations "Fix" and "Seed-Less-Set"

Cluster............1
Date of Flowering....February 23,1948
Treatments...........As Above
Date Treated.........February 28,1948

| Group | Buds on Cluster V121A C | a | b | c | V121B C | a | b | c | AC C | a | b | c | No. of Fruits Set V121A C | a | b | c | V121B C | a | b | c | AC C | a | b | c | Total Across |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Serial Nos. 1 | 7 | 8 | 9 | 8 | 12 | 8 | 8 | 8 | 7 | 8 | 8 | 7 | 6 | 8 | 8 | 8 | 4 | 6 | 8 | 6 | 4 | 8 | 6 | 6 | 78 |
| 2 | 8 | 8 | 8 | 8 | 8 | 11 | 8 | 7 | 8 | 8 | 8 | 8 | 4 | 8 | 8 | 8 | 4 | 8 | 8 | 7 | 4 | 7 | 6 | 5 | 77 |
| 3 | 8 | 10 | 8 | 8 | 9 | 8 | 8 | 7 | 8 | 8 | 8 | 8 | 0 | 8 | 8 | 4 | 5 | 8 | 6 | 7 | 6 | 8 | 8 | 4 | 72 |
| 4 | 12 | 7 | 8 | 8 | 8 | 8 | 8 | 12 | 8 | 8 | 8 | 7 | 8 | 6 | 8 | 4 | 3 | 8 | 8 | 10 | 4 | 7 | 8 | 4 | 78 |
| 5 | 8 | 8 | 8 | 10 | 8 | 8 | 8 | 7 | 8 | 7 | 7 | 8 | 5 | 7 | 8 | 4 | 6 | 8 | 8 | 6 | 3 | 6 | 7 | 5 | 73 |
| 6 | 8 | 8 | 8 | 12 | 8 | 8 | 8 | 12 | 10 | 7 | 8 | 7 | 8 | 8 | 7 | 5 | 8 | 8 | 8 | 8 | 5 | 7 | 8 | 6 | 86 |
| Group Total | 51 | 49 | 49 | 54 | 53 | 51 | 48 | 53 | 49 | 46 | 47 | 45 | 31 | 45 | 47 | 33 | 30 | 46 | 46 | 44 | 26 | 43 | 43 | 30 | 464 |
| Percentage Fruit Set | | | | | | | | | | | | | [illegible] | 91.8 | 95.9 | 61.1 | 56.6 | 90.1 | 95.8 | 83.0 | 53 | 93.6 | 90.3 | 66.6 | Grand Total |

A difference between group totals greater than 9.8 indicates a significant difference.

Table 8

WEIGHTS OF MATURE FRUITS FROM FIRST CLUSTER TOMATOES GROWN DURING THE SECOND YEAR

Fruits were picked as each became ripe. Though most fruits from treated clusters matured, in size, closely together there was some spread in their ripening periods; but this, although up to six days, was not so great as for fruits from untreated clusters, where the spread was up to two weeks.# For marketing purposes it should be possible to pick a treated cluster at one time, for when the first ripened fruits have become red the later ripening fruits are usually of a satisfactory orange-pink.

Total crops were taken for all controls and groups treated with indolebutyric acid 500 p.p.m., and crops from two plants, having 8 and 6 fruits, for all other treatments excepting indolebutyric acid 200 p.p.m., where no harvesting was done.

| Date of Ripening of First Fruit April | 21 | 14 | 15 | 24 | 19 | 19 | 17 | 22 | 16 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|
| Group | V121A | | | V121B | | | | AC | | |
| | C | a | b | C | a | b | c | C | a | b |
| No. of Plants | 6 | 2 | 6 | 6 | 2 | 6 | 2 | 6 | 2 | 6 |
| Total Wt., Grams | 1525.2 | 716.8 | 2458.1 | 1533 | 754.6 | 2212.6 | 684.6 | 1258.4 | 672. | 2119.9 |
| No. of Fruits | 31 | 14 | 47 | 30 | 14 | 46 | 14 | 26 | 14 | 43 |
| Average Wts., Grams | 49.2 | 51.2 | 52.3 | 51.1 | 53.9 | 48.1 | 48.9 | 48.4 | 48 | 49.3 |

First fruits ripened on treated clusters five to seven days earlier than on controls.

The data above show increases in weight on certain treated clusters to be nearly the same as the previous year. Furthermore, there is not always an increase. There are no significant differences between the weights of mature fruits due to hormone treatments.

# Until May 6, 1948.

## DISCUSSION OF RESULTS

The results obtained in the present experiment may be considered from two avenues of approach. In the first place, there are those effects which have been observed directly, and may be interpreted by inspection. Secondly, there is some mass detail which must be analyzed, with the aid of mathematics, before a true picture, of what actually has happened, may be presented. In the following pages an attempt has been made to separate observed detail into logical parts.

### THE FIRST YEAR

#### The Effect of an Excess of Fluorescent Light on the Initiation of Flowering in the Tomato Plant

The L and LT groups started to flower under a fifteen hour photoperiod. Above fifteen hours and thirty minutes flower bud formation ceased. These plants were placed under normal day conditions on February 21, and flowered on the same day as the La and Pb groups, which was after the photoperiod had risen beyond its length on February 21.

The flower buds already formed on the L and LT plants persisted under the normal day, but did not open.

An effective photoperiod and light source does not immediately initiate flowering. The plant must be subjected to it for at least two weeks.

It would appear, that an excess of illumination, of the quality provided by the type of fluorescent lamp, used causes visible changes in the foliage of tomato plants; and that these changes may properly be regarded as injury. Inhibition of flowering may be due to the same cause.

The Comparative Effects of Pre-Irradiation, a Flower Spray of Indolebutyric Acid, 5000 P. P. M., in Water, a Flower Spray of Indolebutyric Acid, 100 P. P. M., and Hormodin No 1 Powder, Applied to the Ovaries of Emasculated Flowers:-

The data from Tables 1, 2, and 3, regarding fruit set, were taken together and subjected to an analysis of variance, the calculations of which are on page 86 . A significant difference between group totals, for $P = 0.05$, was found to be 15.316; and a significant difference between group means to be 1.864.

On the basis of group means, it was found that indolebutyric acid, 5000 p.p.m., applied as a water spray, and Hormodin No. 1 powder, in all cases significantly increased fruit set beyond that of controls and irradiated groups excepting in the case of the first clusters of P group, which set a significantly greater quantity of fruit than first cluster controls, but did not maintain the lead on succeeding clusters. Thus, artificial irradiation of tomato seedlings four hours daily for a period of twenty-two days while the plants were in the flat stage, significantly increased fruit set on the first clusters, and this was further increased by a combined application of indolebutyric acid, 5000 p.p.m. in water and pre-irradiation, making the two together significantly the best treatment for the first clusters. Initially heavy flowering on P seemed a factor.

Indolebutyric acid 5000 p.p.m. and Hormodin No. 1 powder, showed no significant difference between their effects. The spray caused temporary damage to foliage.

Indolebutyric acid 100 p.p.m. set less fruit than controls; and there was no evidence of parthenocarpy. The concentration was completely ineffective.

There was a large increase of fruit set on the second clusters of controls . A further increase on third clusters was much less.

Yield by weight, at an immature stage for the first cluster, is analyzed on page 86 .

Indolebutyric acid, 5000 p.p.m., and pre-irradiation were found to significantly increase yields of immature fruits due to increased set and an even and rapid rate of growth. In the case of pre-irradiation, initially heavy flowering was a factor. The results showed more but smaller fruits, except at maturity (Table 6), when fruits from treated flowers were larger individually, but not significantly so.

Yields, as indicated by fruit diameters at an immature stage of cluster 2, are analyzed on page 86 . Hormodin Powder No. 1 was found to significantly increase the yield of immature fruit from treated plants, over that from untreated plants. The increase was due to greater set and a more even, and rapid rate of growth.

Table 3 shows that there was no significant difference in immature yields due to the use of indolebutyric acid 100 p.p.m., which was completely ineffective.

It was found that Hormodin No. 1 Powder increased the percentage of parthenocarpic fruit 26 to 37 per cent over the numbers of seedless fruits found as a result of the use of indolebutyric acid 5000 p.p.m.

This may be explained by the fact that flowers were emasculated prior to the application of the powder, and there was, therefore, no further opportunity for pollination to take place; whereas pollination frequently took place after the use of the spray, the floral parts not being removed.

The Effect of a Simulated Long Day on Fruit Setting in Tomato Plants.-

By capping the growing tips of the main stems of tomato plants, so that the tips are subjected to alternating periods of light and darkness, not exceeding six hours, a day-length may be simulated which corresponds in its effect to a long day, though less photosynthesis has taken place.

The Pa group flowered at the same times as other members of the P groups and set fruit, and gave yields, in numbers and quantities, paralleling the P group. This is shown when Table 4 is compared with Tables 1, 2 and 3.

Pa received less light than P in the seedling stage. The group, therefore, must have manufactured less carbohydrates. If stored carbohydrates, formed during initial irradiation, influence fruit set later on, group P should have set more fruit than group Pa. This was not the case.

The only logical deduction is that photoperiod, simulated or normal, is the influencing factor in fruit set, and food relationships within the plant.

<u>The Effects of Dilute Concentrations of Indolebutyric Acid Applied in Foliar Sprays to Tomato Plants Prior to Flowering</u>:-

There were no visible effects from the application of these sprays. Table 5 shows that fruit set, and yield closely paralleled those of the control group. The sprays appear to have been completely ineffective.

THE SECOND YEAR

Hormone treatments were applied to the flowers of first clusters only, because# these clusters are the ones which invariably show the poorest fruit set under winter conditions. Many buds remain vegetative and never open into flowers. Open flowers often fail to set fruit. Young fruits sometimes drop.

Of the chemicals used, only indolebutyric acid, 200 p.p.m. in water failed to increase fruit set significantly; but clusters treated with this concentration did show a slight increase, particularly on Ailsa Craig, the poorer setter, all other sprays increased fruit set significantly from 31.9 to 405 per cent. No one of these effective sprays was significantly better than any other, although the proportionate increase on Ailsa Craig was, in all cases , somewhat higher, because its natural set is lower than for Vetomold 121, which seems to be a better greenhouse variety.

From the tables for both years it may be seen that

# See pp. 70 and 71.

indolebutyric acid 5000 p.p.m. and 3000 p.p.m. were no more effective than the acid used in a concentration of 500p.p.m.

As the increased sets this year were not significantly different from those produced by indolebutyric 5000 p.p.m. during 1946-1947, there appeared to be no effect due to the year.

Though not all sown at one time , all plants flowered February 23, 1948. Yields and increases in set did not greatly differ. Thus the time of sowing and season were without effect.

In this experiment variety did not prove to be an important factor, although Vetomold 121 set more fruit naturally than Ailsa Craig. After hormone treatments total sets were nearly the same.

There was no significant increase in the average size of mature fruits due to the use of hormones. Measured by the total weights and the total numbers of fruits, effective hormones did increase yields significantly.

The use of effective organic acid sprays resulted in bands of uniformly sized fruits, for an even growth was stimulated even when natural pollination had already been effective. Fruits were often of better quality and flavour.

No effort was made in 1948 to determine the numbers of seedless fruits; but certain other general observations were made.

Hormones seemed to decrease the ripening period by 5 to 7 days.

Sprayed fruits did not drop; and it was more difficult to remove them from the vines.

Sprayed fruits, in general, displayed a persistence of perianth up to ten days.

Protuberances at blossom ends, due to an over stimulation of styles, made "Fix" a less valuable material than the others used. "Fix" resulted, also, in a greater proportion of hollow locules. With indolebutyric acid spray seedless locules were usually filled, at maturity, with an edible, gelatinous material.

The sweeter flavour of parthenocarpic fruits has been found to be due, mainly, to a slight, but not significant, increase in sugar content. There is, also, a non-significant decrease in ascorbic acid content below the normal for any season or variety; and a lowered pH may accentuate a sweetness of flavour. However, seedless tomatoes are as high in food value as seeded ones (17), and seeded fruits developed from hormone treated flowers differ little from normally produced seeded fruits.

Analysis of Variance of Fruit Set of Tomatoes for Three Clusters Based on Tables 1, 2 and 3.

| Cluster | 1 | | | | 2 | | | | | | 3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | N | NT | P | PT | N | NT | P | PT | L | LT | N | NT | P | PT | Totals Across |
| | 5 | 7 | 15 | 14 | 8 | 12 | 7 | 8 | 5 | 6 | 8 | 6 | 5 | 6 | 113 |
| | 5 | 8 | 13 | 11 | 5 | 7 | 6 | 8 | 4 | 7 | 6 | 5 | 5 | 5 | 97 |
| | 4 | 5 | 7 | 13 | 7 | 8 | 8 | 7 | 5 | 7 | 8 | 6 | 8 | 5 | 103 |
| | 5 | 7 | 7 | 7 | 7 | 7 | 7 | 13 | 5 | 8 | 7 | 6 | 6 | 8 | 102 |
| | 4 | 11 | 4 | 7 | 5 | 7 | 5 | 8 | 5 | 7 | 5 | 7 | 6 | 7 | 90 |
| | 5 | 7 | 8 | 8 | 8 | 10 | 6 | 8 | 5 | 7 | 6 | 7 | 6 | 5 | 94 |
| | 6 | 8 | 7 | 13 | 5 | 9 | 6 | 8 | 6 | 7 | 5 | 7 | 8 | 7 | 102 |
| | 6 | 8 | 11 | 14 | 7 | 8 | 5 | 8 | 5 | 7 | 6 | 5 | 5 | 8 | 102 |
| Group Totals | 40 | 61 | 72 | 87 | 52 | 68 | 50 | 68 | 40 | 56 | 51 | 49 | 51 | 49 | 794 |
| Means | 5 | 7.6 | 9 | 10.9 | 6.5 | 8.5 | 6.2 | 6.5 | 5 | 7 | 6.4 | 6.2 | 6.4 | 6.2 | |

Total S.S is $5^2 + 5^2 + + 7^2 + 8^2 - \frac{794^2}{112} =$ 620.1

Between group S.S. is $\frac{40^2 + + 49^2}{8} - \frac{794^2}{112} =$ 279.35

Within group S.S. is 620.1 - 279.35 = 340.75

| Factor | S.S | Deg. Freedom | Variance | F. |
|---|---|---|---|---|
| Total | 620.1 | 111 | | |
| Treatment | 279.35 | 13 | 21.488 | 6.18 |
| Error | 340.75 | 98 | 3.477 | |

n1 is 13, n2 is 98
F from the table of F for ns 12 and 100 and P 0.01 is less than 2.36
P 0.05 is less than 1.85
proving group variance significantly greater than that for error.

A difference between group totals greater than
$\sqrt{3.477 \text{ times } 8 \text{ times } 2}$ times 2 ( P 0.05 from table of x because Deg. Freedom Error are greater than 30)

equals 7.45 times 2
equals 14.9 is significant

A difference between means greater than $\sqrt{\frac{3.477}{8} \text{ times } 2}$ times 2
equals .932 times 2
equals 1.864 is significant

These figurs show all chemically treated groups, excepting those treated with indolebutyric acid 100 p.p.m., to have set significantly greater quantities of fruits than all other groups excepting P, the pre-irradiated group, PT is significant over all groups.

Analysis of Variance of Yields by Weight for the First Clusters of Tomatoes as Affected by Pre-Irradiation and Applications of Indolebutyric Acid 5000 P. P. M. to Flowers

The arrangement of plants was purely random. Yields were measured in grams, and are given in Table 1 for cluster 1 for each plant in each group. Weights are for immature fruits.

Total S.S. is $111 + + 295^2 - \frac{9117.5^2}{32}$, or 195761.68

Group S.S. is $\frac{1481^2 + + 3060.9^2}{8}$ - C. F., or 172416.71

Error S. S. is the above two subtracted, or 23344.97

| Factor | S.S. | Deg. Freedom | Varience | F. |
|---|---|---|---|---|
| Total | 195761.68 | 31 | | - |
| Group | 172416.71 | 3 | 57472.23 | 68.9 |
| Error | 23344.97 | 28 | 833.88 | |

The reading of F is significant. A significant difference between totals for P 0.05 is

$\sqrt{833.88 \text{ times } 8 \text{ times } 2}$ times 2, or 115 times 2, or 250

Thus NT is significant over N, P over NT, and PT highly significant over all.

Similarly total yields for second cluster fruits at an immature stage show Hormodin No. 1 as causing significant increases. In this case yields were indicated by diameter readings of fruits. When data were analyzed, as above, a significant difference between totals was found to be 29.84 for P 0.05.

ANALYSIS OF VARIANCE OF FRUIT SET OF TOMATOES GROWN THE SECOND YEAR

Data from Table 7

Total S.S. is $6^2 + + 6^2 - \frac{464^2}{72} =$ 233·8

Between group S.S. is $\frac{31^2 + + 30^2}{6} - \frac{464^2}{72} =$ 114.1

Within group group S.S. is 233.8 - 114.1 = 119.7

| Factor | S.S. | Deg. Freedom | Variance | F. |
|---|---|---|---|---|
| Total | 233.8 | 71 | | |
| Treatment | 114.1 | 11 | 10.37 | 5.19 |
| Error | 119.7 | 60 | 2.00 | |

$n_1$ is 11; $n_2$ is 98

F from table of F for the above is : for P 0.01, 2.56

for P 0.05, 1.95 proving group variance significantly greater than that for error.

A difference between totals greater than $\sqrt{2 \text{ times } 6 \text{ times } 2}$ times 2 = 9.8 is significant for P 0.05

Thus, all treatments but indolebutyric acid 200 p.p.m. were significant over controls. None of these effectives were significant over another.

In all cases the increases on Ailsa Craig were somewhat greater than on Vetomold, but not significantly so. Ailsa Craig appears to produce fewer flower buds and set less fruit naturally than Vetomold 121.

There were minor increases in fruit set where indolebutyric acid 200 p.p.m. was used; but these fell far short of significance. These increases were slightly greater in the case of Ailsa Craig.

SUMMARY

The present investigation was conducted under the direction of the Department of Horticulture of the University of British Columbia during the period October 30, 1946 to May 6, 1948. The purpose was to study the effects of light and applications of organic acids on tomato plants of the mould resistant variety Vetomold 121, and on the variety Ailsa Craig.

During the first year fifty-six plants of Vetomold 121, grown in 10 inch pots, were used in the experiment; and eight were set aside, under normal conditions, as a control group.

Photoperiodic effects were studied by subjecting plants to irradiation from fluorescent lamps. Group P were irradiated in the seedling stage for periods of four hours daily for twenty-two days. Group L received up to sixteen hours twenty-nine minutes of light daily until February 21, 1947.

Certain members of all groups received flower treatments of indolebutyric acid 5000 p.p.m., and 100 p.p.m. in water sprays. Others received treatments of a commercial preparation of indolebutyric acid in talc, Hormodin Powder No. 1, applied to the ovaries of emasculated flowers.

Foliar sprays of indolebutyric acid 50, 100, 250, and 500 p.p.m. in water were applied, prior to flowering, to an S group of plants and produced no effects.

Excess fluorescent light was found to inhibit flowering, and

to cause physiological changes of an injurious nature.

No flowers opened until the day-length was ten hours twenty-nine minutes.

Indolebutyric acid 100 p.p.m. was without effect. As a result of the spray of indolebutyric acid 5000 p.p.m. the percentage of buds setting fruit on first clusters was increased 36.5 per cent (Table 1) beyond that of controls. Seedling irradiation brought about an increase of 29.0 per cent. Hormodin No. 1 increased fruit setting on the second cluster by 22.8 per cent (Table 2). Set percentages were based on the proportion of fruit set to the number of buds formed; and, did not indicate the number of buds formed in the first place or the total number of fruits set in a group. In PT, which received a combined treatment of pre-irradiation and indolebutyric acid 5000 p.p.m., total set was significant over that for all other groups.

Indolebutyric acid, 5000 p.p.m., used alone, increased the total yields of fruit, harvested at an immature stage, 50 per cent by weight. Hormodin, as a sole treatment, increased total yields 53 per cent by weight. These tremendous increases were due to an increased set and more rapid growth than normal. The percentage increase became less as fruits on untreated plants matured.

Indolebutyric acid, 5000 p.p.m., appeared to be responsible for an increase of 6 per cent in average fruit weight of mature fruits taken from treated plants. This percentage did not involve a significant difference.

During the second year of the experiment, 1947-1948, seventy-two plants were used. Twenty-four of these were Vetomold 121 sown October 27, 1947, twenty-four were Vetomold 121 sown November 12, 1947, and twenty-four were Ailsa Craig sown November 12, 1947.

Each of these three groups was divided into subgroups of six plants, one subgroup being kept as controls. The remaining subgroups received delayed flower sprays, on first clusters only, of water solutions of indolebutyric acid 3000 p.p.m., 500 p.p.m., and 200 p.p.m. and two commercial preparations "Fix" and "Seed-Less-Set".

Indolebutyric acid 200 p.p.m., in a water solution, failed to influence set significantly. All other treatments increased set significantly over that on controls. No one solution was significantly better than any other.

In all cases fruits from treated clusters developed as uniformly sized bands and were of good quality, excepting that commercial preparations, particularly "Fix", frequently produced unsightly blossom end protuberances. Parthenocarpic fruits were sweeter than normal fruits.

There was no significant difference due to time of sowing, the year, or the variety. Hormones decreased the ripening period 5 to 7 days; and prevented fruit drop. They did not increase fruit s size at maturity.

Indolebutyric acid was the effective producing the best quality fruit. About one gram of indolebutyric acid was used the second year. The cost of the acid to experimenters averages five dollars per gram. Costs may be greatly decreased when the material is supplied for commercial purposes.

Because it was the least concentration of the chemical significantly increasing fruit set, 500 p.p.m. of indolebutyric acid, dissolved in water, and applied with a nasal atomizer, appeared to be the most satisfactory spray for increasing fruit set on greenhouse tomato plants.

CONCLUSIONS

From the data tabulated following observations, and from statistical analyses of these, the following conclusions, valid for the Vetomold 121 and Ailsa Craig varieties of tomato, have been deduced:

(1) The initiation of flowering in tomatoes is governed by the length of the photoperiod; and is not influenced by food relationships within the plant. For the initiation of flowering a simulated photoperiod seems as effective as a normal one. Vetomold 121 must be subjected to an effective photoperiod for two weeks before flowering will be initiated. The effective photoperiodic range for the initiation of flowering in the varieties has a lower limit of ten hours thirty minutes.

(2) Excess fluorescent light inhibits flowering in Vetomold 121; and causes visible physiological changes in foliage which may be regarded as damage.

(3) Foliar sprays of indolebutyric acid in water, 50, 100, 250, and 500 p.p.m., applied prior to flowering, to Vetomold 121, have no effect whatsoever.

Indolebutyric acid 100 p.p.m. and 200 p.p.m. in water are ineffective in influencing fruit set when applied to the flowers of the tomato varieties tested.

(4) Pre-irradiation of seedlings of Vetomold 121 for four hours daily for twenty-two days, following the greening of the cotyledons, results in a significant increase in set and total yield

for first clusters only. A combination of this treatment and a water spray, on flowers, of indolebutyric acid, in an effective concentration, is significantly more effective in inducing the desired results, on first clusters, than is any other treatment used.

"Fix", "Seed-Less-Set", and indolebutyric acid 5000 p.p.m., 3000 p.p.m., and 500 p.p.m., applied in water, and Hormodin No. 1 in talc, significantly improved fruit set and yields for the tomato varieties Vetomold 121 and Ailsa Craig; but the first cluster shows the greatest increases. With regard to increased set no one of these hormone treatments is significantly better than any other; but indolebutyric acid produces the best quality fruits. "Fix" and "Seed-Less-Set" cause unsightly blossom end protuberances. Under ordinary conditions none causes plant injury. There is no significant difference due to variety, season, or year. Organic acids are most conveniently applied in water solutions. They are most effective when applied to flowers as a delayed spray.

(5) All parthenocarpic fruits produced are sweeter than normal fruits.

(6) Applications of effective concentrations of indolebutyric acid in water to the flowers of tomatoes results in the production of bands of uniformly sized fruits of good quality maturing at nearly the same time. These fruits mature and ripen 5 to 7 days earlier than fruits on untreated plants. The development of abscession layers is retarded and, therefore, there is no fruit drop.

Even where increased fruit set and total yields are not required it seems advisable, in view of the advantages referred to above, to apply water sprays of hormones in effective concentrations to all clusters of greenhouse tomatoes. With commercial crops the use of such sprays should prove profitable.

Of the materials and concentrations tested during the present investigation, indolebutyric acid 500 p.p.m. in water, applied as a delayed spray to floral parts, appears the most valuable.

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