EFFECTS OF SOME GROWTH REGULATING SUBSTANCES ON ASPARAGUS SPEAR DEVELOPMENT

by

SURINDER SINGH ATTRI

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INTRODUCTION

Many years ago scientists discovered that the growth and behavior of many plants could be changed and often controlled by applying small amounts of organic chemicals to leaves, stems or roots. These materials have come to be known as "growth regulators", "plant hormones" or "growth regulating substances", etc. They do unusual things to plants, and some have proved to be extremely useful. Within the last 20 years has been seen the advent of chemical growth control, which has brought vast new possibilities of the delicate adjustment of the developmental pattern in plants.

The present work is an attempt to use the accumulated knowledge on asparagus. The literature shows a complete absence of work of this type on asparagus. Numerous experiments have been reported in literature where salt ($NaCl$) was used to determine its effects on asparagus. But no one has yet studied the effect of growth regulating substances on asparagus.

Besides the study of the effects of these materials on the growth pattern of asparagus spears, this experiment was guided by another idea. Mechanical harvesters for asparagus have recently been developed. There is one difficulty with the harvester that was developed in California. Every time the harvester is used, all spears are cut irrespective of their height. It cuts tall as well as short and very short spears. This results in loss of yield as it cuts the short spears which would have grown to a marketable size. However if more spears were to grow to the same height or were to grow at the same time, this difficulty would be partially corrected. The mechanical harvester could then be used with less reduction in yield.

Since growth regulating substances regulate, change and modify the growth of plants, it was decided to try some of these substances on asparagus.

The objectives of this study were therefore the following: 1) To study the effect of some growth regulating substances on the pattern of asparagus spear development. 2) To attempt to find a hormone that would result in a more uniform growth of asparagus spears.

REVIEW OF LITERATURE

The story of growth regulators (or hormones) is one of the interesting chapters in science. Like most discoveries and developments, it came, not as a sudden revelation to a single man, but rather as a gradual unfolding to a great number of individuals over a long period of time. Since the 1930's many investigators have contributed to the knowledge of the use of growth regulators.

Charles Darwin is most commonly associated in literature with the early concepts of growth regulators or hormones in plants. The concept of hormones in plants, according to Thimann (10) developed from the study of tropisms or curvatures. Growing shoots typically curve towards a source of light (positive phototropism) and away from the earth (negative geotropism), and in some cases away from light (negative phototropism). Curvatures may also occur away from or towards wounds (traumatotropism), electrodes (electrotropism), water (hydrotropism), etc. All these curvatures depend fundamentally on a difference in growth rate between the two sides of a growing organ--the convex side grows faster than the concave.

Darwin (2) wondered why plants turned towards the light. In a primitive dark room he germinated grass seed and exposed the coleoptile to an unilateral or unidirectional light (i.e., light coming from one direction). He found that the coleoptile bent towards the light. However, when he covered the tip with tin foil, or cut it off, so that it was not acted upon by light, the coleoptile did not bend. On the other hand, if he placed the tin foil around the base of the coleoptile and exposed the tip to light, there was bending towards the light. From this Darwin concluded that something was transmitted from the upper to the lower part which induced bending. Darwin, by using canary-grass seedlings (Phalaris canariensis), a light source, tin foil and a razor blade found that the tip of the shoot is involved in the overall tropic response. Both for roots and shoots, Darwin (2) was able to show that the effects of light and gravity were perceived by the tip, and that the stimulus was transmitted to the lower regions, which then react. At first Darwin's statements met with opposition, but Rothert in 1894, working with phototropism of shoots, confirmed completely the separation between the zones which perceive and those which react. The connection between these processes was envisaged by Fittings in 1907, as being due to a polarity set up by the light stimulus, which 'spread out' from cell to cell.

At the time that Darwin was studying the nature of phototropic stimulus, Sachs in 1880, launched the first theory of substances controlling plant growth. Leopold (8), and Tukey (11) stated that Fitting in 1909, actually extracted substances from orchid pollen which could cause swelling of the ovary in a manner suggestive of fruit-set. He suggested that these substances were hormones.

Fitting's work closely followed by the experiments of Boysen-Jensen which showed that a phototropic stimulus can be transmitted across a wound gap. Boysen-Jensen cut off the tips of Avena coleoptiles and stuck them on again with gelatin. He then illuminated the tip only and showed that curvature appeared not only in the tip but also in the base.

Boysen-Jensen's experiment was repeated by Paal in 1914, who after excluding the possibilities of the base being influenced by scattered light, by contact stimulus, or by the asymmetrical weight of the bending tip, confirmed

Boysen-Jensen's findings. Varying the conditions of the experiment, Paal showed that the stimulus could cross a layer of gelatin, but not cocoa-butter, mica, or platinum foil. His next step, writes Went and Thimann (12), was to show that, even without light, curvatures could be induced in the base by the simple process of cutting off the tip and replacing it on one side of the stump. This clarified that 'the tip is the seat of a growth-regulating center.' If the movement of this correlation carrier is disturbed on one side, a growth decrease on that side results, giving rise to a curvature of the organ. Here, for the first time, the idea of a growth hormone enters botanical literature.

According to Leopold (8), Blaw in 1918 showed that photoperiodic movement in Avena was due to a retardation of growth on the lighted side. Went and Thimann (12) in 1928 associated this retardation with a decrease in the relative hormone content of the lighted as compared to the unlighted side. Dolk in 1929 showed that geotropic movement in Avena was caused by a simple redistribution of the hormone present. Hawker (5) in 1932 reported that geotropism in roots was brought about by very similar changes in relative hormone contents of the upper and lower root halves.

Paal's findings were confirmed by the careful growth measurements of Soding in 1923. Working not with curvatures but with straight growth, Soding proved that replacement of the cut tip would restore the greater part of the growth reduction which is caused by decapitation.

However no success in obtaining this growth-promoting substance from oat tips was achieved. The failure to extract the growth-promoting substance from coleoptile tips was experienced by Stark, Nielsen and Seubert. However, Seubert was able to prove that agar containing saliva, diastase, and malt extract caused a promotion of growth. This was the first evidence that growth-promoting substances existed outside the plant.

Leopold (8) and Went and Thimann (12) concluded that the demonstration of a correlation carrier in oat tips by Paal attracted many new workers to the field. Among these were Cholodny in Russia and F. W. Went at Utrecht, who independently developed the view of Paal and extended the correlation theory to both phototropism and geotropism. Each attributed all tropisms to asymmetric distribution of the normal growth-promoting substance. They concluded that all tropisms were mediated by a growth hormone system which was essential to plant growth. 'Ohne Wuchsstoff, kein Wachstum'. Without auxin there is no growth.

Success in obtaining the active substance from coleoptile tip was finally achieved by Went in 1928. Using the findings of Paal and adapting the method of Stark, he placed coleoptile tips upon blocks of agar, and then placed the agar on one side of the stumps of decapitated coleoptiles. The result was a curvature away from the agar block (negative curvature). The experiments clearly showed that a substance was produced in the tip of the coleoptile which could be extracted, and which would cause curvature in a coleoptile to which it was applied.

The next question was to secure sufficiently large quantities to identify the substance chemically, and then to synthesize it if possible. The amount of material present in oat seedlings was too small to suit the needs of the chemist. Other plant materials were tested, with the result that it was found in certain fungi. It was also found that human urine had the capacity to cause curvature of the coleoptile of oat seedlings. According to Tukey (11), by 1931, by laborious and skilled chemical means, two chemists in Holland, F. Kogl and A. J. Haagen-Smit, had isolated a substance from human urine which they called 'Auxin' implying growth and cell elongation in the names. Next from maize oil they extracted a closely related material, which they now called 'auxin b', renaming the first 'auxin a'. Shortly thereafter, Kogl and Haagen-Smit, in conjunction with H. Erxleben, identified a third substance in urine which they found to be none other than 3-indole-acetic acid, a chemical compound which had been identified in 1885 in the decomposition of proteins. To this material the name 'heteroauxin' or 'other auxin' was given. It was soon found that material which had been secured from fungi was also 3-indoleacetic acid. Thus in a short period, from 1928 to 1936, three auxins were isolated, characterized and identified, the quantitative relationships of auxin to tropisms of roots and shoots were established, and at the end of this period, recounts Leopold (8), half of the major functions of auxin in growth and development as is known now had already been discovered.

Went and Thimann (12) in 1934 discovered that auxins can stimulate the formation of adventitious roots. La Rue (7) in 1936, found that auxin applied to leaves could retard leaf abscission. Later workers have found that abscission of all plant organs (leaves, flowers, fruits, etc.) is correlated with low natural auxin content. Gustafson (3) in 1936 discovered that auxin plays a key role in parthenocarpy and in fruit-set in general.

Thus in a very short time after the perfection of the Avena test, the essential frame work of auxin functions in plants had been brought to light. Auxin was found to be the controlling agent of tropic responses, the major control of apical dominance, and a primary factor in organ formation, in the abscission or non-abscission of plant parts, and in the commencement of fruit development.

In recent years a large literature on this subject has developed. Went and Thimann (12) give the account of these recent developments.

The occurrence and distribution of the auxins has been investigated by Soding, Thimann, Laibach and others. In this connection the fact that the auxins have no specificity of action was first demonstrated by Cholodny, and confirmed abundantly by Nielsen, Soding, Uyladert, and others. The investigations of van der Weij have brought light to many remarkable facts concerning the transport of auxins in the coleoptile, particularly the strict polarity of its movement.

In roots, the studies of Snow (9), Cholodny, Boysen-Jensen and others have made it clear that the effect of auxin is to inhibit, not to promote elongation, and this makes it possible to explain geotropic behavior of roots along the same lines.

Heyn and Soding succeeded in showing that one of the ultimate effects of auxin is a change in the properties of the cell wall, which allows extension to take place.

As time goes on, new research appears to be attributing more and more physiological functions to the growth hormones in plants. Leopold (8) considers that the magnitude of the influence of hormones on the physiology and anatomy of the plant is undoubtedly still not fully recognized.

MATERIALS AND METHODS

Growth regulating substances were tried on asparagus crowns in the greenhouse in the winter of 1956. Next they were tried in the field early in the spring. Finally they were used on asparagus in the field about the middle of August. The work is therefore divided into 3 stages or experiments:

1. Winter experiment in the greenhouse.
2. Spring experiment in the field on the horticultural farm.
3. Summer experiment in the field on the horticultural farm.

Winter Experiment (Greenhouse)

The following materials and rates of application were selected.

1.	(A)-2,4,5-T Trichlorophenoxy propionic acid. Trichlorophenylamine salt.	20 ppm
2.	Naphthalene acetic acid	30 ppm
3.	Ethylene chlorohydrin	75 ppm
4.	Thio-urea	30,000 ppm
5.	2,4-D - Dichlorophenoxy acetic acid.	10 ppm
6.	Check	
7.	(a)-2,4,5-T	60 ppm

Asparagus crowns (var. Mary Washington) were dug from the horticultural farm on March 1, 1956 and stored for two days. The crowns were planted in a greenhouse bench on March 3. The crowns were immediately covered with 3 to 4 inches of washed river sand. Then the crowns were watered. Twenty-one plots (three replications of seven treatments) were planted. Each plot had five plants. Within the plot the crowns were five inches apart and the plots were 36 inches apart. The treatments were established in a randomized block design. The arrangement of the treatments in the greenhouse bench was as follows:

Block I	Block 2	Block 3
Thio-urea	Ethylene chlorohydrin	2,4-D
Naphthalene acetic acid	Napththalene acetic acid	(a)-2,4,5-T
2,4-D	(A)-2,4,5-T	Ethylene chlorohydrin
Check	2,4-D	Thio-urea
Ethylene chlorohydrin	Thio-urea	(A)-2,4,5-T
(A)-2,4,5-T	(a)-2,4,5-T	Check
(a)-2,4,5-T	Check	Napththalene acetic acid

One litre of solution was applied per treatment on each replication. The solution was sprinkled on the surface of the sand so it would percolate through the sand and hit the buds on the crown. Parallel lines were drawn on each side of the row (plot) line. These lines were placed six inches on either side of the row line. These lines therefore enclosed a width of one foot. The solution was applied uniformly on this one foot wide band.

The soil temperature was controlled in the greenhouse. The temperature in the bed varied from 75 to 80° F. The plants were watered frequently throughout the experiment.

Spear emergence began within a few days. The first records and measurements were taken on March 7 and measurements were continued through March 18. The spears were not harvested on any date. They were allowed to grow and the number and height was recorded on every counting date. The spears which attained a height of eight inches were not measured again, others were measured until they reached the height of eight inches. Diameters of all the spears were taken on March 21.

On every counting date the form of growth of spears in each treatment was observed to see how they compared with the check treatment in growth pattern.

Spring Experiment (Field)

Four chemicals out of six that did better in the greenhouse were selected and used in the field. They were:

1.	2,4,5-T	20 ppm
2.	Naphthalene acetic acid	30 ppm
3.	Ethylene chlorohydrin	75 ppm
4.	Thio-urea	25760 ppm
5.	Check	

These treatments were applied to asparagus plants on March 24. A Latin square design was used for this experiment.

Each replication contained five rows of asparagus plants. Each row was 16 feet long and contained 16 asparagus plants. The asparagus plants which were used, had grown one year in the permanent planting. This experiment was conducted on a variety experiment. This variety experiment was established as a randomised block design. It was assumed that there would be no variety X treatment interaction. The treatments were applied from a sprinkling can, uniformly so as to enable the chemical to percolate and contact the buds on the crown. The arrangement of the planting in the field was as follows:

	Row 1	Row 2	Row 3	Row 4	Row 5
Rep 1	Treatment 5	Treatment 4	Treatment 3	Treatment 2	Treatment 1
Rep 2	" 5	" 1	" 4	" 2	" 3
Rep 3	" 4	" 1	" 3	" 5	" 2
Rep 4	" 3	" 4	" 1	" 5	" 2
Rep 5	" 1	" 3	" 4	" 2	" 5

Two litres of solution per plot was applied on all the plots throughout the five replications except the checks. The solution was applied uniformly over a one foot wide band. The solution was applied a little at a time to ensure uniform application with no run off.

There was no temperature control but the plants were irrigated regularly. The sprouting of spears was slow and delayed in the beginning due to cold weather but increased as the weather became warmer.

The spears were not harvested but they were allowed to grow as in the greenhouse experiment. The first records and measurements were taken on April 4 and they were continued through May 5. On every counting date the numbers of newly emerged spears as well as old spears were recorded. Their heights were also measured. The number and heights of all the spears in the treated and check rows were recorded throughout the five replications on every counting date. The heights were divided into height classes and the number of spears falling in each height class was recorded on every counting date. The following height classes were used to find the number of spears falling into each height class on different treatments with the progress of time:

Up to 1.5 inches, 1.6 to 3 inches, 3.1 to 4.5 inches, 4.6 to 6 inches, 6 to 7.5 inches and over 7.5 inches.

Those spears which passed 7.5 inches in height were also recorded on each date. Diameters of all the spears were also taken at the end of this experiment. Every time the counts were made, observations were also recorded concerning the form of growth of the spears in each treated row and its comparison with the check.

Summer Experiment (Field)

Four new chemicals and three previously used chemicals at different concentrations were used in this experiment. The treatments used were:

1. Maleic hydrazide	120 ppm
2. 2,4,5-T	100 ppm
3. 2,4,5-T	200 ppm
4. Thio-urea	30000 ppm
5. Thioacetamide	100 ppm
6. Thiosemicarbazide	100 ppm
7. Trans-cinnamic acid	50 ppm
8. Check	

Tops of asparagus plants were cut off about two inches above the ground. Then the growth regulators were applied on the crowns. These treatments were applied to asparagus plants on August 21. The plants used in this experiment were of the Mary Washington variety. They had grown one and one-half years in the permanent planting. A randomized block design with four replications was used in this experiment. All the replications were along the same line. The entire length of line consisted of 192 feet with crowns of asparagus growing one foot apart on it. Each treatment was used on six plants which constituted a plot. The arrangement of the treatments in the field was as follows:

Block 1	Block 2	Block 3	Block 4
Treatment 8	Treatment 8	Treatment 4	Treatment 4
" 3	" 4	" 6	" 7
" 1	" 3	" 1	" 3
" 4	" 5	" 3	" 6
" 5	" 1	" 8	" 2
" 6	" 2	" 2	" 1
" 2	" 6	" 5	" 8
" 7	" 7	" 7	" 5

This time the solutions were not applied along the row as in previous experiments. The solutions were applied directly above and around each crown. The treatment was therefore concentrated about each crown. Half a litre of solution was used per plant. The solution was poured on the soil directly above the crown. Soil from between the rows was mounded up around the crowns so that no runoff would occur.

The sprouting of spears was fast due to hot weather. The spears were harvested every third day. The first harvest was on August 24 and harvesting was continued through September 10. The height of spears was not measured.

However the harvested spears were graded into three classes: marketable, too big and injured. The number of spears falling into each class was recorded every harvest date.

The marketable and culls (too big and injured) were then weighed separately. This data was collected for each plot for each date of harvest.

On every harvest date, observations were also recorded concerning the form and pattern of growth of spears in each treatment including the check. The changes in the mode of growth and/or injury resulting from the treatment was also studied by comparison with the check.

RESULTS

Winter Experiment (Greenhouse)

The treatments with corresponding numbers were listed in Materials and Methods. In the results and discussion, the treatments will be referred to primarily by treatment numbers.

Records were taken on March 7, 9, 11, 14, 16 and 18. The following information was obtained.

1. The total number of spears emerged by each date.
2. The number of spear emerged per week.
   a. First week - March 7-11
   b. Second week - March 14-18
3. The total number of spears per treatment for the entire experiment.
4. The number of spears falling in each height class.

The L.S.D. values were obtained by extracting the square root of the following: $\frac{\text{2x error of variance}}{\text{number of replications}}$ X t value for 5 and 1 per cent levels from table of t.

The original data and the analysis of variance for the experiments was filed with the Department of Horticulture.

The Total Number of Spears Emerged by Each Date. There was no significant difference resulting from the application of growth substances on any date except March 9 when significant differences (at the 5 and 1 per cent levels) occurred in the number of spears observed. At the 5 per cent level treatment 3 showed a significant increase in the number of spears when compared to treatments 5, 2, 4 and 6 (check). Treatment 1 showed a significant increase in the number of spears over treatment 2, 4 and 6.

At the 1 per cent level treatment 3 showed a significant increase over treatment 6. These results are shown in Table 1.

Table 1. Mean number of spears per treatment that had emerged by March 9, 1956.

	3	1	7	5	2	4	6
5 per cent LSD value = 9.37	21.3	19.3	13.3	10.7	9.0	8.3	7.7
1 per cent LSD value = 13.13	21.3	19.3	13.3	10.7	9.0	8.3	7.7

Note: 1) The numbers above the lines are treatment numbers. The numbers below the line are the treatment means.

2) The lines stretch across the treatments between which there is no significance.

It would appear from Table 1 that ethylene chlorohydrin (treatment 3) resulted in a large increase in the number of spears. But countings made two days later on March 11 showed no significant increase. All the treatments had more spears than the check although not significantly more. Records taken on all dates after March 9 until the end of the experiment did not show any significant difference in the number of spears produced. Evidently the effect of these growth substances was not persistent.

<u>The Number of Spears Emerged per Week.</u> No significant difference due to different treatments was observed.

<u>The Total Number of Spears per Treatment for the Entire Experiment.</u> Significant differences occurred between treatments, for the total number of spears produced when the data was pooled for the whole experiment. Table 2 shows these differences.

Table 2. Mean number of spears per treatments for the greenhouse experiment, 1956.

	3	1	7	4	5	6	2
5 per cent LSD value = 10.78	194	187	158	147	144	142	108
1 per cent LSD value = 14.13	194	187	157	147	144	142	108

Treatment 3 had the largest number of spears, significantly larger than the check. Treatment 2 had the fewest number of spears, significantly fewer than the check. Treatment 3 was also the one that had the maximum number of spears on March 9. This was the only date that significant differences occurred. Treatment 3 was therefore the best treatment so far as the total number of spears was concerned.

<u>The Number of Spears Falling in Each Height Class.</u> There was significant difference in some cases and not in others as indicated in Table 3. Dates and height classes that were significant are indicated by an asterisk.

Table 3. Dates when significant differences occurred for various height classes.

Dates	Up to 1.5	1.6-3	3.1-4.5	4.6-6	6.1-7.5	Over 7.5
March 4						
" 7						
" 9		*	*			
" 11						
" 14	*				*	*
" 16	*		*	*		*
" 18	*			*		*

March 9. Two height classes showed significant differences in the number of spears resulting from different treatment. These height classes were 1.6-3 inches and 3.1-4.5 inches. Table 4 shows the mean number of spears in this height class according to treatments.

Table 4. Mean number of spears per treatment that had attained a height of 1.5-3 inches on March 9, 1956.

	2	4	6	5	7	3	1
5 per cent LSD value = 2.96	1.0	2.0	2.0	3.0	4.0	5.3	8.0
1 per cent LSD value = 4.15	1.0	2.0	2.0	3.0	4.0	5.3	8.0

Treatments 1 and 3 showed a significant increase over treatment 6 at both the 5 per cent and 1 per cent levels. Treatment 2 showed the lowest number of spears of this height class.

Significant differences occurred between the treatments for the height class 3.1-4.5 inches as indicated in Table 5.

Table 5. Mean number of spears per treatment that had attained a height of 3-4.5 inches on March 9, 1956.

	4	6	2	7	1	3	5
5 per cent LSD value = 0.8	0.0	0.7	1.7	2.0	2.7	3.0	3.0
1 per cent LSD value = 1.1	0.0	0.7	1.7	2.0	2.7	3.0	3.0

Treatments 2, 7, 1, 3 and 5 gave significant increase over the check in the number of spears of this class at both the 5 and 1 per cent levels. Treatment 4 showed the fewest number of spears.

March 14. There were significant differences for three height classes. These were: up to 1.5, 6.1-7.5, and over 7.5 inches. Table 6 shows the mean number of spears for the height class up to 1.5 inches according to treatments.

Table 6. Mean number of spears per treatment that had attained a height up to 1.5 inches on March 14, 1956.

	2	6	3	1	5	7	4
5 per cent LSD value = 1.3	0.0	0.3	0.3	0.3	0.7	0.7	5.3
1 per cent LSD value = 1.8	0.0	0.3	0.3	0.3	0.7	0.7	5.3

Treatment 4 showed a significant increase over all other treatments including the check at the 5 and 1 per cent levels. Treatment 2 had the fewest number of spears in this height class on March 14.

Table 7 shows the results for the height class 6.1-7.5 inches for March 14, 1956.

Table 7. Mean number of spears per treatment that had attained a height of 6.1-7.5 inches on March 14, 1956.

	2	5	1	3	4	7	6
5 per cent LSD value = 1.4	0.0	0.0	0.7	1.3	1.3	1.7	2.3
1 per cent LSD value = 1.98	0.0	0.0	0.7	1.3	1.3	1.7	2.3

Treatment 6 showed a significant increase over all other treatments. Treatment 2 showed the least number of spears.

Table 8 shows the results for the height class, over 7.5 inches for March 14.

Table 8. Mean number of spears per treatment that had attained a height of over 7.5 inches on March 14, 1956.

	4	7	2	5	6	3	1
5 per cent LSD value = 12.6	7.7	14.7	22.3	25.3	25.7	31.7	37.0
1 per cent LSD value = 17.7	7.7	14.7	22.3	25.3	25.7	31.7	37.0

Treatment 1 showed a significant increase in the number of spears when compared to treatments 4, 7 and 2 at the 5 per cent level.

March 16. Four height classes showed significant differences. They were: up to 1.5, 3.1-4.5, 4.6-6 and over 7.5 inches. Table 9 shows the results for the class, up to 1.5 inches.

Table 9. Mean number of spears per treatment that had attained a height of up to 1.5 inches on March 16, 1956.

	2	5	1	6	3	7	4
5 per cent LSD value = 3.7	0.0	0.0	0.3	0.3	0.7	1.0	7.0
1 per cent LSD value = 5.2	0.0	0.0	0.3	0.3	0.7	1.0	7.0

Treatment 4 showed a significant increase over all the treatments including the check (treatment 6) at the 5 and 1 per cent levels.

Table 10 shows the results for the class 3.1-4.5 inches.

Table 10. Mean number of spears per treatment that had attained a height of 3.1-4.5 inches on March 16, 1956.

	2	3	5	6	7	1	4
5 per cent LSD value = 1.5	0.0	0.3	0.3	0.3	0.7	0.7	5.0
1 per cent LSD value = 2.1	0.0	0.3	0.3	0.3	0.7	0.7	5.0

Treatment 4 showed significant increase over all the treatments including the check at both the 5 and 1 per cent levels. Treatment 2 had the fewest number of spears.

Table 11 shows the results of the height class, 4.6-6 inches.

Table 11. Mean number of spears per treatment that had attained a height of 4.6-6 inches on March 16, 1956.

	2	1	5	7	3	6	4
5 per cent LSD value = 1.85	0.0	0.3	0.7	1.0	1.3	2.7	3.7
1 per cent LSD value = 2.6	0.0	0.0	0.7	1.0	1.3	2.7	3.7

Treatment 4 showed a significant increase over all treatments except the check treatment. Treatment 2 had the fewest number of spears in this height class on March 16, 1956.

Table 12 shows the results for the height class, over 7.5 inches.

Table 12. Mean number of spears per treatment that had attained a height of over 7.5 inches on March 16, 1956.

	4	2	5	6	7	3	1
5 per cent LSD value = 12.3	12.0	26	30.0	36	36.7	40.7	42.3
1 per cent LSD value = 17.3	12.0	26	30.0	36	36.7	40.7	42.3

Treatment 4 had significantly fewer spears than any other treatment. This showed that very few spears in treatment 4 obtained a height of over 7.5 inches. Treatment 1 had a significantly larger number of spears than the check treatment. This demonstrated treatment 4's height depressing effect.

<u>March</u> <u>18</u>. Three height classes showed significant differences due to treatments. They were: up to 1.5, 4.5-6, over 7.5 inches. Table 13 shows the results for the height class, up to 1.5 inches.

Table 13. Mean number of spears per treatment that had attained a height up to 1.5 inches on March 18, 1956.

	1	2	3	5	6	7	4
5 per cent LSD value = 1.15	0.0	0.0	0.0	0.0	0.3	1.0	5.7
1 per cent LSD value = 1.6	0.0	0.0	0.0	0.0	0.3	1.0	5.7

Treatment 4 showed a significant increase over other treatments at both the 5 and 1 per cent levels.

Table 14 shows the results for the height class 4.6-6 inches.

Table 14. Mean number of spears per treatment that had attained a height of 4.6-6 inches on March 18, 1956.

	1	2	5	3	7	6	4
5 per cent LSD value = 0.8	0.0	0.0	0.3	0.7	0.7	1.0	2.7
1 per cent LSD value = 1.1	0.0	0.0	0.3	0.7	0.7	1.0	2.7

Treatment 4 showed a significant increase over all other treatments including the check at both the 5 and 1 per cent levels.

Table 15 shows the results for the height class, over 7.5 inches.

Table 15. Mean number of spears per treatment that had attained a height of over 7.5 inches on March 18, 1956.

	4	2	5	6	7	1	3
5 per cent LSD value = 11.2	22	26.3	31.3	33.3	38.3	41.7	42.7
1 per cent LSD value = 15.7	22	26.3	31.3	33.3	38.3	41.7	42.7

Treatment 4 had the smallest number of spears in this height class. It showed that many spears in treatment 4 did not reach the height of over 7.5 inches. Treatment 4 therefore had a height depressing effect.

In addition to the statistical differences for height and number of spears for different treatment, some morphological differences were also observed.

Spears treated with treatment 1 showed a cork screw type twist (anti-clock-wise). Spears kept two height levels in the beginning but later on the heights became irregular. Some spears were curved and some were growing at a slant.

Spears treated with treatment 2 showed a clock-wise twist. Heights were at two distinct levels in the beginning but irregular later on. Spears were straight and they appeared to be larger in diameter than the check.

Spears of treatment 3 had a marked clock-wise twist. Spears were branched and curved and in the beginning showed two levels.

In treatment 4 height growth was markedly suppressed. The spears were short and stumpy, internodes were shorter. There was no twist.

In treatment 5 spears showed both clock-wise and anti-clock-wise twist. Many spears were strongly curved in the center. Spears in general were irregularly shaped and branched.

Treatment 6 (check) had normal spears.

Treatment 7 caused low branches to form. Spears were primarily straight but some were curved in the middle. There was no twist.

There was no significant difference in diameter of spears due to any treatment. However, spears of treatment 2 looked thicker by appearance and spears of treatment 4 appeared to be stunted. Spears from treatment 4 also appeared to be larger in diameter.

Spring Experiment (Field)

The treatments with corresponding numbers were listed in the Materials and Methods section. In the results and discussion, the treatments will be referred to primarily by treatment numbers.

Records were taken on April 4, 7, 11, 14, 18, 21, 25, 28 and May 2 and 5.

From these records the following information was obtained:

1) The number of spears emerged on each date;

2) The number of spears emerged each week.

   a) first week --------- April 4-11

   b) second week --------- April 14-21

   c) third week --------- April 25-May 2

   d) fourth week --------- May 5

3) The number of spears per treatment in each height class for each date.

The results of this experiment were probably affected by freezes which destroyed many spears. Also the interaction of variety X treatment possibly caused the results to differ from the greenhouse experiment. The following results were obtained:

There were no significant difference in the number of spears emerged for each date due to treatments. This was in sharp contrast to the situation in the greenhouse experiment conducted in the winter.

Number of Spears Emerged per Week. No significant differences due to treatments were obtained in the first week.

In the second week, treatment 4 and 3 showed significantly fewer spears than the check at the 5 per cent level as indicated in Table 16.

Table 16. Mean number of spears per treatment that had emerged during the week April 14-21, 1956.

	2	5	1	4	3
5 per cent LSD value = 25.5	106.5	104	96.3	72.3	69.5
1 per cent LSD value = 35.7	106.5	104	96.3	72.3	69.5

Ethylene chlorohydrin, treatment 3, had the smallest number of spears in the second week. This was in marked contrast to the effects of ethylene chlorohydrin in greenhouse experiment where it gave the highest number of spears on the second counting date. Ethylene chlorohydrin in the field appeared to be acting as an inhibitor. Low temperature in the field experiment possibly caused this effect.

In the third week the differences between treatments were insignificant.

No significant differences between treatments occurred during the fourth week either.

Number of Spears in Each Height Class for Each Date. No significant difference due to treatments was obtained on any counting date.

Although there were no quantitative differences in height or number of spears between the treatments, some morphological differences were noticed.

Spears treated with treatment 1 were twisted and bent. Some were curled and crooked.

In treatment 2 spears were bent and curled near the ground. Spears were dense and profuse.

In treatment 3 spears were definitely supressed in height. Some spears were curled near the ground, many were bent at the top forming hooks. Some spears were bent twice at right angles. Some spears showed fasciation or extremely deformed growth.

Treatment 4 stunted the spears. These spears appeared to be larger in diameter. The spears in Treatment 5 had good height and were straight. Spears in this treatment appeared to be taller than the spears in the other treatments.

Summer Experiment (Field)

The treatments with corresponding numbers were listed in the Materials and Methods section. In the results and discussion, they will be referred to primarily by treatment numbers.

Records were taken on August 24, 29, September 1, 4, 6 and 10. The following information was obtained for each treatment:

1) The number of injured spears per week
   a) First week ---- August 27, 29, 1956
   b) Second week ---- September 1, 6, 1956
   c) Third week ---- September 10, 1956
   d) Total number of spears injured for the whole experiment.
2) The weight of marketable spears
   a) First week ---- August 27, 29
   b) Second week ---- September 1, 6
   c) Third week ---- September 10
   d) Total weight of marketable spears for the entire experiment.
3) The weight of cull spears
   a) First week
   b) Second week
   c) Third week
   d) Total weight of cull spears for the entire experiment.
4) The number of marketable spears; week-wise
   a) First week
   b) Second week
   c) Third week
   d) Total for the whole experiment period.

5) The number of cull spears; week-wise

   a) First week

   b) Second week

   c) Third week

   d) Total for the whole experiment period.

6) The total number of spears

   a) First week

   b) Second week

   c) Third week

   d) Total for the whole experiment period.

<u>Number of Injured Spears per Week</u>. Significant differences between treatments were observed during the first week as indicated in Table 16.

Table 16. Mean number of spears per treatment that were injured during the first week.

	8	4	1	3	7	6	5	2
5 per cent LSD value = 3.97	1.3	4	4	8.8	11.0	11.3	12.8	14.5
1 per cent LSD value = 5.4	1.3	4	4	8.8	11.0	11.3	12.8	14.5

Treatments 3, 7, 6, 5 and 2 showed a significant increase in the number of spears injured over the check (treatment 8) at the 5 and 1 per cent levels.

Significant differences in the number of spears injured with different treatments were observed during the second week also as shown in Table 17.

Table 17. Mean number of spears per treatment that were injured during the second week.

	8	2	1	6	5	7	3	4
5 per cent LSD value = 2.7	0.8	5.0	5.3	5.8	6.3	6.5	6.8	7.5
1 per cent LSD value = 3.68	0.8	5.0	5.3	5.8	6.3	6.5	6.8	7.5

As indicated in Table 17, all the treatments showed a significant increase in injury over the check both at the 5 and 1 per cent levels. It was interesting to observe that treatment 2, which had the largest number of injured spears in the first week, was next to the check treatment in number of spears uninjured in the second week. The toxic effect of this treatment therefore declined in intensity with the passage of time.

Treatment 4 apparently caused an increase in toxicity in the second week. During the first week, treatment 4 was not significantly different from the check at the 5 per cent level. But during the second week treatment 4 was not only significantly more toxic than the check but it also showed maximum toxicity among the treatments applied. Treatment 3 was comparable to the check treatment in the first week but in the second week it became very toxic. Other treatments behaved similarly the second week when compared to the first week.

In the third week no significant differences in injury were noticed between the treatments. The toxic effects therefore disappeared during the third week.

Analysis of the pooled data for the entire experiment again showed significant difference in injury resulting from different treatments. These significant differences were recorded in Table 18.

Table 18. Mean number of spears per treatment that were injured during the entire experiment.

	2	5	6	7	3	4	1	8
5 per cent LSD value = 5.2	23	21.5	21	21	18.0	13.5	12.25	2.25
1 per cent LSD value = 7.08	23	21.5	21	21	18	13.5	12.25	2.25

All the treatments used showed a significant increase in injury over the check at the 5 and 1 per cent levels. Treatment 4 which had the maximum toxicity during the second week ranked near the check treatment in injury for the entire experiment.

Weights of Marketable Spears. No differences in the weight of marketable spears between the different treatments were observed during the first week.

In the second week significant differences were obtained as depicted in Table 19.

Table 19. Mean weight of marketable spears in grams per treatment that had emerged during the second week.

	3	8	7	6	5	1	2	4
5 per cent LSD value = 14.8	56.3	61	63.5	65.8	68.8	71.8	82.3	88.5
1 per cent LSD value = 20.2	56.3	61	63.5	65.8	68.8	71.8	82.3	88.5

It is interesting to observe, that although treatment 8 had significantly fewer injured spears than any other treatment, it did not produce as much marketable weight as several other treatments. Treatments 2 and 4 produced a significantly larger weight of marketable spears at both the 5 and 1 per cent levels. No significant differences were obtained during the third week.

The data of all the three weeks pooled together did not show any significant difference.

<u>Weights of Cull Spears</u>. During the first week significant differences due to treatments were found. These differences are shown in Table 20.

Table 20. Mean weight of cull spears in grams per treatment that had emerged during the first week.

	1	4	3	6	8	5	7	2
5 per cent LSD value = 196.1	172.1	211.9	307.4	403.1	416.1	478	495	528.2
1 per cent LSD value = 266.96	172.1	211.9	307.4	403.1	416.1	478	495	528.2

Treatment 2 had the largest weight of culls and treatment 1 the least.

During the second week no significant differences were observed.

During the third week no significant differences occurred either.

The data of the three weeks pooled together did not show any significant difference due to the treatments.

<u>Number of Marketable Spears</u>. In the first week, significant differences due to treatments occurred as illustrated in Table 21.

Table 21. Mean number of marketable spears per treatment that had emerged during the first week.

	3	4	1	5	2	6	7	8
5 per cent LSD value = 4.93	5.0	7.3	7.5	8.5	9.8	10.3	10.3	14.3
1 per cent LSD value = 6.71	5.0	7.3	7.5	8.5	9.8	10.3	10.3	14.3

As shown in Table 21, treatment 8 gave the largest number of marketable spears both at the 5 and 1 per cent levels. Treatment 3 gave the least number of spears among the treatments.

In the second week the differences in the number of marketable spears due to treatments became insignificant.

There was no significant difference in the third week.

The data for the three weeks when pooled together, showed significant differences in the number of marketable spears due to the treatments as illustrated in Table 22.

Table 22. Mean number of marketable spears per treatment that had emerged over the whole season.

	8	2	1	4	6	7	5	3
5 per cent LSD value = 8.9	30	24.3	22	21.8	19.5	19.5	17.5	12.3
1 per cent LSD value = 12.17	30	24.3	22	21.8	19.5	19.5	17.5	12.3

Treatment 8 gave the largest number of marketable spears and treatment 3 gave the fewest number of marketable spears in the overall analysis for the whole season. This also occurred during the first week when treatment 8 gave the largest and treatment 3 the fewest number of marketable spears. The results were therefore consistent.

Number of Cull Spears. In the first week significant differences occurred in the number of cull spears for the different treatments as given in Table 23.

Table 23. Mean number of cull spears per treatment that had emerged during the first week.

	1	4	3	7	5	6	8	2
5 per cent LSD value = 5	10	11.8	18.5	21.8	22.3	22.5	26.8	30
1 per cent LSD value = 6.85	10	11.8	18.5	21.8	22.3	22.5	26.8	30

Treatment 2 gave the largest number of culls and treatment 8 produced the second largest number.
Treatment 1 had the fewest number of culls.

In the second week there was no significant difference in the number of culls.

In the third week there was also no significant difference in the number of culls. However when the data of all the three weeks was pooled and analyzed, it showed significant differences between the treatments as shown in Table 24.

Table 24. Mean number of cull spears per treatment that had emerged over the whole season.

	2	8	6	5	7	4	3	1
5 per cent LSD value = 7.3	50.5	49	44.3	43.8	41.5	37.5	37.5	28.5
1 per cent LSD value = 10	50.5	49	44.3	43.8	41.5	37.5	37.5	28.5

Treatment 2 had the largest number of culls. Treatment 8 ranked next. Treatment 1 had the fewest. These results show a resemblance to the results obtained during the first week.

Total Number of Spears. Significant differences between the treatments were observed during the first week as pointed out in Table 25.

Table 25. Mean total number of spears per treatment that had emerged during the first week.

	1	4	3	5	7	6	8	2
5 per cent LSD value = 9	17	19	24.3	31.8	32	32	39.3	41.7
1 per cent LSD value = 12.26	17	19	24.3	31.8	32	32	39.3	41.7

Treatment 2 had the largest total number of spears and treatment 1 had the fewest number of spears.

Differences in the total number of spears were significant between the treatments during the second week also as shown in Table 26.

Table 26. Mean total number of spears per treatment that had emerged during the second week.

	6	7	5	3	1	2	8	4
5 per cent LSD value = 6.18	19.8	20.5	20.8	20.8	24	24.3	27.3	31.04
1 per cent LSD value = 8.41	19.8	20.5	20.8	20.8	24	24.3	27.3	31.04

Treatment 4 had the largest number of spears and showed a significant increase over treatment 8 at the 5 per cent level. Treatment 2 which was at the top in the total number of spears in the first week dropped down during the second week. Treatment 1 was at the bottom during the first week but it increased during the second week.

An important observation of this week was that treatment 4 which had reduced the number of spears during the first week stimulated the number of spears considerably during the second week.

During the third week there was no significant difference between the treatments. The treatment effect apparently subsided after 2 weeks.

The pooled data for the whole season again showed significant differences due to treatments as shown in Table 27.

Table 27. Mean total number of spears per treatment that had emerged over the entire experiment.

	8	2	6	7	5	4	3	1
5 per cent LSD value = 11.96	78	77	63	62.3	62.3	58.8	51.3	50
1 per cent LSD value = 16.28	78	77	63	62.3	62.3	58.8	51.3	50

Treatment 8 produced the largest number of spears over the entire period, however there was no significant difference between treatments 8 and 2. Significant differences did occur between treatment 8 and the other treatments at the 5 per cent level.

It was interesting to find that treatment 4 which had the lowest number of spears during the first week, showed the maximum number of spears during the second week but this increase did not last over the entire experiment.

Besides the previously mentioned quantitative differences, there were some morphological differences due to the treatments.

Spears treated with treatment 1 were severely stunted. The spears were injured at the apical end. Some spears showed fasciation and were also flat-shaped and hollow in the center.

Spears of treatment 2 were about as high as the check but crooked and bent in all sorts of ways. They were bent at the base, in the middle and at the top. Spears were sparse around each plant and a few were also flat and hollow.

In treatment 3 the spears were severely stunted, and had different shapes. Several were bent at the base, in the middle, and at the top and were spreading on the ground. Some had bent back so much at the top as to form a loop with the main stem. Spears showed fasciation but no hollow centers. Injury to the spears was very severe.

Treatment 4 stunted the spears very close to the ground. No bending or curling was noticeable. There were also no flat spears.

In treatment 5 the height of spears was not much reduced but was shorter than the check. Bending and curling injury was noticed at the base, in the middle and at the top of the spears. A few spears were flat and crooked.

The spears which received an application of treatment 6 were suppressed but not too close to the ground. They were bent and crooked at the base, in the middle and at the top. Spears were very much distorted, they showed fasciation and severe injury. Spears were very flat and hollow centered.

Treatment 7 had shorter spears than the check. Some were suppressed close to the ground and some showed fasciation. Others were bent toward the ground, from the middle of the spears. Some spears were bent twice. Some of the spears were flat shaped and hollow on the inside. Severe injury occurred to the spears.

In treatment 8 there were normal spears with no injury.

DISCUSSION

In the greenhouse experiment there were significant differences in the number and height of spears due to different treatments. Ethylene chlorohydrin produced the largest number of spears. This may have been due to the formation of auxin by the sprouting process. Ethylene chlorohydrin probably caused the appearance of large amounts of glutathione which promotes sprouting. Guthrie (4) found similar results in potato. He found that ethylene treatment of potato tuber breaks dormancy and caused the presence of large amounts of glutathione. It is likely therefore that ethylene chlorohydrin increased the sprouting of spears.

Ethylene chlorohydrin also stimulated the height growth of spears although not as much as 2,4,5-T (treatment 1). This difference was significant over the check treatment. Ethylene chlorohydrin therefore increased both the number of spears and their height significantly over the check treatment. But the ethylene chlorohydrin treatment caused a marked clock-wise twist in the spears. Also the spears were branched and curved.

Thio-urea acted as a height inhibitor. Among all the treatments it had the strongest height depressing effect. Spears were short, stumpy and robust. Internodes were shorter but did not have any twist.

Naphthalene acetic acid reduced both the height as well as the number of spears. The spears showed a clock-wise twist, therefore it was a poor treatment.

2,4,5-T (treatment 1) no doubt increased the height of spears but the spears showed anticlock twist and many were also curved.

In the Spring experiment in the field the chemicals did not show any statistical differences in height, number, etc., but morphological differences resulting from the treatments did occur.

It is not known why the chemicals failed to show any significant differences from the check but there could be many reasons. In the first place in the field the chemicals were applied early in spring when the temperature was very low. The growth regulators were not as effective as in the controlled temperature conditions of the greenhouse. Temperature probably played a very important role in the effectiveness of hormones. This was in agreement with the findings of Kelly (6) and Leopold (8) who reported that temperature had a pronounced effect on the absorption and translocation of growth regulators.

Secondly many of the spears were fatally hit by a freeze about a week after emergence. Then other freezes occurred at two later dates which killed the emerged spears. This resulted in the loss of data early in the season. The spears definitely showed morphological differences resulting from the use of chemicals as they emerged from the ground. It was most likely that the toll of death taken by repeated freezes might have affected the data in such a way as to nullify the differences occurring from the use of growth regulators.

Thirdly in this experiment (spring experiment) we had five varieties of asparagus. Also we had five treatments and five replications. The experiment was designed in the form of a Latin square. The asparagus planting on which these growth regulating substances were tested was not arranged in such a manner, so that the Latin square design would be applicable. However by assuming there would be no differences between varieties as far as the chemical treatments were concerned, it was permissible to use this design.

Varieties have inherent differences. Chemicals were also different. It is very probable that differences due to treatments were neutralized by the inherent differences of the varieties themselves.

Some of the morphological effects due to chemical treatments will be described.

2,4,5-T (treatment 1) caused the spears to bend and curl. Naphthalene acetic acid also caused the spears to bend and curl but the spears were dense and profuse.

Ethylene chlorohydrin suppressed the height of the spears. Many were curled, bent, bent twice and were showing fasciations. Spears were extremely deformed. This was exactly the opposite of the effect that occurred in the greenhouse experiment where ethylene chlorohydrin stimulated height growth. This difference in response to ethylene chlorohydrin is hard to explain. It was likely that temperature might have caused this difference. The freezes might have enhanced the already adverse conditions resulting in extreme deformity and stunting and curling, etc. of spears.

Thio-urea stunted the spears in the field also. This was similar to its effect on spears in the greenhouse. This stunting effect was stronger than the stunting effect of ethylene chlorohydrin mentioned above. The stunting effect was visible on every single spear. Thio-urea was clearly a height inhibitor. If the chemicals had been entirely ineffective these definite morphological differences would not have occurred.

In the summer experiment (in the field) four more chemicals were used. All the treatments caused significant injury on the spears. 2,4,5-T (treatment 2) caused the greatest injury followed by thioacetamide (treatment 6). In this connection it was interesting to note that the chemicals lost their effectiveness or were rendered insignificant after 2 weeks. Again most chemicals were more effective during the first week than during the second week.

2,4,5-T showed another interesting effect. 2,4,5-T (treatment 2, 100 ppm) showed maximum toxicity. At a concentration of 200 ppm (treatment 3) it showed reduced toxicity. These two concentrations of 2,4,5-T might be compared with the concentrations used in the winter experiment in the greenhouse which was 30 ppm (treatment 1) and 60 ppm (treatment 7). The concentrations used in summer experiment were therefore much higher. At 100 ppm, 2,4,5-T (treatment 2) showed maximum toxicity. But at 200 ppm (treatment 3), its effect was not so great. The toxicity caused by these two concentrations might be related to the problem of absorption of the material within the plant tissues. It could be that the absorption of material in the plant decreases as concentration of the material is increased above a certain limit. Effectiveness of a growth substance applied to a plant is a function of the absorption and distribution of the material through the plant. This reversion of response to a higher concentration (of 2,4,5-T) could then be understood.

Significant differences were also obtained between the treatments in the total number of spears, in the number and weight of marketable and cull spears.

The check treatment had the largest total number of spears and the largest number of marketable and cull spears. 2,4,5-T (treatment 3), thio-urea and maleic hydrazide had the fewest spears.

2,4,5-T (treatment 2) gave the largest weight of culls. Evidently the large number of spears injured by 2,4,5-T (treatment 2) contributed to the large cull weight for this treatment.

As in the case of injury, significant differences in the total number of spears and in the number and weight of marketable and cull spears for the different treatments, were obtained during the first two weeks. Again growth regulating substances were more effective during the first week than during the second week. The chemicals lost their effect after the second week.

Many morphological differences occurred due to the treatments. Of these the most conspicuous was the effect of thio-urea. It stunted the spears but it did not cause any bending or curling of spears. Its effect in the winter and spring experiments was similar. It stunted every spear in the treated area.

All other treatments in the summer experiment caused bending and curling of spears in varying degrees. Trans-cinnamic acid, 2,4,5-T (treatment 3), and thio-semicarbazide caused fasciation of the spears. Other treatments did not cause fasciations.

Thio-acetamide, maleic hydrazide, 2,4,5-T (treatment 2) and trans-cinnamic acid caused the spears to appear flat and the spears were hollow. Other treatments did not give rise to flat and hollow centered spears.

It is clear therefore that each treatment had a different specific effect on the form of spears. The treatments also differed in the degree of effect. The treatments did not cause any twisted spears in the summer experiment.

In general the chemicals were more effective in the summer experiment than other experiments. High temperatures prevailing during August and September (period of this experiment) contributed to greater activity of the chemicals. It is known that high temperature increases plant sensitivity to growth substances and that high temperature also increases absorption of growth substances. Therefore the greater responsiveness to chemicals in this experiment was due to greater absorption of chemicals during the high temperature periods. Further, although total absorption was greater due to high temperature at this time, the duration of absorption was probably greatly reduced. This was evident from the fact that all results became insignificant after two weeks and decreased effectiveness was observed in the second week as compared to the first week.

This is in accordance with the findings of Leopold (8) that at higher temperatures the duration of absorption of growth substances is apparently somewhat reduced by warmth in the absence of a carrier.

In the present work on asparagus no carrier was used with any growth regulating chemical in any of the three experiments.

The increased activity of the growth regulators in the greenhouse in winter, the much reduced activity of the chemicals in the field early in spring and the increased activity of chemicals again in summer showed that temperature was certainly a factor in determining the responsiveness to a growth regulating chemical.

CONCLUSIONS

An examination of the results of the three experiments would enable one to arrive at the following conclusions:

In the greenhouse experiment ethylene chlorohydrin produced a significantly larger number of spears than any other treatment including the check. Ethylene chlorohydrin also stimulated the height of spears. But it induced marked clock-wise twist in the spears and caused them to curve.

In the spring experiment ethylene chlorohydrin actually suppressed the height of spears. This was exactly the opposite of the effect of ethylene chlorohydrin in the winter experiment.

In the spring experiment owing to adverse factors due to low temperature, repeated freezes and variety interaction, the results were not conclusive so far as quantitative effectiveness of different treatments was concerned. But the treatments did show their influence on the pattern and shape of spears that emerged.

In the summer experiment the check treatment did the best from the standpoint of total number of spears, number of marketable and cull spears. Treatment 2 (2,4,5-T, 100 ppm) was the most toxic.

Thio-urea acted as a height inhibitor in all three experiments. It did not bend or curl the spears. This effect was highly specific for thio-urea. All other growth regulators that were tested deformed the spears. They produced abnormal spears. The treatments used clearly altered the growth habit of asparagus spears.

The effect of the treatments decreased with the passage of time. Temperature was definitely a factor in the responsiveness to growth regulators. High temperature increased responsiveness to chemicals due probably to greater absorption of materials but the duration of absorption was probably reduced at higher temperature as evidenced in the results of summer experiment.

Concentration of growth regulators determined greatly the type of response obtained. The toxicity of 2,4,5-T increased as its concentration was increased from 30 ppm to 100 ppm. But when used at 200 ppm it showed reduced toxicity.

SUMMARY

The effect of growth regulating chemicals on asparagus spears was studied through three experiments conducted in winter (in the greenhouse), in spring

(in the field) and in summer (in the field). Different growth regulating chemicals were used although some of them were repeated in two experiments and some were repeated in all three experiments.

In the greenhouse, temperature was controlled and the plants were irrigated regularly. In the field there was no temperature control but the plants were irrigated regularly.

In the winter and spring experiments, the spears were not harvested, but in the summer experiment the spears were harvested every time records were taken. The growth of spears was much faster in the summer experiment due to high temperature at the time.

In all three experiments, thio-urea stunted the height of spears. It did not cause any bending or curling or twisting of spears. Further it affected all the spears. Its effect was consistent through the three experiments.

Significant differences in the height and number of spears between the treatments were noticed in the greenhouse experiment.

In the spring experiment, the method of applying the treatments and taking the counts was the same but the experiment was designed in a different way. The treatments were applied across different varieties of asparagus and apparently there was a variety interaction. The spears were damaged repeatedly by fatal freezes. No significant quantitative differences were obtained, but there was a definite effect on the form and pattern of growth of the spears.

Effect of ethylene chlorohydrin was reversed under field conditions of the spring experiment. Ethylene chlorohydrin in this experiment suppressed the height of spears whereas in the greenhouse it actually stimulated significantly the height growth of spears.

Then in the summer experiment, the spears were harvested and weighed by dates. The spears were divided into separate classes (marketable, culls, injured, etc.) for each date.

Significant differences in the number and weight of spears were obtained. Significant differences were also obtained in the number of spears injured by the treatments. All treatment differences became not significant after two weeks and they were most noticeable during the first week.

2,4,5-T caused reversed effects above a certain concentration of the material used.

Some treatments altered the shape and form of spears considerably. Bending, curling, hollow centers and fasciation were caused by some treatments. The treatments in the summer experiment showed greater activity probably due to high temperatures.

Structural differences in spears due to the treatments were observed in all three experiments irrespective of differential conditions under which the three were conducted.

Growth regulating substances had pronounced effects on spear emergence and development in asparagus plantings. However from the practical standpoint, no growth regulating substance, at the concentration used, was tested that would completely control the growth of asparagus spears so that mechanical harvesters could be used.

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EFFECTS OF SOME GROWTH REGULATING SUBSTANCES ON ASPARAGUS SPEAR DEVELOPMENT

by

SURINDER SINGH ATTRI

B. A., Punjab University, Solon, Punjab, India, 1954

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The objectives of this study were: (1) to study the effect of some growth regulating substances on the pattern of asparagus spear development, (2) to attempt to find a hormone that would result in a more uniform growth of asparagus spears.

The effect of growth regulating substances was investigated in three experiments conducted in winter, spring and summer. Temperature was controlled only in the winter experiment.

The treatments were applied on a one foot wide band of the asparagus row, in the winter and spring experiments. In the summer experiment the treatments were applied directly above the crowns. The spears were not harvested in the winter and spring experiments but were harvested on every counting date in the summer experiment. The spring experiment was designed in the form of a Latin square. The winter and summer experiments were designed in the form of a randomised block design.

Significant quantitative differences due to treatments resulted in the winter and summer experiments. In the spring experiment no significant quantitative differences were obtained with the different treatments. But sharp structural differences were obtained in spears treated with the different growth regulating substances. Definite structural differences were also observed in the spears that resulted from the use of different growth regulators in the winter and summer experiments.

In the winter experiment ethylene chlorohydrin significantly stimulated the height of spears and also significantly increased the number of spears. In the spring experiment ethylene chlorohydrin suppressed the height of spears. In the summer experiment the check treatment produced the largest total number of spears, and number of marketable and cull spears. All hormone treatments injured the spears by varying amounts in this experiment.

The effect of thio-urea was markedly consistent through all three experiments. It acted as a height inhibitor but, it produced spears of normal shape. It did not bend, twist, curl or deform the spears. All other treatments deformed the spears in varying degrees and showed bending, curling, twisting, hollowness, fasciation, etc. of spears.

Low temperature, repeated fatal freezes and variety interaction effects in the spring experiment probably nullified the differences occurring from the use of growth regulating substances.

The effect of the treatments was reduced with the passage of time. Their greatest effectiveness was during the first week. After two weeks there was no significant difference due to treatments. Differential responses were obtained with the same chemical when used at different concentrations. Differential responses were also obtained with the same growth regulator under different temperature conditions.

No treatment had any altering effect on the diameter of spears. No treatment, at the concentration used was tested that would completely control the growth habit of asparagus spears so that a set-level mechanical harvester could be used without loss of yield.