https://doi.org/10.29321/MAJ.10.A04586

Practical Applications of Growth Hormones in Crop Production—A Review

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During the last fifteen years, a large number of chemical compounds capable of inducing, even in very minute amounts a variety of effects on plant growth and development, have been discovered and also synthesised. These are known by the general name of growth-promoting substances, auxins or phytohormones. A hormone is any substance that can act as a "chemical messenger", which, after being produced in any part of the living organism, is transferred to another part and there influences a specific physiological process. This term 'hormone' was first used in connection with plants by Fitting in 1910, who showed that the shedding of flowers in orchids soon after flowering was brought about by the presence of the pollen grains and could also be effected by water extracts of the pollinia. The terms "Wuchsstoff", growth-regulator, growth-substance, growth-promoting substance, growth-hormones, plant-hormones, phytohormones and auxins, all refer to the same group of substances, so far as they relate to the plant kingdom.

The literature on this subject has become very voluminous within the last ten years and is still growing rapidly. Extensive reviews on the effects of these growth hormones, chiefly upon the rooting of plant cuttings, and curvatures in the oat coleoptile have been published by Went and Thimann (1937), Pearse (1939) and Nicol (1941). The present article is intended as a review of progress made on certain other effects of these auxins with special reference to the growth and yield of crop plants.

Occurrence. In nature, the auxin content in seeds is normally very low and even negligible, but it increases very rapidly during their germination and attains a maximum by about the fifth day of germination. In the growing plant the main centre of auxin formation is the terminal bud with its embryonic leaves. Auxin is produced only in the light and is at its maximum during the period of maximum growth of the plant. Auxin is also abundant in the pollen especially in *Hibiscus*, *Segucio*, etc., and also in the pollinia of various orchid species (Went and Thimann 1937). Wheat germ oil, maize germ oil and rice polishings are other sources of auxins from the plant world. In animal material, auxins may be present in considerable concentrations in the saliva, pepsin, but is usually most abundant in the urine. Human urine is extremely rich in auxins and was in fact the first source for the isolation of pure auxins. The urine of other animals like horses, cattle and pigs is also fairly rich in these growth hormones.

Mode of action in plants. It has been proved by experiment that cell elongation is dependent on and is controlled by the presence of auxins. They are able to decrease the structural viscosity of protoplasm and bring about a dissociation of the cellular proteins which in turn brings about an increase in the rate of imbibition of water and other nutrients, in diastatic activity and eventually modifies plant growth and development (Northen, 1941). The limits of optimum concentration of these auxins are very narrow and seem to be almost specific for each plant and each substance as well. Concentrations below the optimum have no effect, while higher concentrations inhibit the growth and can even prove lethal to plants.

Effects on plants. (a) *Rooting of plant cuttings.* The role of auxins in stimulating root development is a good example of academic research in plant physiology which has had an immediate practical application. Dipping plant cuttings in suitable dilutions of growth-hormones, has become in recent years quite an established practice in horticulture, especially for species that are classed as difficult to strike root, such as Bearberry (De France 1938), the Norway Spruce (Grace 1939) and many species of Rhododendrons (Doak, 1940). In certain parts of Holland and Scotland there is a curious practice that has a basis in the production and transport of auxins, of inserting germinating wheat grains into the split apical buds of plant cuttings, to make them strike root quicker. (Went and Thimann, 1937). Indole-acetic acid, indole-butyric acid and α-naphthalene-acetic acid are found to be the most effective in stimulating root production among all the various growth hormones tested so far. The optimum concentration varies for different plants and is the lowest for herbaceous cuttings. A strength of 0·2 milligrames per c. c of water and an immersion period of 12 – 24 hours may be recommended, but in practice it is usually necessary to first ascertain by preliminary trials both the effective and the toxic limits before using any of these substances on a large scale. For treatment by the lanolin method (Sheep's-wool fat) a concentration of one milligramme of indole-acetic acid per gram of lanolin is found generally satisfactory. An extensive review has been made by Pearse (1939) on the importance of plant hormones in horticulture.

(b) *Effect on germination and seedling growth.* In disinfecting wheat and other cereals with formalin or copper sulphate for smut control, the germination is often adversely affected. Grace (1938) found that this could be remedied by adding ·01 to 5 parts per million of indole-acetic acid or naphthalene-acetic acid to the disinfecting solution. This pre-soaking in dilute hormones was also effective in improving the germinating power of old seeds. Davis et al (1937) have reported however that indole derivatives retarded germination while ascorbic acid (vitamin C) was able, in sufficiently low concentrations, to stimulate both germination and seedling growth in oats, mustard and water cress. Albaum (1940) found that pre-soaking oat grains in indole-acetic acid improved the final growth of the coleoptile, though the early growth was retarded. Pratt and Albaum (1939)

have observed that when seeds of Yellow Milo Sorghum were soaked in water for different periods before putting out for germination, the shoot growth was adversely affected in proportion to the duration of soaking. Under similar treatment the shoot growth of another variety of sorghum, Dawn Kafir, was not affected. Since it was found by test that the latter variety was richer in auxins than Yellow Milo, it is suggested that auxins get leached out by prolonged soaking, thereby affecting the subsequent growth in Yellow Milo. This effect was not so pronounced in the case of the other variety Dawn Kafir, on account of its higher auxin content.

(c) *Effect upon plant growth* Vitamins of the B group (i. e., vitamin B1, B6, nicotinic acid) and other hormones like estrone and adenine were reported as improving the growth of mustard and *Cosmos* plants in sand cultures, by Bonner and Bonner (1940). They failed however, to obtain a similar effect on wheat and tomatoes, two much-selected crop plants. Since other workers, notably Templeman and Pollard, Minnum, Tincker and Minarik also failed to obtain any increase in growth as a result of adding these vitamins of the B group to the nutrient solution the question can only be regarded as still unproven.

Vitamin C (ascorbic acid) has also been noted as able to stimulate plant growth by Havas (1935) who reported an increase of 25 to 30 percent in the weight of shoots, in wheat and tomatoes. Hansen (1935) has reported an increase of 35 to 75 percent in peas and found that such treated plants were also much richer in vitamin C content than the control plants. A combination of vitamin C and indole-acetic acid was found by Davis et al (1937), to stimulate growth in mustard, oats, cress and willow. In all cases it was noted that concentrations higher than the optimum retarded plant growth.

Indole derivatives and allied substances. The Russian worker Cholodny (1936) obtained with oats, evidence to show that vernalization, which hastens flowering and fruiting increased also the concentration of growth hormones in the cells of the embryo. Seeds were soaked for 24 to 48 hour periods at 15 – 20°C, in different dilutions of indole-acetic acid in water (10 –20 parts per million) and then grown in the greenhouse with appropriate controls. An increase of 55% was obtained in grain weight as compared to control plants grown from seeds soaked in plain water. Loehwing and Baugess (1936) using the same substance at a concentration of 60 parts per million found only a temporary stimulation lasting for about six days in the ornamental plant *Matthiola incana.* A similar result was observed by Greenfield also (1937). N. H. Grace and his co-workers in Canada (1938) tested the effect of pre-treating seeds of wheat, barley and soybeans with different concentrations of various growth hormones mixed with talc dust. It is claimed that such dusts were simpler to use, easier for storage and safer than solutions in inexperienced hands and also that higher concentrations could be used without toxic effects on plants, than is possible with aqueous solutions of these growth substances. An increase of 20 percent

in dry weight and from 55 to 103 percent in root length was obtained in wheat as a result of treating the seed before sowing, with a 2 parts per million concentration of indole-acetic acid and naphthalene-acetic acid in talc dust. With barley and soybeans in sand cultures, they found that the optimum concentrations were 2 p. p million and 10 p. p million respectively of α naphthalene-acetic acid. In a subsequent trial however, with ten varieties of winter wheat in replicated plots under field conditions, Grace (1938) was unable to obtain any consistent result, as the responses varied very widely, with a maximum increase of 13 percent in grain weight and 20 percent in straw weight.

Working with rice, tomatoes and white mustard in Yunnan, the Chinese workers Pei-Sung-Tang and Shei-wei-Loo (1940) have reported acceleration of growth and flowering as a result of pre-treatment with dilute indole-acetic acid. Seeds were soaked in water for 24 hours, then taken out and superficially dried and then again soaked for 24 hours, either in plain water for controls or in agueous solutions of indole-acetic acid at three different concentrations, viz. 1, 10 and 100 milligrammes per litre. After germination, the seedlings were planted out in pots with sandy loam. It was observed that leaf production was accelerated in all the three crop plants studied, and flowering also hastened by 3 to 7 days as a result of the pretreatments. The experiment could not unfortunately be continued till the plants were fully ripe, owing to the exigencies of the war in China. The earliness of flowering was more pronounced with the higher concentrations of the growth hormone, but the number of leaves produced was fewer. A similar hastening of flowering has been reported by Chailakhyan and Zhdanova (1938) with certain concentrations of indole-acetic acid on a large variety of crops, like wheat, millet, flax, peas, hemp and vetch. Amlong and Naundorf (1937) reported an increase over 150 percent in the weight of sugar beet and 9 5 percent in radish, but with seed potatoes they failed to secure any increase of yield Thimann and Lane (1938), using relatively high concentrations of indole-acetic acid on wheat and oats, found an acceleration of growth, earlier flowering and an increase of more than 50 percent in the dry weight of plants Stier and Dubuy (1939) also found that certain concentrations of naphthyl-acetic acid in talc dust, were able to hasten the flowering and also increase the yield in tomatoes The optimum was 100 parts per million of naphthyl-acetic acid as seed dressing in talc dust, followed by 2 minutes dipping in an aqueous solution of 10 p. p. m. of indole-butyric acid: Croxall and Ogilvie (1939) treated seven varieties of peas and two varieties of beans with 5—20 parts per million strengths of β—indolyl-butyric acid, and naphthalene-acetic acid as seed dressings and grew them in field trials during summer. The yields of three varieties of peas were up to 80 per cent greater than from untreated seed. A concentration of 5 parts per million of α—naphthalene-acetic acid was found to be the best on the whole, but there was considerable variation in the responses of different varieties to different dressings. They also varied

somewhat with external conditions; so that no one dressing gave an optimum effect on all varieties and under all conditions. Ogilvie subsequently was unable to get any such positive responses with two other crops, sugar beet and lettuce. Zimmerman and Hitchcock (1938) found that root development was improved considerably by soaking the seed of onions, garlic, carrots, parsnip and sugar beet, in suitable concentrations of growth hormones like indole-acetic, indole-butyric and naphthalene-acetic acids, but these substances had no useful effect on the shoot growth, being ineffective in low concentrations and retarding growth at higher concentrations. At the optimum strengths, treatment with growth hormones increased the rate of metabolism as measured by the evolution of carbon dioxide. Tobacco plants when sprayed at suitable intervals with a solution of β—naphthalene-acetic acid at 300 mgm per litre, grew taller and flowered earlier than the controls (Zimmerman, 1941).

(d). *On Parthenocarpic development of fruits.* A number of these growth-substances could also induce fruit-setting without pollination, when applied as a spray or paste to the stigmas or cut surface of the styles. Gustafson (1936), induced such parthenocarpic development of fruits in tomato, pepper, eggplant, crookneck squash, *Petunia* and *Salpiglossis*, by applying 1 per cent lanolin pastes of indolyl-acetic acid and other synthetic hormones. In other fruits however, like watermelon, and pumpkin, he failed to secure such fruits and in cucumber the results were not consistent. Similarly Wong (1939) found that lanolin pastes of indolyl-acetic and indole-butyric acid of 0·5 and 1·0 per cent, did not induce parthenocarpic fruit-setting in a commercial variety of seedless orange and Varrelman (1938) obtained only negative results with a normally parthenocarpic type of apple. In a later communication Wong (1941) was successful inproducing parthenocarpic fruits of cucumber, water-melon and pepper, using α—naphthalene-acetic acid in lanolin paste.

Howlett (1940) obtained parthenocarpic tomatoes by spraying the flowers and buds with 0·5% solutions of indoleacetic-acid and indole-butyric acid. Such fruits were more solid, 'meaty' and milder in flavour than those formed after normal pollination Between the two substances, the fruits were larger in size when indole-butyric acid was used for spraying. Burrell (1939) was able to increase the proportion of fruit-setting in musk-melons (*Cucumis melo*) from 26% to 59% by smearing a lanolin paste of 1% indole-acetic acid to the stigmas immediately after pollination. From the practical standpoint, it can only be said that growth-hormones can induce parthenocarpic fruits in some species, but it is not yet certain whether this will have any commercial importance.

In storing unripe fruits, Traub (1938) found that a weak solution of 0·01 % to 0·001 %, of a number of growth hormones could arrest senescence and prolong the storage life of orange, lemon, lime, grape-fruit and tree tomatoes. Solutions of 0·05 % and higher strengths, on the other hand accelerated senescence and shortened the storage life.

(e) *On fruit shedding.* It was observed as early as 1939 in America that many of these growth hormones when sprayed in suitable dilutions on apple trees were effective in reducing the pre-harvest drop of fruits (A. C. Murneek, Gardner et al., McCown and Burkholder, Babjer and Marth, 1939). Enzie and Schneider (1941) were able to delay this 'pre-harvest drop' of apples by 15 days, by spraying with a 0·001 percent concentration of naphthalene-acetic acid. A second spray fifteen days later, was not quite so effective as the first. Hoffman (1941) sprayed McKintosh apple trees 10 days prior to harvest, with a 10 parts per million solution of naphthalene acetic acid and 50 parts per million of naphthalene acetamide and both were effective in reducing the shedding to 3 to 6% as compared to 40 to 48% in the controls. It was noted that the temperature prevailing at the time of spraying was an important factor in the success of the spray in preventing shedding. Hitchcock and Zimmerman (1936) tested naphthalene-acetic acid and its derivatives on five varieties of apple trees and found that there was considerable variation in the response between varieties and even between different trees of the same variety itself. All the derivatives of naphthalene-acetic acid tried were more or less equal in effect Cool weather at spraying time was in general unfavourable for shedding control. Vyvyan (1941) at East Malling also obtained similar results with growth hormones on apple trees, but pointed out that it was first necessary to make sure that such sprayed fruits could be consumed without injury to health before these substances could be used in general practice. For Indian conditions and crops, it may perhaps be worthwhile to test these substances on mango trees and oranges and also whether these hormones would be effective as a spray or mixed with irrigation water, in reducing the bud and boll shedding in Indian cottons caused by untimely rains at flowering time.

(f) *Negative effects.* Against the positive effects reviewed above, must be considered also a number of negative responses obtained by a number of workers on various crops. Thus Templeman (1939) failed to observe with wheat, barley, white mustard, tomatoes, lettuce and sugar beet in sand cultures, any useful or favourable effect with any of the different growth hormones he tried Low concentrations had no effect, while higher concentrations were often toxic and depressed growth, Mitchell (1939) tried the effect of various concentrations of indole-acetic acid in water, ranging from 1 to 300 mgm per litre, on beans, marigold, coleus and four o' clocks both as a spray and mixed with the nutrient solution, but the only visible effect was a temporary curling up of the shoots. No increase was obtained in total dry matter. Hwang and Pearse (1940) also found no increase in the dry weight of plants, although the rate of regeneration of buds was accelerated when indole-acetic acid was applied to the cut ends of shoots in Broad beans and oats.

Barton (1940) also treated a large variety of plants with different growth hormones as vapors, liquids and as dusts, but was unable to observe any stimulating effect on any of the plants he studied. Similar negative

results have been reported by De France (1941), Hamner (1941), Minnum (1941), Swartz (1941), and Youden (1940) on a large variety of species and with various growth substances applied in various ways. In no case was there any definite increase in growth or yield as a result of pretreatment with growth hormones.

Sreenivasan (1941) at Indore treated cotton seeds with a 1 in 20,000 solution of β—indolyl-acetic acid and also in plain water before sowing them in the field in plots treated with a mixture of compost and also the growth substance. He found that plants from seed soaked in plain water gave a higher yield of seed cotton than those soaked in the growth substance This was sought to be explained as being due to the total concentration of the growth substance attaining somewhat toxic levels in the latter case. A much fuller study is obviously necessary before the optimum concentrations of plant hormones could be specified for all the various crops grown under Indian conditions.

Conclusion. The practical utility of growth hormones can be taken as established in the rooting of plant-cuttings, though even here negative effects are not at all uncommon owing to the fact that the doses of hormones that the cuttings receive must fall within very narrow limits. Not only is there no single treatment effective for all species of plants but it is found that varieties of even the same species may vary in the optimum dose of hormones required for successful rooting Went and Thimann (1937) found that addition of sucrose and dextrose increased the number of roots formed on etiolated pea cuttings by indolyl-acetic acid. Other substances, like vitamin B_1, theelin, Bios and various amino acids have also been found to increase the effectiveness of growth hormones in promoting root development. Laude (1941) found an increase of up to 12 5 % in the dry weight of Red Kidney bean (Phaseolus vulgaris), by adding indolyl-acetic acid, but a high level of potassium was also found necessary in the nutrient solution for the effect of the growth substance to be fully manifested.

In the control of fruit shedding also, the practical value of growth hormones is coming to be recognised. In the parthenocarpic development of fruits, the results are less definite and the methods suggested, of treating the style or stigmas with sprays or pastes of the growth substance, are less easy to apply on a large scale.

Treatment with hormones for increasing crop yields, is still only in the stage of possibilities. The results on crop yields after treating the seeds with aqueous or talc mixtures, or their nutrient medium with growth hormones, are still very variable and rather contradictory.

In evaluating these contradictions it has to be borne in mind that growth substances like auxin *a* and auxin *b* are liable to get spontaneously inactive (Went and Thimann 1937) in the dark and in *vacuo*. Analysis of the inactive product (pseudo-auxin) shows no change in composition or molecular weight, so that the change must be one of isomerisation. Where

negative results were obtained, it is seldom mentioned whether the growth substances used, were first tested for their activity before being used in seed-dressings and in other ways. It has also been suggested that often the lack of response is due to enzymes which rapidly destroy these applied growth hormones. Another complicating feature is that substances that have chemically little in common, produce the same type of physiological response, while others more closely related differ widely in their activity. For example α-naphthalene acetic acid is one of the most effective in stimulating root development, while its isomer β-naphthalene-acetic acid has only a very slight activity. Different soils also differ in their relative auxin content. And again, in many crop plants and even varieties of the same species, the auxin contents of the germinating seeds are apt to be very widely different; in such cases it may so happen that pre-treatment with growth hormones brings up the concentrations to toxic levels that depress growth. It may therefore be concluded that although this method seems to have some possibilities, a good deal of further work is necessary before the apparent contradictions are fully elucidated and a set of practical recommendations formulated for general use.

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APPENDIX I

Effects of Growth Substances upon Plant Growth. (a) Positive Effects.

Date	Worker	Place	Plant	Growth Hormone	Concentration	Method of Application	Method of Culture	Effects
1935	Havas	Hungary	Wheat, Oats, Tomatoes	Vitamin C (=Ascorbic acid)	100—500 p. p. m.	Added to nutrient solution	In pots	Root weight increased by 50% Shoot weight „ „ 25—30%
1935	Hansen	Finland	Peas	Ascorbic acid			In pots	Dry weight of shoots increased by 35—75%
1936	Cholodny	U. S. S. R.	Oats	β-indole-acetic acid	10—20 p. p. m.	Seeds soaked for 24—48 hrs. at 15—20°C		55% increase in grain weight over control (seeds soaked in water)
1936	Loehwing and Bauguess	U. S. A.	*Matthiola incana*	„	1—150 p. p. m.	Added to nutrient solution	In pots	Temporary stimulation for six days only
1937	Davis	U. S. A.	Oats, Cress, Mustard, Willow	Ascorbic acid and Heterauxin				Ascorbic acid stimulated growth Indole derivatives retarded growth
1937	Greenfield	U. S. A.	*Matthiola incana*	Indole-acetic acid	12—1600 p. p. m.	Added to nutrient solution	In pots	Lower concentrations had no effect Higher concentrations retarded growth
1937	Grace	Canada	Wheat, Barley	Indole-acetic acid, naphthalene-acetic acid	Various	Seed smeared in talc dust with growth-substance	In pots (sand cultures)	Responses varied very widely
	„	„	Winter Wheat, (10 varieties)	„	„	„	Replicated trials in the field	Maximum increase 13% grain and 20% in straw

Date	Worker	Place	Plant	Growth Hormone	Concentration	Method of Application	Method of Culture	Effects
1937	Amlong and Naundorf	Germany	Sugar Beet, Radish, Seed Potatoes	Indole-acetic acid	0 01 to 0 001 N solution	Seeds soaked for 24 hours		Sugar Beet--157% increase in yield, 1.9% in leaf area, 123% in sugar content with 0·001 N. Soln. Radish 98% increase Seed Potatoes No effect
1938	Chailakhyan and Zhdanova	U. S. S. R.	Wheat, Flax, Peas, Hemp, Vetch, Millet	β-Indole-acetic acid	10 -50 p. p. m.			Flowering was hastened in some cases
1938	Thimann and Lane	U. S. A.	Wheat, Oats	"	Relatively high concentrations			Growth was accelerated, flowering hastened and 50% increase obtained in dry weight of plants
1938	Mitchell and Hamner	"	Kidney Bean, (*Phaseolus vulgaris*)	" and naphthalene acetamide	0·002%	Lanolin paste applied to cut apex		If axillary buds were first removed before treatment an increase of 23 —85% in solid matter and 6 to 11% in total dry weight was obtained
1938	Zimmerman and Hitchcock	"	Various root-crops, Onions, Garlic, Beets, Carrot. Parsnip	Various substances including 1) indole-acetic acid 2) indole-butyric acid 3) naphthalene acetic acid 4) phenylacetic acid 5) cinnamic acid	50 to 100 mgms. per litre	Soaked for 24 hours		Root Production i. e. number and size of roots was increased.(3)>(2)>(1)
1939	Zimmerman and Hitchcock	"				and also as vapours and solutions		Treated plants had a higher rate of metabolism as measured by the carbon dioxide evolved
1939	Croxall and Ogilvie	Bristol (England)	Peas, Beans, Lettuce. Beet-root	α-naphthalene acetic acid β-indole butyric acid	5—20 p. p. m.	Dry seed dressing	Field	Crop yields were up to 80% more in treated plants. 5 p. p. m. α-naphthalene acetic acid was the best on the whole but responses varied very widely. No effect on lettuce and sugarbeet

1939	Stier and DuBuy	U. S. A.	Tomatoes	Indole-acetic acid Indole butyric acid α-naphthyl-acetic acid	10 – 100 p. p. m.	As seed dressing in talc dust		Certain combinations hastened flowering and also increased the yields. e. g. 100 p. p. m. of naphthyl-acetic acid as seed dressing followed by 2 minutes dipping in an aqueous solution of 10 p. p. m. indole-butyric acid
1940	Bonner and Bonner	U. S. A.	Wheat, Mustard Tomatoes, Cosmos	Vitamin B_1, B_6, Nicotinic acid	10 p. p. m.	Added to nutrient solution	Sand cultures	Growth improved in mustard and cosmos. No effect on the much-selected crops, wheat and tomatoes.
1940	Hopkins	U. S. A.	Barley	Indole-acetic acid	2·5 to 5 0 p. p. m.	Seed dressing in talc dust		Tillering was accelerated by 2 days only. No increase in number or final weight of shoots with sub optimal moisture. Height was 3% and straw wt. 10% more than control but there was no increase in grain weight.
1940	Howlett	U. S. A.	Tomato	Indole-acetic acid Indole-butyric acid	0·02–·5% 0 5% was the best			Treatment induced parthenocarpic fruit-setting. Fruits were better in quality. Fruit size was larger with indole-butyric acid.
1940	Pei-Sung-Tang and Stei-wei-Loo	Yunnan [illegible]	Rice, Tomatoes, Mustard	Indole-acetic acid	1—100 mgm. per litre.	Seeds soaked for 24 hours in water and hormone solution	Sand cultures	Leaf production accelerated ; Flowering was 3 to 7 days earlier in all the three crops. Higher concentrations earlier but leaves fewer. Expt. could not be completed till ripe stage.

Date	Worker	Place	Plant	Growth Hormone	Concentration	Method of Application	Method of Culture	Effects
1941	Laude		Red Kidney Bean, (*Phaseolus vulgaris*)	Indole-acetic acid and naphthalene acetamide	Various	Added to the nutrient solution	sand cultures	Wide variations noted. Increase up to 13%. High level of potassium necessary to get increase in dry weight of total plant material.
1941	Sreenivasan	Indore (India)	Cotton	Indole-acetic acid	50 p. p. m.	Seeds soaked for 12 hours in hormone solution and also mere water	Field	Soaking in plain water gave higher yield than hormones.
1941	Zimmerman and Hitchcock	U. S. A.	Tobacco, Delphinium	β-naphthoxy-acetic acid	300 mgm per litre	Sprayed on the plants at periodic intervals		Sprayed plants grew taller and also flowered earlier.
1942	Overbeek	"	Ten-day-old embryos of *Datura*	Coconut 'milk'				An increase of nearly 500—8000 times was found in the growth of the young embryos as a result of using coconut 'milk'.
				(b). Negative Effects.				
1939	Mitchell	U. S. A.	Beans, Coleus Marigold, Four o'clocks	Indole-acetic acid	1—300 mgm per litre	Sprayed on plants, mixed with irrigation water	In pots	There was no increase in total dry matter produced. The only effect was a temporary curling and bending of the shoots.
1939	Templeman	Great Britain	Barley, Mustard	Sodium salts of β-indolyl-acetic acid α-naphthalene acetic acid	4—400 mg. per 26 lb. of sand	Sprayed on the plants	Sand cultures in pots	No positive response in any case though depressing effects were often observed.

1940	Templeman and Marmoy	"	Wheat, Barley, Sugar-beat, Oats, Tomatoes, Mustard		·01 to 30 p. p. m.	100–400°C added to nutrient solution also as seed dressings		No useful effects with any concentration Low concentrations had no effect, higher ones were toxic.
1940	Barton	"	Various	Various growth substances		As vapours, liquids and dusts.		No positive stimulating effect seen on any plant.
1940	Hwang and Pearse	"	Oats, Broad Beans	Indole-acetic acid	2 20, 200 p p m	Seeds soaked 24 hours		Growth studied only for 2 weeks after sowing. No effect on dry weight of plants– but if applied to cut ends of shoots, there was a stimulation of growth.
1940	Youden		Wheat, Soybeans	Indole-acetic acid Indole-butyric acid Naphthalene-acetic acid		As seed dressing in talc dust		No useful effects could be observed.
1941	De- France	U. S. A.	Kentucky Blue grass	Auxan 1, auxan 2 Rootone naphthalene acetic acid		"		There was no consistent increase in the density of grass with any of the treatments.
1941	Hamner		Beans Tomatoes	α-naphthalene acetamide phenyl acetic acid	Various	Spraying and mixed with the nutrient solution		No effect on dry weight of beans. Treatments beneficial on growth of tops and roots but evidence not conclusive.
1941	Minaum		Radish, Cauliflower	Vitamin B_1, B_2, B_6	0·01–10 m.m. per litre	seed dressing in talc dust		Treated plants were in no case significantly better than the controls.
1941	Swartz		Cosmos, marigold, chrysanthemam	Vitamin B_1, naphthalene acetic acid				No positive effect on any plant by any of the substances tried.