GROWTH SUBSTANCES IN PLANTS

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During the past few years a tremendous quantity of publicity has been given to the use of various substances to stimulate growth in plants. Most of the emphasis has been laid on the use of such substances for the rooting of cuttings of woody plants such as Camellia, rhododendrons, holly and others which ordinarily are extremely difficult to root, and for accelerating the rooting of other cuttings which are more easily rooted with the customary propagating practices.

More recently, the effect of these same substances on seed germination has been capitalized upon in the seed trade. As is frequently the case in commercial propaganda, promises are made which far exceed, and in some cases have but little bearing on, the actual facts which have been demonstrated in well-controlled scientific experiments. For this reason, as well as because of the confusion and disagreement which appears to exist among the various investigators themselves, it has seemed wise to make an effort at this time to give our readers some notion of the actual principles involved in the use of growth substances, and of what they can and cannot be expected to accomplish.

Materials having the ability to affect the growth and development of plants when applied in almost infinitesimal amounts are spoken of variously as hormones, phytohormones, auximones, auxones, phytamines, vitamins, growth regulators, growth promoting substances, and simply growth substances. The latter is perhaps the most generally accepted and widely

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used term, largely because it is all-inclusive and yet suggestive of the physiological activity of all of these substances.

Kinds of Growth Substances

The substances which have been found to stimulate growth of plant cells vary widely in characteristics from the gas, carbon monoxide, to the complex organic compounds such as vitamins. Various methods of classifying them have been proposed in the literature but the simplest, for our purposes, is to divide them into two groups.

Hormones

These are substances which are produced by the individual, the development of which they influence. The term was first applied to certain secretions present in man and other animals, and implies that they are "chemical messengers." By definition they are substances which are manufactured in one part of the animal or plant and carried to some other part of the organism where, in extremely minute quantities, they influence such physiological activities of the cells as growth.

To the group of plant hormones belong various organic compounds. The first to be recognized as such are two compounds, auxin a and auxin b, which have been isolated and purified from various plant tissues and from urine. They have not, however, been successfully synthesized in the chemical laboratory. Another compound intimately associated with auxins a and b is heteroauxin which has been shown to be indole-3-acetic acid or beta indole-acetic acid. Since this compound has been synthesized in the laboratory and was understood chemically long before it was recognized as a plant hormone, and since it is an active root-forming substance, it has naturally been among the first of the chemicals to be used extensively in investigations concerning the practical value of plant hormones to the propagator.

The vitamins, of which so much is written in connection with human and animal nutrition, are specific substances which are needed in minute quantities by, but not generally manufactured in, the animal body. They are manufactured by plants, but their function in the physiology of the plant has not been understood until recently. Now, it has been found that several of them, notably vitamin B_1 (known to the chemist as thiamin or aneurin), are growth substances for plants. Therefore, such compounds as thiamin are vitamins for animals and at the same time hormones for plants, because they are produced in one part of the plant and transported to other parts where, in extremely minute quantities, they influence physiological processes such as growth.

Auximones

These are substances which alter the rate, kind, and direction of growth of plants when introduced from without in extremely high dilution. When present in sufficiently small amounts they stimulate the growth of plant cells, but when still less is present the stimulating effect is decreased. Moreover, the stimulation of growth diminishes rapidly with increasing amounts of these compounds until a concentration is reached above which the compounds become increasingly toxic.

To this group of substances which are sometimes collectively termed synthetic hormones, belong compounds with widely diverse physical and chemical properties. Investigators in plant research laboratories around the world have been working with such substances, with the result that scores of different compounds are now recognized as having the ability to influence plant growth. Materials as well known and as varied as the gas, carbon monoxide on the one hand, and the much talked-of drug, sulfanilamide on the other hand, have been shown to belong to this group of compounds.

Kinds of Effects Produced

The general effects on cell growth in plants may be expressed in various ways, such as increase in leaf and shoot development, increase in number or length of roots, and general increase in dry weight of plants produced. As a rule, these substances alter the distribution rather than the total amount of growth, so that when a given substance is applied at a rate to stimulate root-formation it will probably inhibit top-growth, at least temporarily. This is the reason why the term growth regulators or simply growth substances is preferred to growth-promoting substances.

Growth of plants takes place by two distinct processes, cell-enlargement and cell-division. The actual existence of plant hormones was first discovered through their stimulation of localized cell-elongation which resulted in the bending of the stem or other plant part to which the growth substances were applied. It has since been shown that the same substances applied at slightly greater rates or to other plant parts induced growth by the other process, cell-division. Growth by cell-division, for instance, results in the formation of new roots on cuttings of stems and in some cases even on leaves. In still larger quantities, these same substances become growth inhibitors rather than growth stimulants.

It is believed by some that the natural bending of shoots toward the light and away from gravity is due to a localized effect of plant hormones present in those organs. In the first case, the auxins, which are the hormones stimulating cell-elongation, concentrate on the shaded side of the stem or leaf with the result that the shaded side grows faster than the lighted side and the stem or other plant part concerned bends toward the light. In the case of the response to gravity, it has been shown that in horizontally placed stems the auxins accumulate on the lower side causing a localized increase in growth in that region. The result is that the stem curves up or away from gravity.

Various more or less localized effects can be induced in plants by the external application of these growth substances. When leafy shoots are exposed to dilute vapors of these compounds or when the same compounds are applied to limited areas of plant organs in lanolin paste, in solution, or in talc, the leaves may grow down, stem tips may become enlarged, root formation may be induced, or stems may be caused to grow in the direction of gravitational pull rather than away from it. There is some evidence that seed germination can be accelerated. In one laboratory it has been shown that the damage caused by disinfecting seed with formaldehyde, copper sulfate, and mercuric chloride is reduced by the addition of small amounts of some of the synthetic hormones.

Certain compounds when applied to the pistil of some flowers have the power to stimulate cell growth in the ovary so that sterile fruits are produced. By such means, seedless fruits of such plants as watermelon, crooked neck squash, pepper, holly, and others have been produced experimentally. However, because of the difficulty of preventing on a large scale the occurrence of natural pollination, this method has not yet come into commercial use.

The inhibiting effect of hormones not only occurs when the synthetic compounds are applied externally at excessive rates but also occurs commonly in nature. For instance, the well-known fact that many plants are pinched back to encourage the development of lateral shoots may now be explained by the fact that the auxins which are produced in the terminal bud stimulate the growth of the shoot but inhibit the development of the lateral buds. When the source of these growth substances is removed by taking off the terminal bud, the lateral buds are no longer inhibited. As they begin to develop, they in turn become sources of auxins for subsequent shoot growth.

Effects of Concentration

It appears that the concentration of growth substances used plays an important role in determining the effect which that substance will have on a given plant. Generally speaking, roots seem to be more sensitive than shoots to the synthetic hormones. A concentration which will stimulate root-elongation may not be sufficient to have any effect on shoot growth. When the same substance, however, is applied at a sufficiently high rate to stimulate shoot growth it may inhibit the elongation of roots. When applied at a still higher rate, the same substance may cause the development of new roots at the points where it is applied and at the same time inhibit shoot growth. Moreover, it may also inhibit the subsequent growth of the roots which it has initiated.

This effect of concentration is far-reaching in its applications. Natural growth hormones are present in varying amounts in most plant tissues. The quantity present varies with the species of the plant, the organ of the plant, the stage of growth, the environmental conditions under which the plant has been growing, etc. If all other factors necessary for growth are uniform, the plant which has the largest quantity of growth hormones in its tissues may be expected to give the least response to added growth substances.

When one considers that the concentrations with which the experimenter is dealing are rarely over 1 part in 1,000 and in many instances may be less than 1 part per million (p. p. m.), it becomes evident how careful the practical man must be in making up the solution or dust in which he intends to apply the growth substance.

Chemicals May Affect Specific Organs

The kind of response which may result from the application of growth substances to plants depends not only on the species of plant, its stage of development, and the rate at which the substance is applied, but also on the part of the plant to which it is applied and the kind of growth substance used. Certain compounds are decidedly specific in the effects they produce and the plant parts which they influence.

Vitamin B_1, for instance, has been shown to be indispensable for the elongation of roots but it does not actually initiate the development of new roots. So far, no direct effect on the growth of stems, the time of flowering, or the number and size of flowers and fruits, has been satisfactorily demonstrated. The increase in vegetative vigor of some plants in response to treatment with vitamin B_1 is believed by authorities to be caused by the increased vigor of the roots. Other vitamins such as B_2 and B_6, nicotinic acid, and thiourea have been shown to be necessary for root growth in some species but vitamin B_1 appears to be necessary universally.

On the other hand, the synthetic hormones such as beta indole-acetic, beta indole-butyric, and alpha naphthalene-acetic acids appear to be less specific in their effects, the exact nature of the effects being determined by the rate of application and the organ treated. When applied at the right concentration to cuttings they have the ability to induce the formation of roots at the site of application but may inhibit their subsequent growth. A combination of one or more of the synthetic hormones to initiate new roots with vitamin B_1 to stimulate their growth may, therefore, be expected to give the best results so far as rooting of cuttings is concerned.

In the following table the various kinds of effects are listed together with some of the compounds which have been shown to produce these effects, at least with certain species. This list is by no means complete and includes chiefly those compounds which are referred to most commonly in the literature on growth substances. A few compounds are included because they are well known for their physiological activity but are not generally recognized as having any influence on the growth of higher plants. The latter are included only to indicate the diversity of the compounds which produce these effects.

A few generalizations have been ventured by certain authorities concerning the use of some of the more commonly employed synthetic compounds. For instance, according to some investigators, indole-acetic acid and the naphthalene compounds tend to spread throughout the plant and produce general or systemic effects, whereas indole-butyric acid tends to induce a more localized response. According to some, there appears to be less danger of shock to the cuttings when the naturally occurring hormone, indole-acetic acid, is used to induce root-formation, although in many cases superior rooting results from the use of indole-butyric acid, alpha naphthalene-acetic acid and other synthetic compounds.

Generally speaking, the naphthalene-acetic acid is more potent than the indole compounds and should be used at lower

PLANT ORGANS AND COMPOUNDS AFFECTING THEIR GROWTH AND DEVELOPMENT

Roots:	
FORMATION OF NEW ROOTS	ELONGATION (NOT FORMATION OF NEW ROOTS)
Auxins a and b	Vitamin B_1 (thiamin or aneurin)
Beta indole-acetic acid (hetero-auxin)	Vitamin B_2 (riboflavin)
Potassium indole-acetate	Vitamin B_6
Beta indole-butyric acid	Nicotinic acid
Beta indole-propionic acid	Thiourea
Alpha naphthalene-acetic acid	
Phenyl-acetic acid	
Coumarin	
Vanillic acid	
Sulfanilamide	
Methylene blue	
Shoots:	
GENERAL TOP GROWTH	LEAF GROWTH
Auxins a and b	Adenine
Biotin	Alanine
Vitamin B_2 (riboflavin)	Arginine
Vitamin C (ascorbic acid)	Uric acid
Thiourea	Other amino acids and purines
Beta indole-acetic acid	
Beta indole-butyric acid	
Beta indole-propionic acid	
Alpha naphthalene-acetic acid	
Naphthalene-acetamid	
Indole-acetamid	

Ovaries:

Sterile Fruit Production
Beta indole-acetic acid
Beta indole-butyric acid
Beta indole-propionic acid
Alpha naphthalene-acetic acid
Ethyl alpha naphthalene-acetate
Methyl alpha naphthalene-acetate

Seeds:

Increase or Acceleration in Germination	Effect on Subsequent Seedling Growth
Auxins a and b	Beta indole-acetic acid
Beta indole-acetic acid	Beta indole-butyric acid
Beta indole-butyric acid	Alpha naphthalene-acetic acid
Alpha naphthalene-acetic acid	Vitamin C (ascorbic acid)
Phenyl-acetic acid	

rates. Phenyl-acetic acid, on the other hand, is only about one-tenth as active as indole-acetic acid and must be applied at heavier rates. The metallic or ammonium salts of the acids are apparently less toxic to the plant and more effective in inducing formative effects than are the acids themselves. The same is true for the methyl and ethyl esters.

Also, there is apparently a difference in the quality of the roots formed as a result of treatment of cuttings with the various synthetic compounds. Those resulting from a treatment with indole-butyric acid are more nearly normal than those which develop after the use of alpha naphthalene-acetic acid.

Natural Occurrence

The discussion thus far has been concerned with the response of plant organs to applications of various growth substances.

It should be remembered, however, that auxins and vitamins are manufactured almost universally by green plants for their own use and are, therefore, hormones in the true sense of the word. The actual amount of these compounds which may be synthesized by any particular plant depends on the species of plant and the conditions under which it is grown.

Auxins, for instance, are present throughout all parts of higher plants, but tend to be most abundant near the regions where they are manufactured or stored. They are synthesized in the tips of actively growing organs and are transported down toward the base of the plant. Long before the existence of auxins as such was understood, the fact was recognized that cuttings without leaves rooted better when at least one bud was present. It is interesting to note that as early as 1880 this fact was explained by the assumption that a specific substance was formed in the shoot and was normally transported toward the base. In cuttings, this substance was believed to accumulate at the base because it could go no farther, and there to result in the formation of roots. In recent years it has been shown that this assumption was correct and that the specific substance was an auxin which was synthesized in the growing bud.

Vitamins, on the other hand, are believed to be manufactured in the leaves of green plants, the slow-growing plants such as *Camellia*, *Rhododendron*, and *Azalea* producing materially less than the rapidly growing annuals. From the leaves, the vitamins are translocated to all parts of the plant, the seed frequently containing the highest percentage of them.

Moreover, it has been shown that manure, compost, plant debris, soil microflora, seed meal products, and other organic materials used to enrich soil contain appreciable amounts of vitamin B_1. Therefore, plants growing in soil which contains generous quantities of organic matter have an abundant supply of Vitamin B_1 even if they do not make it in sufficient quantity for themselves. In fact, the addition of Vitamin B_1 to plants growing in such soils may result in a reduced growth due to the toxic effect of an over-abundance of growth substance. It has been suggested that "sickness" of highly manured greenhouse soils which is sometimes described may be simply a matter of toxic concentrations of growth substances.

In view of this universal distribution of growth substances it is not reasonable to expect phenomenal results from their addition to plants growing under normally good cultural conditions. When normal conditions are disturbed, such as occurs when cuttings are made, when well-established plants must be transplanted, or when an attempt is being made to germinate old or poor seed, there is a good possibility that some of the growth substances may become limiting factors in the growth of the plants concerned and that a favorable response might be expected if the right growth substance were added in the right concentration. When plants are grown in water or sand culture, or in poor soil lacking in organic matter, it may be that they do not have available a sufficient supply of hormones for best growth and will therefore respond to their addition from without.

Factors Complicating Results with Growth Substances

It should be remembered that growth substances represent only one group of factors necessary for plant growth. Among other factors involved, are the external ones such as light, temperature, soil moisture, and nutrients; and the internal ones such as proper activity of the various enzymes, normal synthesis of carbohydrates, and the stage of development of the plant or part of the plant concerned. For optimum growth, the status of all of these factors should be favorable. Moreover, increasing any one of these factors will not result in increased growth unless all of the other factors are already present in quantities sufficient to support such increased growth. Therefore, it is only when the growth substances are the factors limiting growth that their addition may be expected to stimulate growth. Even then, the proper compounds must be added at the right concentrations if growth is to be stimulated in any desired direction.

There is some evidence that these compounds give better results in acid than in neutral or alkaline media. Vitamin B_1, for instance, has been shown to decompose when in contact with alkaline materials and therefore may not be expected to give satisfactory results in alkaline or "sweet" soils or where lime-impregnated water is used. Some investigators also have found that beta indole-acetic acid and other synthetic compounds are more effective when applied in solutions with an acidity between pH 4 and 6 than in neutral or alkaline solutions. It would seem wise, therefore, in making up the final dilute solution to use water which had been acidified with a weak acid such as acetic acid. Vinegar is a readily available source of acid for this purpose. In field work, it would seem that better results might be expected generally on acid than on alkaline soils.

Frequently, the addition of two or more different growth substances may give better results than is obtained by the addition of either alone. For instance, Vitamin B_1, yeast extract, biotin (a component of the vitamin complex in yeast extract), such as proper activity of the various enzymes, normal synthesis of carbohydrates, and the stage of development of the plant or part of the plant concerned. For optimum growth, the status of all of these factors should be favorable. Moreover, increasing any one of these factors will not result in increased growth unless all of the other factors are already present in quantities sufficient to support such increased growth. Therefore, it is only when the growth substances are the factors limiting growth that their addition may be expected to stimulate growth. Even then, the proper compounds must be added at the right concentrations if growth is to be stimulated in any desired direction.

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Recognizing the importance of the many interacting factors which influence the growth of plants, it is not surprising to find the literature filled with conflicting results following treatment of various plant organs with growth substances. Moreover, there are probably other internal and soil factors the importance of which is not recognized today. Particularly with plants grown under field conditions, it is difficult, if not impossible, to evaluate all of the factors influencing their growth and to determine which are limiting ones. Locally planned and executed field tests on a small scale may frequently indicate, however, whether or not favorable results can be expected from a given type of treatment.

Methods of Application

Growth substances have been applied to plants in various ways, the method depending on the compound used, the plant parts to be treated, and the kind of results desired. The most common method used practically is to immerse the bases of cuttings in dilute solutions for 12 to 48 hours, depending on the concentration of the solution and the kind of cutting. Immersion in talc mixtures of the same compounds just before planting the cuttings has also proved effective in many cases.

When decidedly localized areas are to be treated such as is necessary for the production of sterile fruit, the compounds are applied in a paste of lanolin or sheep's wool fat. On the other extreme, whole plants or parts of plants have been exposed to vapors such as carbon monoxide, ethylene and others.

The effect on germination of seed and on subsequent growth of seedlings has been investigated by soaking seed in solutions of these compounds or by dusting them with the talc mixtures and then following the rate and final percentage of germination as well as the vigor of resulting seedlings and mature plants.

Also, there are some experiments described in which solutions of these compounds have been sprayed on foliage of growing plants or applied to the soil in which they are growing.

As is to be expected from the foregoing discussion, the rates recommended in many cases vary over a wide range for the same compound. With vitamin B_1, however, investigators are comparatively well agreed that in solution a concentration of 0.01 to 0.1 p.p.m. is a safe starting point. The rates at which the synthetic hormones have given favorable results have varied from 0.01 to 1,000 p.p.m.

Practical Results with Growth Substances

Unquestionably the hormones play fundamental roles in the physiology of plant growth, some of which are now recognized and understood at least in part. However, because of the almost universal distribution of hormones throughout plant tissues and in fertile soils, and because of the minute concentrations required, beyond which the compounds become toxic, the problem of using them practically to stimulate various types of growth of plants or plant organs is not a simple one to solve. The results which have been published to date vary over a wide range from actual inhibition of growth, through failure to get either stimulating or inhibiting results to outstandingly successful stimulation. Therefore, it is impossible in the limited space of a few pages to summarize the results which appear in the literature. An attempt has been made in that direction, however, to give the reader an idea of where to start if he is anxious to try some of these materials on his plants.

Results with Cuttings

The immersion of the bases of cuttings in dilute solutions or dust mixtures of synthetic hormones has in many cases stimulated the formation of roots. The successful rates used have varied over a wide range from 0.01 p.p.m. to 1,000 p.p.m. Generally speaking, dust treatments can be made at the higher rates with less danger of injury. Also, the dust treatment is perhaps simpler because the base of the cutting can be immersed in it and planted immediately, whereas when solutions are used the cuttings must remain in them for 12 to 48 hours, the length of time depending on the concentration of the solution and the species of plant.

With solutions of indole-acetic and indole-butyric acids, rates as low as 0.1 p.p.m. have been effective in some instances but 5 to 20 p.p.m. may be considered a safe starting point. Less alpha naphthalene-acetic acid is required, effective stimulation having been achieved at rates as low as 0.01 p.p.m. In general, when applied at the base of cuttings, the highest non-toxic concentration of these synthetic compounds will give the best results. This concentration varies with the species of plant used, but generally is less for green cuttings than for dormant ones. With mixtures in talc, effective stimulation has resulted from use of mixtures varying in concentration from 50 p.p.m. to 1,000 p.p.m.

Subsequent treatment with vitamin B_1, biotin, or yeast extract has in many cases resulted in much improved final results, probably because of their stimulating effect on root elongation. Biotin has also stimulated shoot growth.

Hormone treatment, however, is not the "shot-gun prescription" which will solve all of the problems of the propagator. It should be regarded merely as an additional tool to be used in conjunction with the most careful practices which the propagator has at his disposal. Their use neither guarantees successful rooting of cuttings which are otherwise difficult to root nor the acceleration of rooting of cuttings which are normally easily rooted. In fact, numerous individuals have published the results of experiments in which they have been partially or entirely unsuccessful in stimulating root production in cuttings with growth substances.

Results with Entire Plant

Experiments have been performed in which whole plants grown in water or sand culture have responded favorably to hormone treatment. It should be remembered that plants grown under these conditions do not have access to the organic matter and microflora present in fertile soils which are natural sources of abundant supplies of growth substances. Stimulating effects might be expected, therefore, under these conditions which would not appear if the same plants were grown in good fertile soil.

Vitamin B_1, in extremely low concentrations, has stimulated root growth of seedlings which in turn has resulted in generally increased vegetative vigor of the entire plant. When various species were grown in sand, watered with nutrient solutions and treated with vitamin B_1 it was found that common crop plants such as tomato, peas, and corn, which contain relatively large quantities of vitamin B_1 in their leaves, showed no response. On the other hand, plants like *Camellia* which contain no detectable vitamin B_1 in the leaves, and other species which contain less than 10 milligrams to 1 kilogram (2.2 pounds) of dried leaf tissue, showed increased growth as a result of the addition of 0.01 p.p.m. of vitamin B_1. Moreover, the less vitamin B_1 there was present in the leaves, the greater was the increase in weight. For instance, trivialis bluegrass (*Poa trivialis*) which had a vitamin B_1 content of 4.2 milligrams gave more response than did Colonial bent (*Agrostis tenuis*) which contained 6.0 milligrams. It should be remembered that these experiments were performed on plants growing in sand rather than soil.

In other experiments, adenine, uric acid, riboflavin (vitamin B_2), and ascorbic acid (vitamin C) have been shown definitely to influence top growth under some conditions. The first two, used at the rate of 0.01 p.p.m. have also been shown to stimulate the plant to synthesize vitamin B_1. Solutions containing 2.5 p.p.m. of riboflavin or 10 p.p.m. of ascorbic acid when added to plants growing in sand have decidedly stimulated leaf growth, the leaves of the treated plants being consistently coarser in texture, thicker, and darker in color than those of the untreated plants. This increased growth was associated with a general increase in vigor of both top and root growth.

In field grown plants, root growth and resultant vegetative vigor has been increased by dipping the roots of the plants into solutions containing 1 or 10 p.pm. of vitamin B_1 at the time of transplanting. The transplants were dipped into the solutions momentarily and immediately reset into the soil. Such treatment not only resulted in helping the plants to become reestablished more quickly but also in increasing the ultimate size and vigor of the plants. In some cases, time of flowering came earlier and size of fruit was increased. In other experiments, stimulation of growth has resulted from watering the soil in which plants were growing with a solution containing 0.1 p.p.m. of vitamin B_1, and in a few cases stimulation has resulted from actually spraying the foliage of field grown plants with such a solution.

Field grown plants have also been stimulated to increased growth by some of the synthetic hormones. Plants growing in rich soil did not show as much response as those growing in poor soil or sand which was watered with nutrient solutions. Some plants have been stimulated when watered with solutions of the synthetic compounds at concentrations as low as 0.01 to 0.05 p.p.m. whereas others showed no effect at these concentrations and definite repression of growth with a concentration of 1.0 p.p.m. Another investigator reports that spraying seedlings with a solution of 1,800 p.p.m. of indole-acetic acid accelerated both vegetative growth and flowering.

When it comes to stimulating the growth of plants by incorporating the synthetic hormones in the soil, the optimum dosage apparently varies with the substance used, the method of application, the composition of the soil, the climatic conditions and the age and kind of plant. More field work is necessary before any conclusions can be drawn or recommendations made concerning the practical use of growth substances on plants growing in soil.

Results with Seeds

The results from seed treatment are as contradictory as are those from the treatments already described. Of 22 articles written in half a dozen countries, 12 give evidence showing either increase in or acceleration of germination, increase in vegetative vigor, shortening of time required to come into flower, or increase in size and number of fruits produced. On the other hand, the remaining 10 articles give equally as convincing evidence that germination and subsequent growth of seedlings were either not affected or were inhibited by similar seed treatments.

One laboratory in this country claims as a result of extensive work with oats, tomato, and wheat, that soaking seed in solutions containing beta indole-acetic acid at concentrations not exceeding 10 p.p.m. increased the percentage of germination, whereas treatments of seeds with solutions containing 100 to 200 p.p.m. of the same compound, retarded germination but eventually resulted in improving the seedling root system, hastening shoot growth, and possibly increasing the size of fruit.

As opposed to this, there are the results from another laboratory in which seeds of 29 species including Kentucky bluegrass and perennial ryegrass were used. The seeds were soaked for 24 hours in solutions of beta indole-acetic, beta indolebutyric, and alpha naphthalene-acetic acids at concentrations varying from 0.316 to 316 p.p.m. Seeds were germinated in the laboratory, in sand, and in the field, and the general conclusion had to be drawn that there was no effect on germination, vegetative growth of the seedlings, nor on time of maturity and flowering.

Others claim that dust treatment is more effective, safer, and easier to apply than solutions. In one series of investigations, the injury resulting to crop seeds from treatment with formaldehyde, copper sulfate, or hot water to kill fungus infections, was materially reduced by the addition of beta indole-acetic, alpha naphthalene-acetic, or phenyl-acetic acids in concentrations varying from 0.01 to 5.0 p.p.m. Such treatments did not accelerate the time of germination, although applications of the indole-acetic acid in dust to cereal seed at the rate of 2 p.p.m. did result in increased yield of roots and tops.

In another laboratory the application of this dust containing 1,000 p.p.m. of alpha naphthalene-acetic acid stimulated germination of tomato seeds, when applied at the rate of 1 ounce of dust to 9 or 10 pounds of seed. When combined with an immerson of the roots of the seedlings for 2 minutes in solutions containing 10 p.p.m. of beta indole-butyric acid at the time of transplanting, the treatments resulted in hastening the time of flowering and increasing the yield of fruit. Similar but preliminary treatments of Kentucky bluegrass and Chewing's fescue seed gave indications of an acceleration of germination, increase in root growth, and greater drought resistance of the turf the following summer, but these results have not been confirmed.

So far, as stated in the article on page 110 of this issue, preliminary tests which have been made by members of the Green Section staff on Kentucky bluegrass and perennial ryegrass seed, although made at the same rate and following the same method, have shown no such effects.

Absence of beneficial effect either on germination or subsequent growth and development of the seedlings has also been reported recently from an extensive series of dust treatments in which beta indole-acetic, beta indole-butyric and alpha naphthalene-acetic acids and a commercial preparation were applied to wheat and soybeans, although the plants were followed until maturity. In fact, the final results indicated slightly lower values for the treated lots of seed. This the investigator feels may have been due to the talc, since talc alone produced corresponding results. He applied the dusts, which contained the growth substances in concentrations ranging from 250 to 32,000 p.p.m., at rates varying from 1 ounce for 3 pounds to 1 ounce for 30 pounds of seed.

Other workers, applying vitamin B_1 and synthetic compounds to agricultural seed actually obtained inhibition and in addition found double the number of mold- and bacteria-infected seedlings. Since many fungi and bacteria do not manufacture their own growth substances and must therefore obtain them from the medium on which they grow, it is not surprising that, if present at all, they would be most abundant on the seeds coated with growth substances.

According to an article in *Science*, the vitamin content of grass leaves is much greater than that of any of the four standard classes into which all fruits and vegetables are divided. On an equal weight basis, grass leaves in general contain 10 times as much vitamin B_1 and 25 to 250 times as much vitamin A as can be obtained from any of the vegetables or fruits.