ANTIBIOTICS AND PLANT DISEASE

Effects of Antibiotics in Control of Plant Diseases

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The selective action and the great activity of antibiotics are of much interest to the plant pathologist, who deals primarily with diseases incited by fungi, bacteria, and viruses. Members of each type of causal agent have been inhibited by antibiotics under experimental conditions. Successful control of plant disease in field tests has been reported using antifungal and antibacterial antibiotics for foliage sprays or for seed treatments, purposes for which most of the plant disease chemicals are now employed. Certain antibiotics have been shown to control disease by acting systemically in the plant, a property with inherent advantages over the nonsystemic type of surface toxicant now used extensively. Factors that will govern the use of antibiotics on a wide scale include effectiveness in given disease situations, freedom from toxicity to plants and animals, cost and availability, mode and cost of application, compatibility with insecticides, and stability with time and to such weathering agents as light or the washing of rain.

ANTIBIOTICS FOR CONTROL OF PLANT DISEASES have received increasing attention during the past few years from plant pathologists in this country and abroad as offering possibilities for significant fundamental and practical advances. Members of industry, particularly fermentation firms, have also realized these potentialities, and a number of concerns now include plant pathogenic microorganisms in their screening tests for new antibiotics and are otherwise studying new materials from plant pathological and physiological standpoints. The purpose of this paper is to review briefly recent literature on this subject and point out some aspects of the control of plant diseases by chemicals, especially through the use of antibiotics.

Plant Diseases and Their Control with Chemicals

In this country the plant pathologist deals with a group of plant maladies loosely called "diseases," the most important incitants of which are fungi, bacteria, and viruses. Plant diseases may be controlled in a number of ways, but the two most important to the farmer are the use of chemicals and resistant varieties. For the production of many important crops he must employ both methods of attack, and others as well. The cost of chemicals used for disease control is about $35,000,000 annually. Their value in terms of the prevention of losses due to diseases is far greater, on the order of two billion dollars annually in the United States, according to one estimate (*78*). The beneficial effects of chemicals in some disease situations are remarkable—for example, in many areas such crops as apples and potatoes could not be produced commercially without fungicides.

Most chemicals for the control of plant diseases are applied to the aerial parts of the plant and are used primarily to control diseases incited by fungi. Their action is usually prophylactic; they form a protective coating over the plant surface, thus killing or preventing the growth of the pathogen on its arrival. Examples are Bordeaux mixture, a copper preparation discovered some 75 years ago and still used extensively, and the dithiocarbamates, a group of fungicides patented in 1934 and now used widely. These chemicals exert direct inhibitory action on the pathogen. Nearly all of them possess low solubility in water; and, unless they are redistributed by rain or by other natural means, they are effective only at or near the point of application. There is no penetration of or movement within the plant. Therefore, materials of this sort may be called nonsystemic or residual toxicants.

In contrast to this type of compound, other chemicals exert their action from within the plant, usually at some distance from the point of application. These substances have been called chemotherapeutants, or if the term is used in a broad sense, they may be called systemic fungicides (or bactericides). For various reasons, neither term is wholly satisfactory, but in this paper "systemic" is used, as at this time it is the feeling of the writers that the term used should convey the conception of action from within the plant in other areas in addition to the area of application. Some toxicants, particularly those with eradicant or therapeutant action against certain leaf pathogens, appear to penetrate into the plant to a very limited degree. These materials are here classed as nonsystemic. As yet systemic chemicals are matters of intense research interest and promise, but as far as the writers know they are used commercially on a very limited scale, if at all.

The subject of antibiotics in relation to plant diseases has been reviewed most recently by Anderson and Gottlieb (*1*) and Weindling *et al.* (*77*). Therefore, chief emphasis is placed on the literature that has appeared since these papers were published. The main concern is with the use of pure or partly purified antibiotics for the control of plant diseases, especially under greenhouse and field conditions. Reports on the use of liquid culture filtrates of antibiotic-producing organisms are mentioned, but in this type of experiment the antibiotic organism is usually present in the material applied to the plant. Under such conditions it is difficult to determine the exact nature of action, as the growing antagonist and the living pathogen are in the same arena—the infection court. The addition of antibiotic microorganisms to the soil or to the seed with the aim of controlling disease, and matters dealing with the importance of antibiotics in these situations are not covered here. There is no coverage of the many papers dealing with the in vitro inhibition of plant pathogens by antibiotics or by antagonistic organisms.

Antibiotics as Nonsystemic Toxicants

Because of the widespread use and comparative ease of evaluation of nonsystemic compounds, it is natural that as antibiotics became more available and less expensive they should be tested for nonsystemic action. Most of the recent papers have dealt with this aspect of disease control.

Cycloheximide (Actidione) has been used for most of these studies. This material is produced by *Streptomyces griseus*, which also produces streptomycin. Cycloheximide was until recently the only antifungal antibiotic that was available in amounts suitable for large scale experimental use in plant sprays and dusts. It was first reported to be effective for the control of the bean powdery mildew, a disease incited by a member of a group of fungi whose hyphae are primarily on the exterior parts of plants. Since then the powdery mildews of apple (*53*), onion (*67*), and dewberry (*83*) have been reported to be controlled in varying degrees. Yarwood (*79*) further studied the antibiotic for control of bean powdery mildew and found it to be the most potent material tried for the therapy of the disease. Ten times as much cycloheximide was needed for protection as for therapy. Cycloheximide has given good control of the leaf spot of cherry (*30, 52, 53, 58, 63*), a disease for which it has been reported to have eradicant properties (*30, 58, 63*), and has also been used successfully for the control of turf diseases (*70–72*) and mint rust (*60*). As a preharvest spray for the brown rot of peaches cycloheximide was found to be of doubtful value, especially since pronounced phytotoxic effects were produced (*63*). It was not effective for the control of turf snowmold (*55*), nor for the azalea blight (*27*), and it gave but slight control of the powdery mildew of raspberry (*26*).

Streptomycin has been used in plant sprays and dusts, primarily for the control of diseases incited by bacteria. For purposes of this presentation the antibiotic is considered to be nonsystemic; however, in view of certain reports (*3, 57*), it is likely that it may also act systemically, at least in some plants. Ark (*3*) found that under greenhouse conditions streptomycin completely controlled bacterial speck on tomato leaves when used as a protectant material, and that the antibiotic appeared to possess some eradicant properties. Three papers have been published on the successful field control of bacterial fire blight of apple or pear with streptomycin applications at the blossom stage (*2, 35, 59*). Crude streptomycin was used in one of these investigations (*2*). Against the frogeye disease of apple, incited by a fungus, the antibiotic was not effective (*35, 64*), nor did it control the bacterial blight of walnut (*3, 4*) or the powdery mildew of barley (*14*).

Other antibiotics have been stated to give varying degrees of disease control under greenhouse or field conditions. Reports of successful experiments on the control of fungal diseases include the use of thiolutin for the frogeye disease of apple (*35, 64*) and for late blight of potato (*7*); fungicin for the late blight of potato and for diseases incited by *Puccinia graminis tritici*, *Helminthosporium sativum*, and *H. teres* on grain (*10, 11*); Toximycin (*68*), Helixin (*48*), and partly purified Antimycin A-102 (*50*) for the early blight disease of tomato; and crude Candicidin for the bean powdery mildew (*49*). In field tests thiolutin was effective for the control of the bacterial fire blight disease of apple (*35, 59*); terramycin and copper Rimocidin did not control this disease (*35*). Mirzabekyan (*56*) has reported the eradicant action of antibiotics designated 15 and 15n against a bacterial disease of apricot and peach trees.

French workers have reported partial or complete control of a number of diseases, using the culture fluids of various microorganisms as plant sprays. Thus, in a single plant test, the complete control of the early blight disease on tomato was noted (*17*). Protectant and eradicant action were reported against the powdery mildews of barley and apple (*14*), and in field tests both types of action against the apple scab organism were produced by the culture fluids of a number of fungi (*15*).

Antibiotics for Systemic Use

In much of the work on systemic action, the antibiotic has been applied to the roots with the aim of influencing disease in the aerial parts of the plants. Thus, Brian *et al.* (*9*) have shown that when the antifungal antibiotic griseofulvin was applied to the solution in which lettuce plants were growing, infection by *Botrytis cinerea* was less than with plants grown in a solution without the antibiotic. In the same type of experiment, leaves of tomato plants were protected from attacks by the early blight fungus. Stubbs (*69*) has also experimented with this antibiotic and the early blight disease; the work of Brian *et al.* was confirmed, the order of disease control being 99 to 100%. Blanchard (*6*) used a root absorption method and the crown-gall bacterium. He reported that aureomycin gave nearly complete control of crown gall on the stems of tomato plants. Complete control of tomato *Fusarium* wilt was obtained by Gopalkrishnan and Jump (*28*), who used thiolutin. Roots of tomato plants were freed of soil, soaked in the antibiotic preparation, and inoculated with the pathogen. Plants were then repotted in sand. Control was partial when plants growing in soil were watered with the antibiotic; this was attributed to adsorption of the antibiotic by soil. The application of antibiotics to the soil for disease control on the aerial parts of plants has not been successful in other tests (*7, 57*).

Yoshi (*80–82*) has described interesting work with a *Cephalothecium* sp. in relation to the control of the rice blast disease, which is incited by a fungus. When rice seedling roots were immersed in the *Cephalothecium* culture filtrate, aerial parts of the plant were reported to show a degree of resistance to blast. Treatment with mycelium powder was also effective. Treatment of root or seed with cephalothecin, extracted from cultures of the organism, reduced germination and appressorium formation of spores of the pathogen in drops of water on plant leaves.

A somewhat different approach was used by Mitchell *et al.* (*57*), who reported the control of two bacterial diseases on bean leaves by means of stem applications. The antibiotic in a mixture of lanolin and a surface active agent was applied prior to the inoculation of the foliage. Streptomycin sulfate and dihydrostreptomycin sulfate provided complete control. Terramycin partly controlled both diseases, and Aureomycin partly controlled one disease. In a later work by this group (*84*) blight was controlled by means of streptomycin sulfate sprays; it seems likely that control in these experiments was due to systemic action, at least in part. A trunk injection method was used by Dunegan and Wilson (*22*), who reported that in a single peach tree, Terramycin greatly lessened leaf drop due to infections by *Xanthomonas pruni.* Phytotoxic effects were noted, however.

Other modes of application have been used. In tests made by Bonde (*7*), potato cuttings were placed in solutions of a number of antibiotics prior to inoculation with the late blight fungus. Disease was reduced in cuttings that had been treated with Terramycin. In similar tests, helixin did not control the early blight disease of tomato (*48*). Stubbs (*69*) has reported the application of griseofulvin to tomato leaves for the control of the early blight disease through systemic action.

Much interest attaches to studies of antibiotics for the control of the crown-gall disease, which is incited by a bacterium. This organism grows mainly within the hyperplastic galls it incites on various parts of many hosts. The successful use of Aureomycin in root absorption studies has already been noted. In the more recent work, Dye and Hutchinson (*24*) used penicillin for the treatment of marigold plants and found that the antibiotic did not prevent gall formation, nor were treated galls retarded or killed. Negative results were also reported with the culture fluids of organisms that produce streptothricin and actinomycin (*25*). In later work Dye (*23*) used streptomycin and the culture fluid of a streptomycin-producing organism. Galls were neither killed nor retarded, but if the materials were applied at inoculation time, the formation of galls was prevented or their numbers greatly reduced. Repert and Havas (*65*) have reported that penitalin was inhibitory to gall formation, and Darpoux and Faivre-Amiot (*14*) stated that galls treated with the culture fluid of a *Penicillium* species became completely necrotic. The influence of a number of antibiotics on crown galls on plant tissues grown in vitro has been studied by de Ropp. Streptomycin, and to a less extent penicillin G, were found to inhibit the initiation of galls on carrot tissue; streptomycin did not produce regression of galls already formed, although their growth was slowed (*19*). In subsequent publications it was stated that six unnamed antibiotics did not prevent the initiation of galls on chrysanthemum tissue (*20*), and that aureomycin did not seem to influence gall growth on carrot tissue, even though the growth of bacteria in the galls was reduced (*18*).

Pure or partly purified antibiotics have been tested for systemic effects on plant viruses. Beale and Jones (*5*) found that six antibiotics introduced into the plant by means of stem wicks did not inhibit the development of two viruses. On the other hand, Leben and Fulton (*47*) demonstrated local systemic action of streptothricin against two viruses and Terramycin against three viruses in detached leaf studies. Since the antibiotics did not influence infectivity of the viruses when tested in vitro, these writers suggested that inhibitory effects in vivo were due to action on the host. No systemic effects were demonstrated by seven other antibiotics.

In a consideration of this work on antibiotics for systemic use it is well to bear in mind the experience that has been gained with other types of systemic compounds that have been used for disease control. A number of these materials are not particularly potent when tested in vitro, even though they control disease when introduced into the plant. Among the antibiotics griseofulvin is a compound of this type; its major in vitro action is a curling of the germ tubes of some fungi. It has been suggested that these chemicals control disease by some means other than direct inhibition of the pathogen. The nature of this action is not known. One possibility is that the metabolism of the plant is altered and the alteration confers immunity; another is that the systemic material is changed into a more active toxicant within the plant. In any event, if this situation is found to hold generally, the problem of finding and developing new systemic materials will be complicated because the host must also be considered in all bioassay procedures. A discussion of these and other problems in relation to systemic action may be found in the work of Brian (*8*), Crowdy (*12*, *13*), Dimond *et al.* (*21*), Horsfall and Dimond (*38*, *39*), and Wain (*73*).

Antibiotics for Seed Treatment

The treatment of seed with chemicals for the control of disease is a common practice today, and a number of antibiotics have been used for this purpose. The aims of treatment are twofold: to protect seeds and seedlings from attack by plant pathogens in the soil, and to prevent infection by pathogens that may be carried on or in the seed. In this report seed treatment is dealt with separately as a matter of convenience, since in seed treatments both systemic and nonsystemic action of antibiotics have been demonstrated.

Most of the recent work has been with the fungicide cycloheximide. Wallen and Skolko (*75*) reported that the antibiotic gave good control of the deeply seated fungus *Ascochyta pisi* in pea seed, as determined by a Petri dish test. This result is in contrast to that reported earlier (*76*), but the conditions of the tests were not the same. Henry *et al.* (*34*) soaked oat and barley seed for 4 hours in a cycloheximide solution and obtained field control of the covered smuts of these grains. Tests with wheat bunt were also successful, although the seed was injured. In a later paper, workers at the same station reported obtaining control of bunt with cycloheximide by means of a 1-minute soaking period, or with dust treatments (*32*). Cycloheximide, for bunt control, and captan, for increasing seedling emergence, have been combined successfully in a dust treatment of wheat seed (*33*). The cycloheximide dust treatment was not effective for the control of bunt in the tests of Holton and Woo (*37*).

Streptomycin has been used for seed-treatment purposes, particularly for the control of bacterial diseases. Ark (*3*) reported that the soaking of cucumber seeds infected with the angular leaf spot bacterium in streptomycin solutions was an effective control practice. He likewise noted the control of tomato bacterial canker by the same means. Systemic action is indicated, since both of these pathogens are carried within the seed. In greenhouse tests bean blight, likewise incited by a bacterium within the seed, has also been reported to be controlled by a streptomycin soaking treatment (*36*, *66*), although the treatment was not satisfactory in the field (*67*). The antibiotic has also been claimed to have reduced the loose smut disease of barley, which is incited by a fungus that is carried within the embryo of the seed (*62*); other unspecified antibiotics were stated to be ineffective. Henry *et al.* (*34*) noted that streptomycin did not control wheat bunt and the covered smuts of barley and oats.

A number of other antibiotics have been used in seed-treatment tests. In laboratory experiments, antibiotic XG has been reported to control the *Ascochyta* fungus in pea seeds (*74*, *75*); gladiolic acid, viridin, humulon (from the hop plant), and gliotoxin did not give adequate control (*75*). Hildreth and Starr (*36*) have presented limited evidence of effectiveness of a number of antibiotics beside streptomycin in a seed steeping treatment for the control of bacterial bean blight. The antifungal antibiotic helixin B has been found to be effective for the control of certain *Helminthosporium* diseases of oats and barley, and for three covered smuts of small grain (*46*). This antibiotic was ineffective for the control of the *Helminthosporium* blight of oats if applied as a dust (*46*) or in a solvent other than ethyl alcohol (*45*); similar formulation problems for seed-treatment materials have not been encountered heretofore, as far as is known. Two related antibiotics from the Wisconsin laboratories, antimycin A-35 and antimycin A-102, have been shown to provide a degree of control for certain oat diseases (*45*, *50*). Presumably pure or partly pure antibiotics were used by Krasil'nikov (*44*) and Mirzabekyan (*56*), who reported the successful treatment of cottonseed for the control of the angular leaf spot disease. Culture fluids of microorganisms have been reported effective for disease control in seed treatment studies with *Sclerotinia libertiana* (*14*), *Pseudomonas tabaci* (*14*), and *Tilletia tritici* (*16*). On the other hand, seed treatments with the antibiotic PF did not protect cereal plants from a *Fusarium* disease (*40*), and fradicin was not effective for the control of the damping off of alfalfa (*29*).

Allied to the control of diseases incited by the soil-borne pathogens through the use of seed treatments is the practice of applying chemicals to the soil for the prevention of these diseases. Tests with antibiotics for this purpose have been reported. Gregory *et al.* (*29*) found that the damping off of alfalfa seedlings was prevented by adding cycloheximide solutions to soil containing damping-off pathogens; however, the antibiotic inhibited plant growth. In similar experiments, fradicin and two other antibiotic materials did not control the disease. Johansson (*40*) reported that antibiotic PF was not effective for the control of *Corticium solani*.

Other Considerations

For the sake of brevity two important aspects of the control of plant diseases with antibiotics have not been considered fully in the foregoing: phytotoxicity, and the concentrations necessary to provide disease control. Both aspects are related to two important general properties of antibiotics as a group—their selective action and their great potency. In the reports covered here, in other papers, and undoubtedly in unpublished work, the fact that antibiotics can be seriously harmful to plants when applied in amounts necessary for disease control is clear. This may be noted with cycloheximide and streptomycin, which have been investigated the most. However, not all plants are harmed by a particular antibiotic, and a few antibiotics do not appear to be harmful at all, at least in so far as they have been investigated. It seems possible, therefore, that among the antibiotics selective materials will be found that will control one or several diseases and at the same time have little or no effect on the plant or on other forms of life.

Table I. Concentrations of Antibiotics and Conventional Toxicants Used for Control of Certain Plant Diseases[a]

Disease	Antibiotic	Concentration Used for Disease Control, γ/Ml.: Antibiotic	Conventional material	Reference
Cherry leaf spot	Cycloheximide	2	8,400[b]	(*58*)
		1	9,900[b]	(*53*)
Fire blight of apple	Streptomycin sulfate	30	2,400[c]	(*35*)
	Thiolutin	120	2,400[c]	(*35*)
Fire blight of pear	Crude streptomycin	3.3 g./acre	2,724 g./acre[d]	(*2*)
Tomato early blight	Crude helixin	38	68,000[e]	[f]

[a] Results on basis of field tests except for helixin, which was tested in greenhouse.
[b] Bordeaux mixture.
[c] Parzate. Contains disodium ethylene bisdithiocarbamate.
[d] On basis of active material (copper sulfate).
[e] ED_{95} level, early blight greenhouse test.
[f] (*48*) for helixin. Conventional material was Bordeaux mixture, and results are given on the basis of copper sulfate (data from McCallan and Wellman, *57*).

With respect to the second property, the great potency of antibiotics, it may be said that the concentration of antibiotics required for disease control is usually no greater than for conventional materials, and in many instances it is considerably less. Some idea of the high level of activity of certain antibiotics may be gained from Table I; some substances are in the order of thousands of times more potent than conventional materials. This high activity has an important bearing on the economics of disease control, since even though antibiotics may be more expensive than conventional materials in terms of cost per gram, they may be more economical to use because of their greater activity. Other factors that bear on cost are the degree of purity needed for controlling plant disease and whether or not the fermentation that produces the antibiotic also produces other merchantable chemicals—e.g., antibiotics for use in medicine or as feed supplements.

Antibiotics, if they are to be of importance from a commercial standpoint in plant disease control, must compete with existing materials, many of which are inexpensive and effective. An ideal chemical should have many meritorious features beside the ability to prevent or cure one or preferably more diseases. These include freedom from toxicity to plants and animals, low cost and ready availability, ease and low cost of application, compatibility with other materials applied to the plant, and stability with time and to such weathering agents as light and the washing of rain. In recent publications McNew (*54*) and Harry (*37*) have discussed certain of these and other pertinent matters more fully. Information on these subjects for most antibiotics in relation to plant disease control is sparse indeed.

Significant progress has been made, however. The antibiotics that have been studied the most were not developed primarily for plant disease control. Several materials of promise are still in an early stage of study or are available in amounts too small for other than limited greenhouse or field experimentation. In view of these considerations, and because of the many exacting properties a successful compound must possess, extensive and well organized efforts may be required to find suitable new antibiotics or to test adequately the ones now at hand. Some idea of the magnitude of an undertaking of this sort is indicated by the effort given to the development of new fungicides. McNew (*54*) has estimated that it may require an investment of $200,000 to find and bring a new material to the stage where it may be offered to the sales department, and then it has no more than a 50% chance for success. From the business standpoint, the magnitude of the enterprise seems to be justified by the outstanding successes of some of the new organic fungicides. Furthermore, a broadly based program on antibiotics for use on plants may be expected to yield other types of compounds of possible agronomic or horticultural importance—for example, materials useful for controlling insects or for inhibiting or promoting the growth of plants.

Some time ago it was pointed out that the currently dominant philosophy of chemical control, the philosophy of protecting plants from attack by microorganisms by oft-repeated application of toxicants, leaves much to be desired (*41*). A different approach has been a direct attack on the pathogen at a vulnerable point of its life cycle through the use of eradicant toxicants (*41–43*). Systemic materials offer another approach; control is promoted from the inside of the plant rather than from the outside alone. Thus, it may be possible to prevent disease in all parts of the plant, particularly those actively growing aerial areas that may be left unprotected by conventional treatments during an infection period. Because of their selectivity and great potency, antibiotics as a class seem to offer unusual opportunities for finding systemically active chemicals for control of plant diseases.

Tremendous advances have been made in the past 75 years, and particularly in the past 15 years, in control of diseases by chemicals, but probably few plant pathologists believe that the apogee of chemical control has been reached. It is the feeling of the writers that great opportunities for further advances in this field lie ahead, and that antibiotics may well play an important role in these advances.

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SIDE EFFECTS OF CONTROL AGENTS

Effects of 2,4-D on Quality of Cotton As Determined by Alkali Centrifuge Value

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Information was needed as to the extent of damage to cotton fiber caused by direct contact of 2,4-D with field-grown plants. Field-grown Coker 100 Wilt cotton sprayed with the sodium salt of monohydrated 2,4-dichlorophenoxyacetic acid in concentrations of 5 through 500 p.p.m. acid equivalent had shown reduced yield of cotton lint. This cotton fiber when tested by the alkali centrifuge value method was found to have been damaged. Statistical analysis of the data showed the cotton fiber absorbed the alkali, essentially, in direct proportion to concentrations of 2,4-D from 5 through 50 p.p.m. regardless of the time of application, whether applied at time of first true leaves, first flowers, or first true leaves and again at time of first flowers. Relatively small amounts of 2,4-D may impair cotton quality severely, depending upon the stage of growth when field-grown plants come in contact with this herbicide. Therefore, 2,4-D should not be used near cotton.

Small amounts of 2,4-dichlorophenoxyacetic acid (2,4-D) applied to cotton grown in the field have been found to cause severe formative effects (*1*). It was considered important, therefore, to determine further the extent of damage to cotton fiber which may be caused by 2,4-D, so as to afford a better working knowledge of the probable extent of injury to cotton in contact with 2,4-D by direct application or by drift.

Field tests using Coker 100 Wilt cotton sprayed to runoff at two stages of growth with known concentrations of the sodium monohydrate salt of 2,4-D, were made in 1952 with the cooperation of the Virginia Tidewater Experiment Station, Holland, Va. The fiber harvested from this test was examined for quality by the alkali centrifuge value test.

It was found (*1*) that plants sprayed only at the time of first two true leaves (L stage) showed less severe response relative to number of flowers and squares, bolls set, and yield, than did plants sprayed twice (LF stage) or only at time of flowering (F stage). Formative responses to treatments appeared to be in direct proportion to concentration of the acid applied at any stage. The severity of response for plants treated in the first true leaf stage decreased in time and appeared only to delay the maturing of the plants. Plants twice sprayed or treated at the flowering stage showed more pronounced formative effects which were not mitigated in time. Yields responded to the major effects of concentration applied as well as the stage of plant growth when the plants were treated. Lint yields were drastically reduced by even 5 p.p.m. of 2,4-D acid, which caused a 60.2, 84.4, and 65.2% decrease compared with the untreated checks in the L, LF, and F stages, respectively. As the concentration of the acid was increased, lint yields were further reduced but at a slower rate. These decreases were found by analysis of variance of the data to be significant at the 1% level. Furthermore, plants treated twice (LF stages) produced no cotton when from 100 through 500 p.p.m. of 2,4-D acid were applied.

It was believed that this 2,4-D effect on lint yield could possibly be correlated with differences in fiber quality—length of fiber and thickness of wall, for example.

This paper presents an analysis of the