A LABORATORY COMPARISON OF THE PHYTOTOXICITY OF SEVERAL DDT FORMULATIONS, AND AN EVALUATION OF THE METHOD USED

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A LABORATORY COMPARISON OF THE PHYTOTOXICITY OF SEVERAL DDT FORMULATIONS, AND AN EVALUATION OF THE METHOD USED

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William D. Shea

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Ray Hutson
Major professor

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A LABORATORY COMPARISON OF THE PHYTOTOXICITY OF SEVERAL DDT FORMULATIONS, AND AN EVALUATION OF THE METHOD USED

By

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INTRODUCTION

Phytotoxicity of insecticidal chemicals has for many years been a problem to the entomologist. Many workers have reported that DDT emulsions of different manufacturers varied in their toxicity to plants. The injury was usually attributed to the DDT or the solvent used. Emulsifiers have received little or no recognition as agents in the phytotoxicity of agricultural sprays. Therefore, these tests were undertaken to determine the phytotoxicity of emulsifiers and their relation to the toxicity of DDT emulsions. Eighteen emulsifiers and eleven DDT emulsions were tested.

The test method used was reported recently by Casida and Allen (1951 & 1951a). This method has been given the name "Wisconsin test" in this paper. The Wisconsin test in many respects parallels methods used to identify plant hormones. Although methods used to determine plant growth regulators have been known to the plant physiologist for about forty years, the Wisconsin test is probably the first encounter with plant growth regulators for the entomologist. Therefore, this method was used to determine its possibilities and to evaluate it as a means of determining the phytotoxicity of chemicals by the entomologist.

LITERATURE REVIEW

A characteristic of DDT phytotoxicity is its variability. Species and varieties differ markedly in their sensitivity to this insecticide. For example, Hervey and Schroeder (1946) reported a difference between varieties of cucumber in their susceptibility to foliage injury from DDT. There was also a difference in response of some plants under different conditions and different plants under the same conditions.

Cullinan (1949) has noted that when DDT was applied to the soil or to the plant foliage of certain sensitive plants growth will be retarded without any other obvious symptoms. This insecticide has rendered the seeds of many plants more susceptible to invasion by pre and post-emergence damping-off organisms.

Lumsden and Smith (1948) observed that in ten to twelve days after kalanchoes were sprayed with DDT the symptoms of epinasty, leaf fall and necrosis became evident.

Chapman and Allen (1949) reported that DDT acts as a growth promoting substance. The experiments of these authors showed that as the concentration was reduced injury disappeared and plant stimulation occurred at a definite level for each species tested. There was also a greater stimulation when only the lower leaves of a plant were sprayed. Injured plants usually recovered if the growing tip had not been damaged. A difference was noted in the foliage symptoms of different plants sprayed with DDT formulations. Characteristic cucumber symptoms appear as a chlorosis of the leaves which advanced from the margin with the veins remaining green. The margins of the leaves are turned upward. Lower leaves are necrotic, stunted and distorted. In general, the plants have smaller leaves, fewer blossoms and shorter internodes. Beans have the veins clear and a general mottling and chlorotic condition which involves the entire leaf. The growth above the primary leaves is generally short compared with that of untreated plants. Tomatoes show a slight yellowing of the leaves. Potatoes have a dark green foliage. The above symptoms are usually displayed at concentrations of insecticide recommended for insect control.

Merrill (1949) found no marked interior alterations in the leaves of peach seedlings grown in soil containing two hundred pounds of technical grade DDT and seedlings which received two aerial applications of 0.125 percent technical grade DDT per acre. A chemical analysis showed that seedlings grown with a DDT residue of twenty five pounds per acre or more in the soil would have a lower carbohydrate and slightly higher nitrogen content then the untreated peach seedlings. The amount of dextrins and starch are reduced in peach seedlings treated with DDT sprays or grown in soils containing DDT residues.

Spray injury, nutritional excess and the deficiency symptoms and weather injury may be very similar. It is necessary to inspect an unsprayed plant or tree before the correct amount of injury may be determined. Foliage that has been injured by insects, disease, hail, wind or drought is more susceptible to spray injury than healthy foliage. Therefore, plants that are maintained in a healthy condition are injured less frequently by spray materials. Only a very few correlations of weather and DDT in respect to plant injury have been reported in the literature. A few of these observations are stated here briefly.

Dudley (1947) noted that the greatest amount of injury appeared in years having the greatest amount of rainfall. The injury was usually greatest when heavy rainfall followed the application of the insecticide. Other authors have noticed increased injury on wet foliage. Gunther et al. (1946) reported that DDT was not leached away by rainfall. Deposits persisted on the foliage forty days before fifty percent loss of the residue. It has been noted that tropical temperatures and humidities may decompose DDT comparatively rapidly.

Hot dry weather hastens the loss of DDT from foliage, possibly by raising its volatility to an appreciable extent. Magie (1947) observed that DDT injury to gladiolus occurs on warm sunny days.

Lindquist et al. (1946) reported that sunlight does not markedly decompose DDT. The insecticide was almost completely stable to ul

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stable to ultraviolet light when in the solid form; but in oil solution it was slightly decomposed.

The decomposition of DDT under certain weather conditions may be of significance in plant injury. Casida and Allen (1951b) have shown in their Wisconsin test that the impurities of the technical grade DDT and decomposition products of DDT were more toxic than the p,p'DDT. Of the impurities in the technical grade DDT, the inhibitory action of 2-(p-chlorophenyl)-1,1,1,trichloroethanol helps to explain the field observations of some authors. It is the most volatile and water soluble impurity of the technical grade DDT. This might explain injury to wet foliage since it would be present in the greatest concentration in water solution from the technical compound and its more rapid penetration in a gaseous state might explain the observations of Magie. Another possibility of the toxic action of DDT involves the degradation to the highly toxic 4,4,-dichlorodiphenylacetic acid (DDA). The delayed effect of DDT in some cases where applications were made over a period of time suggest that the toxic action may be due to metabolism. Casida and Allen state that DDA inhibits primarily by affecting membrane permeability. They also report that the hydogen-ion-concentration was critical in the growth responses of plants treated with DDT. An increasing toxicity with an increasing hydrogen-ion-concentration was noted.

Many other factors are important in the phytotoxicity of DDT. These factors for a given location remain relatively constant throughout the growing season and will not be considered in this paper. However, a ground dust, an impregnated dust, an emulsion, a solution a wetting agent or a solvent may be a new factor. The use of lime as reported by Cullinan (1949) increased the toxicity of DDT.

Lumsden and Smith (1948) tested various formulations of DDT on the kalanchoes. These tests indicated that the most severe injury resulted from emulsions, less from suspensions and least from dusts. The aerosol grade showed less injury than the technical grade. However, in the emulsions both grades produced equal injury.

Wester and Weigel (1949) have shown that the unknown wetting agent in a DDT wettable powder caused significant reduction in average plant weight of Triumph bush lima beans. This wetting agent also intensified plant injury. The wetting agent caused no significant injury by itself.

Wilson and Sleesman (1948) noted a difference in the toxicity of DDT formulations of different manufacturers. These authors have noted that when talc, clay, and bentonite when used as conditioners of DDT stunted in that order, but that the talc would have caused less injury if these materials had been applied alone. The oil-soluble form of DDT known as Deenol caused marked stunting of plants. This formulation also caused a marked reduction in the transpiration of potato and tom

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and tomato plants. Most insecticides have been found to depress rather than accelerate transpiration.

Substances readily soluble in water are more toxic than substances sparingly soluble in water especially if conditions favor a high rate of evaporation. With compounds of low vapor pressure the available evidence indicates that in aqueous sprays entry is confined to the epidermis and that the penetration is largely arrested once the spray droplets have dried out and the substance is deposited on the leaf (Blackman, 1952).

Emulsions penetrate more slowly into the leaf than pure oil applications and cause less injury. Quick breaking emulsions were usually more injurious since they leave a continuous oil film (Brown, 1952).

In general, formulators of insecticidal formulations do not make public the kind of surface-active agent used in their sprays. Therefore, the toxic effects of these compounds have not been reported. However, a few workers have reported how they affect the deposit of spray materials.

Ebeling (1939) has shown that both wetting and spreading are functions of the contact angle. The nature of the substratum has a great influence on the contact angle. Thus, leaves of different ages on the same plant and on different sides or portions of the same leave cause variations in contact angle of a given liquid.

Ben-Amotz and Hoskins (1938) found that the greatest deposits were obtained with the least stable emulsions. Brown and Hoskins (1936) found that as a general rule the more acid the system the greater the deposit.

Surface-active agents can be classified as non-ionic, anionic and catonic. Emulsifying agents, in general, are non-ionic. Sisley and Wood (1952) in their book "Encyclopedia of Surface-Active Agents" give the classification, properties and the application of many surface-active agents.

Casida and Allen (1951a,b) have reported two methods for evaluating insecticidal inhibition and stimulation. These tests were used in this paper for testing the emulsifiers and DDT formulations. Therefore, the following part of this review is concerned with the literature relating to the method used.

The Wisconsin test in many respects parallels methods used to identify plant hormones. Went (1937) has defined two of these tests. They are the Avena test and the split pea test. The Avena test is carried out by applying the material to be tested, dissolved in agar, to one side of a decapitated coleoptile of Avena sativa. This substance enters the coleoptile to which the agar is applied. In the presence of auxins growth is promoted giving a rise to a curvature which within limits is proportional to the concentration of active substance. Standard conditions have been defined and must be carefully followed.

The split pea test depends upon the curvature of stem sections of etiolated <u>Pisum</u> seedlings. Four-cm. sections which are split longitudinally down the center will curve towards one another in active solutions. The curvatures in this case are proportional, within limits, to the logarithm of the concentration of active substance. Went (1937) has summarized all the physiological details and the literature of both these tests in his book "Phytohormones".

One important difference between these two tests is that many substances active in the pea test are not active in the Avena test. There are many adaptations of these tests with the evaluations of activity in weight or elongation in length of etiolated or green plant sections.

Chemical and physical factors play an important part in the stability of indole-3-acetic acid (IAA). The Wisconsin test, apparently, is one of the first tests to use IAA in a nutrient solution to which other chemicals are added for the evaluation of their toxic properties to plants. Therefore, very little is known of the compatibility, reactions and responses of plants to IAA in the presence of many chemicals.

Burkholder and Johnston (1937) demonstrated the inactivation of growth substances by exposure to light. The ultra-violet region of the spectrum is very effective in the breakdown of IAA solutions. However, red light has no effect on IAA solutions.

Galston and Hand (1949) demonstrated that auxin-induced growth in length of sub-apical sections of etiolated pea stems was greatly inhibited by light. They report that periods of light as short as one minute or less are effective in causing marked inhibition of growth of etiolated pea sections. These authors report no significant difference of IAA in dark or illuminated pea seedlings. Therefore, they concluded that the disappearance of IAA from solution is not due to plant absorption. Experiments conducted with IAA solutions indicate that disappearance of IIA from solutions is dependent on the presence of sugar in the medium. The average rate of disappearance of IIA from illuminated solutions is almost double that of unilluminated solutions. Galston and Baker (1949) interpeted this inhibition in the terms of riboflavin sensitized photoinactivation of IAA. IAA is also destroyed in light in the presence of other inactivators which investigators are now studying.

The production of growth by etiolated cuttings deprived of food reserves in its seed requires carbohydrate. The sugar must be applied soon after the auxin treatment (Went, 1937). The kind of sugar is of considerable importance. The effect of sucrose in the presence of IAA is very interesting because of the conflicting reports in the literature. Christiansen and Thimann (1950) claimed that they could find no effect of sugar on the total growth extension. However, Galston and Hand (1949) observed a considerable increase in the total growth in two percent sucrose although higher concentrations reduced growth. Audus (1953) found that final lengths attained by sections in sucrose plus IAA were considerably in excess of those in IAA solutions.

One minute contact with IAA may cause great growth stimulation (Galston and Hand, 1949).

One of the most marked chemical properties of IAA is its sensitivity to oxidative destruction (Went, 1937). IAA is stable in alkaline solutions but not in acid solutions (Went, 1937). Avery et al. (1947) recommends that plant hormone solutions be stored at refrigeration temperatures and should not be used with lime.

Audus (1949) has reported the toxicity of very low concentrations of buffer salts to plants. Casida and Allen (1951b) reported that the hydogen-ion-centration did not significantly alter the growth of the plant in the range of pH 4.0 to 10.0. However, with the phosphate buffer (K_2HPO_4 plus KH_2PO_4) a change in the pH distinctly altered the plant growth due to a change in the potassium/phosphorus balance in the solution.

Transport of IAA is from the apical to basal end of the section, and not inversely (Went, 1937).

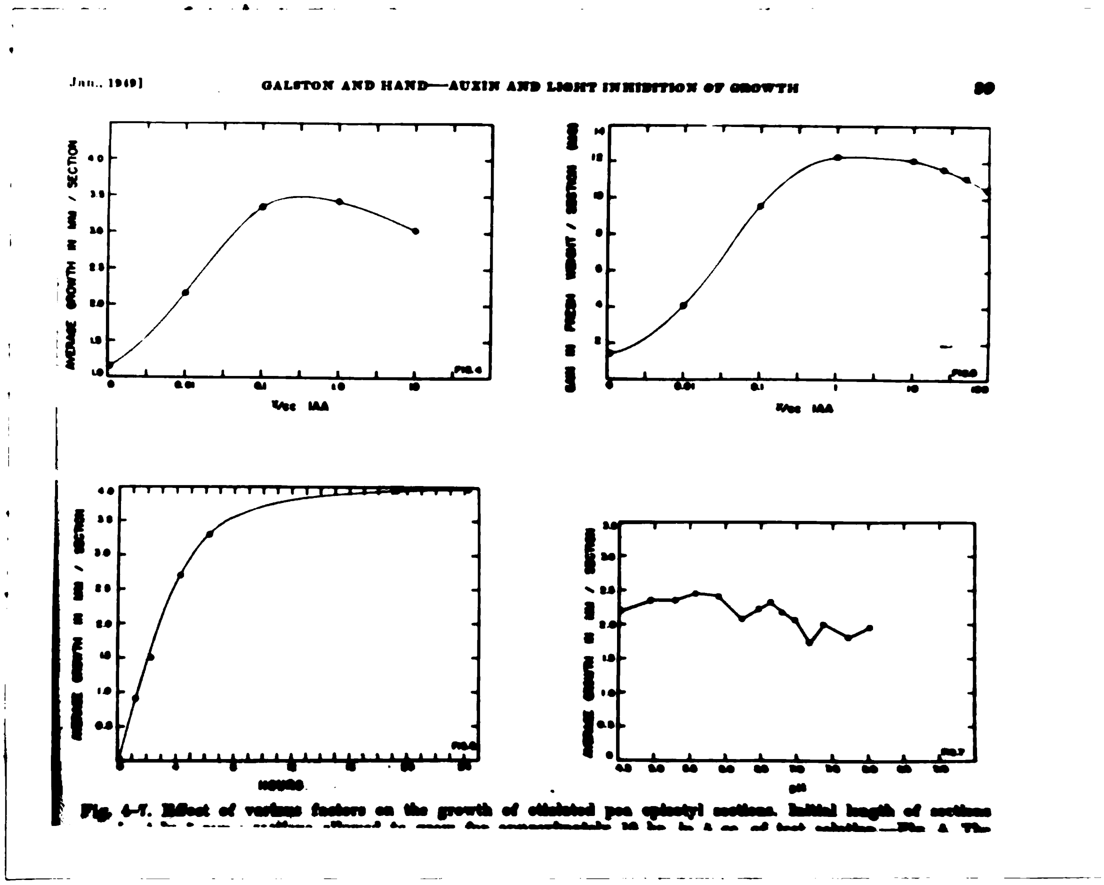
A marked affect upon the activity of growth regulating substances by wetting agents and by some hygroscopic substances that dissolve growth regulating chemicals has been observed (Zimmerman and Hitchcock, 1942). Mitchell and Hamner (1944) claim that polyethylene glycols serve as solvents and wetting agents and tend to keep the growth-modifying substance in close contact with the surface of the plant.

Mitchell (1949) states that the uptake of auxins by plants was greatly influenced by such factors as age of the tissues, temperature, light and the presence of surface-active substances which tend to increase the rate and extend the period of absorption.

Hildebrandt (1951) summarized the effects of growth regulating substances on plant tissue cultures. He concluded that the tissue could produce roots, stems and leaves in high concentrations. In low concentrations growth regulating substances favored cambium development and cell division while still higher concentrations stopped cell division and favored cell enlargement or stopped growth completely. deRopp (1947) observed disorganized growth in fragments of sunflower stem tissue cultured on agar containing 1 mg. per liter of IAA.

The six graphs which follow illustrate the effect of various factors on the growth of etiolated epicotyl sections. The steep slope of the growth curve in time, temperature and concentration of IAA shows a very sensitive response of plant sections to a small change in the variable.

FIG. I. THE EFFECT OF VARIOUS FACTORS ON THE GROWTH OF ETIOLATED PEA EPICOTYL SECTIONS[1]



Composition of solutions.

Figures 4-5. IAA in distilled water.

Figure 6. One microgram of IAA/cc. in distilled water.

Figure 7. One microgram of IAA/cc. and a KH_2PO_4 - Na_2HPO_4 buffer.

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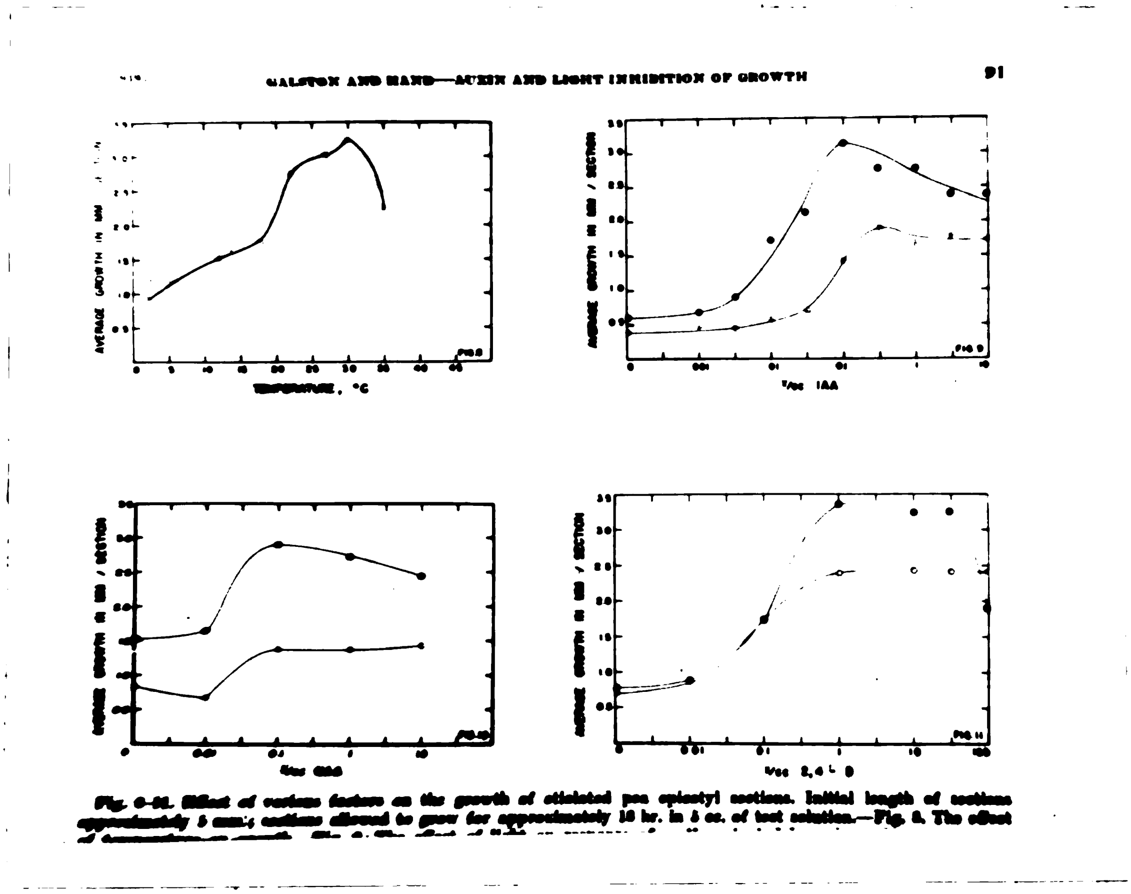
1 Arthur W. Galston and Margery E. Hand, "Studies on the physiology of light action. 1. Auxin and the light inhibition of growth, American Journal of Botany 36, p. 89.

FIG. II. THE EFFECT OF VARIOUS FACTORS ON THE GROWTH OF ETIOLATED EPICOTYL SECTIONS[2]



Composition of solutions.

Figure 8. One microgram of IAA/cc., 2 per cent sucrose and a pH 6.1 phosphate buffer.

Figure 9. Two per cent sucrose, 6.1 phosphate buffer and IAA as indicated. The solid dots = dark cultures; open dots = light grown cultures.

Figure 10 - 11. As indicated.

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[2] Ibid., p. 91.

APPARATUS AND METHODOLOGY

The experiment was carried out in the entomology darkroom. However, there was not enough space in the darkroom for the incubator so the seeds had to be transported in covered boxes to another room were they were placed in the incubator.

A standard method for mixing and applying the toxicant solution was devised. This was necessary in order to eliminate any variables that might enter into the mixing or spraying of the petri dishes.

Apparatus

The apparatus consisted of a spray tank, an electrical stirrer, a 100 ml. graduate and a number of eight ml. graduates. The apparatus was assembled on a ring stand as shown in figure 7. A black cloth was placed over the spray tank when in operation to decrease the exposure of the toxicant solution to the yellow safe-light. A yellow light is safe for indole-3-acetic acid solutions (Avery et al., 1947).

All handling of the nutrient solution prior to its entry into the spray tank was in amber glassware.

The spray tank consisted of a modified beaker with two double stopcock outlets on the bottom. To standardize the spray tank the blade of the stirrer was placed two cms. above the bottom of the tank.

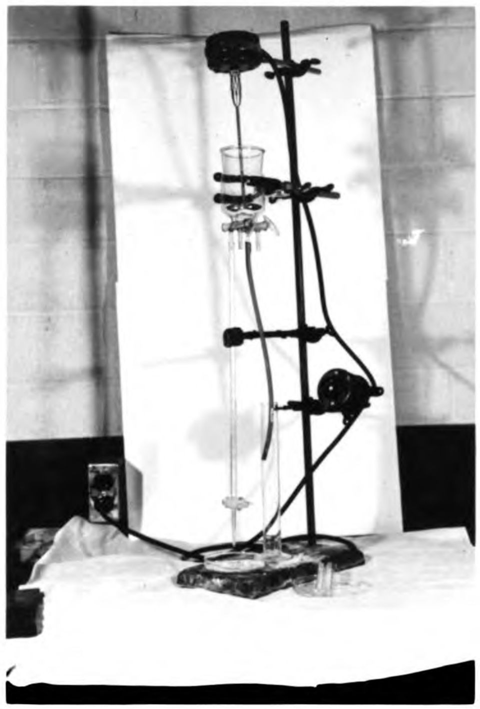


FIG. III. APPARATUS.

The purpose of each piece of the apparatus is explained in the test precedure.

Nutrient Solution

The nutrient solution consisted of one-half milligram of indole-3-acetic acid and ten grams of sucrose diluted to one liter with distilled water. This solution was buffered to a pH of six with M/40 potassium phosphate buffer. For formulation, a given volume of each stock solution was added to a volumetric flask (see Table 1). Ten grams of the crystalline sucrose was then added and the resulting solution diluted to one liter with distilled water. This nutrient solution was prepared immediately before use.

TABLE 1

COMPOSITION OF STOCK SOLUTIONS

Stock Solutions	IAA	K_2HPO	KH_2PO
Composition	50 cc. of absolute alcohol 50 mg. of IAA enough distilled H_2O to make 1 liter	40.930 g. per liter	61.648 g. per liter
CC./liter of nutrient solution	1 cc.	10 cc.	50 cc.
grams/liter	.5 mg.	.409 g.	3.082 g.

The indole-3-acetic acid stock solution decomposed in a week or two. Therefore, a new stock solution of the plant hormone had to be made weekly. A brownish tint to the solution indicated that it was inactive.

Water from stills containing copper should not be used in preparing the nutrient solution. The presence of copper was found to retard the growth of plants in this experiment.

Test Procedure

Chemicals tested are listed in Table 2 and the formulations tested are listed in Table 4. The DDT used was a technical grade (special grind) which was manufactured by the Michigan Chemical Corporation of Saint Louis, Michigan. The xylene was a chemically pure grade.

All materials were dissolved or dispersed in the nutrient solution at the following rates given as a percentage of the total weight of the solution or mixture. For the surface-active agents alone, the rates used were 0.16%, 0.08%, 0.04% and 0.02%. The DDT formulations were applied at the following percentages of the total weight: 0.9%, 0.45%, 0.22% and 0.11%. The DDT applications are equal to about two pounds, one pound, one-half pound and one-quarter pound of DDT per one hundred gallons of water. The test materials were mixed and applied by the following steps:

1. A known weight of the test material was added to the spray tank and then diluted with the nutrient solution to the proper concentration of the toxicant. (Specific gravities were obtained for all liquid materials and a known volume was added to the spray tank.)

2. The solution was then mixed with the electrical stirrer at a standard rate for two minutes.

3. The toxicant solution was than drawn off at the bottom until only a hundred and fifteen ml. of the toxicant remained in the spray tank. The solution that was drawn off went into the 100-ml. graduate for measurement. (Since xylene type emulsions tend to be top creamers it was necessary to remove about one-half the sample for the test.)

4. Then five ml. of the toxicant solution was drawn off and added to a petri dish. This procedure was repeated for three petri dishes.

5. After all the petri dishes for one concentration were plated with the toxicant solution 100 ml. of the toxicant solution remained in the tank.

6. One hundred ml. of the nutrient solution was then added to the tank. (The one hundred ml. was previously measured and placed in an amber flask.)

7. Step two was repeated. Then eighty-five ml. of the toxicant was drawn off into the 100 ml. graduate.

8. Three petri dishes were then plated with five ml. of the toxicant solution. This concentration was one-half the first concentration.

9. Steps six, seven and eight were repeated until the desired number of concentrations were obtained.

Cucumber seeds of the National Pickling variety from a standard lot were immersed in water for one hour then germinated between wet paper towels in covered petri dishes for twenty-four hours. After the incubation period seeds which had sprouted one or two ml. were selected for treatment in the darkroom under a yellow safe-light.

Fifteen seeds were placed in each petri dish and three petri dishes were used for each concentration. The petri dishes with a filter paper on the bottom were previously treated with toxicant solution or emulsion.

The seeds in covered petri dishes were then incubated at twenty-six degrees centigrade for thirty-six hours. After the incubation period the seeds were removed from the incubator and placed in the refrigerator at four degrees centigrade until measured. All seeds were measured within four days of treatment.

The evaluations of the toxic action was based on inhibition of growth in length and in weight. The entire seedling was measured from the tip of the root to the point of attachment of the cotyledons. The weights were based on the wet weight of the roots when cut off at the cotyledons.

Evaluations of toxicity were made by the phytotoxic index. The formula for this index is:

$$\frac{(\text{ control } - \text{ treatment })}{\text{control}} \times 100.$$

Although no evaluations of the test materials on the Kentucky Wonder pole bean are made in this report the method was tried and is treated in the discussion of the Wisconsin test. The procedure for this method follows.

A uniform standard lot of bean seeds were immersed in water for one hour and planted in moist vermiculite in darkness. The plants were grown at room temperature. Seven-day-old plants from which the epicotyl had not yet emerged and which ranged from ten to twenty cm. were selected for testing. A twenty-mm. section was removed from the hypocotyl of each plant beginning at a point one cm. below the node at which the cotyledons were attached. The cutter consisted of two rows of razor blades mounted twenty mm. apart on a handle. The handle was attached by a hinge to a cutting board. The plants were placed on this board and the handle was moved down to cut the stems.

The stem sections were placed on a watch glass with one end towards the center and the other towards the rim. Fifteen stems were placed on each watch glass. The watch glasses were than placed in the petri dishes. At this point the toxicant solution or emulsion was applied to the center of the watch glass. The petri dishes were than placed in the incubator and the sections allowed to grow for thirty-six hours and then measured by the shadow graphs.

The nutrient solution and the method of mixture was the same for both tests.

Materials and Formulations

TABLE 2

DDT EMULSIFIABLE CONCENTRATES
FORMULATED AND TESTED

Emulsifier	Percent of concentrate		
	% DDT	Xylene	% emulsifier
Aerosol OT	25	72	3
Emcol H-77	25	72	3
Santomerse D	25	73	2
Areskap	25	71	4
Polyethylene Glycol 400	25	71	4
Toximul 300*	25	71	4
Toximul 400*	25	69	6
Triton X-100*	25	72	4
Triton X-150 plus Triton X-160*	25	71	2 1
Triton X-155*	25	70	4
Triton X-155 plus Triton B-1956	25	70	2 3

*Formulated as recommended by the manufacturer.

TABLE 3

COMPOSITION, SOURCE AND TYPE OF EMULSIFIER

Emulsifier	Chemical Composition	Company	Type
Aerosol OT	sodium dioctyl sulfosuccinate	American Cyanamid Co.	(1)
BPE	....	American Cyanamid Co.	
Emcol H-77	A blend of polyalcohol carboxylic esters and sulfonated oils	Emulsol Corp.	
Santomerse D	100% alkyl aryl sodium sulfonate	Monsanto Chem. Co.	(1)
Areskap 50	monobutyl phenylphenol sodium monosulfonate	Monsanto Chem. Co.	(1)
Polyethylene Glycol 400 (MONO) Laurate	as indicated by name	Glyco Products Co.	(4)
S-1132	....	Glyco Products Co.	
S-1207	....	Glyco Products Co.	
Toximul 300	....	Ninol Laboratories	(2)
Toximul 400	....	Ninol Laboratories	(2)
Triton X-100	alkyl aryl polyether alcohol	Rohm & Haas Co.	(3)
Triton X-150	alkyl aryl polyether alcohols with organic sulfonates	Rohm & Haas Co.	

TABLE 3 cont.

Emulsifier	Chemical Composition	Company	Type
Triton X-155	alkyl aryl polyether alcohol	Rohm & Haas	(3)
Triton X-160	alkyl aryl polyether alcohol with organic sulfonates	Rohm & Haas	
Triton X-177	alkyl aryl polyether alcohol and a modified phthalic glycerol alkyd resin with emulsion stabilizer, corrosion inhibitor and a foam reducer	Rohm & Haas	(3)
Triton X-188	alkyl aryl polyether alcohols with an emulsion stabilizer	Rohm & Haas	(3)
Triton B-1956	77% of a modified phthalic alkyd resin in ethylene dichloride	Rohm & Haas	(4)
Du Pont	contains sodium oleyl sulfate	E. I. Du Pont De Nemours Co.	(2)

(1) anionic and water soluble
(2) anionic and water insoluble
(3) non-ionic and water soluble
(4) non-ionic and water insoluble

RESULTS

The graphs and pictures in this section illustrate the effect of various emulsifiers and DDT formulations on cucumber plants. The abbreviations used in this section are P. I. for the phytotoxic index and G. U. for growth units. The control for the growth units is taken as one hundred percent and the treated plants as a percent of the control.

The concentration of toxicant is given as a percentage of the total weight of solution or mixture.

FIG. IV. THE PHYTOTOXICITY OF EMULSIFIERS TO CUCUMBER PLANTS

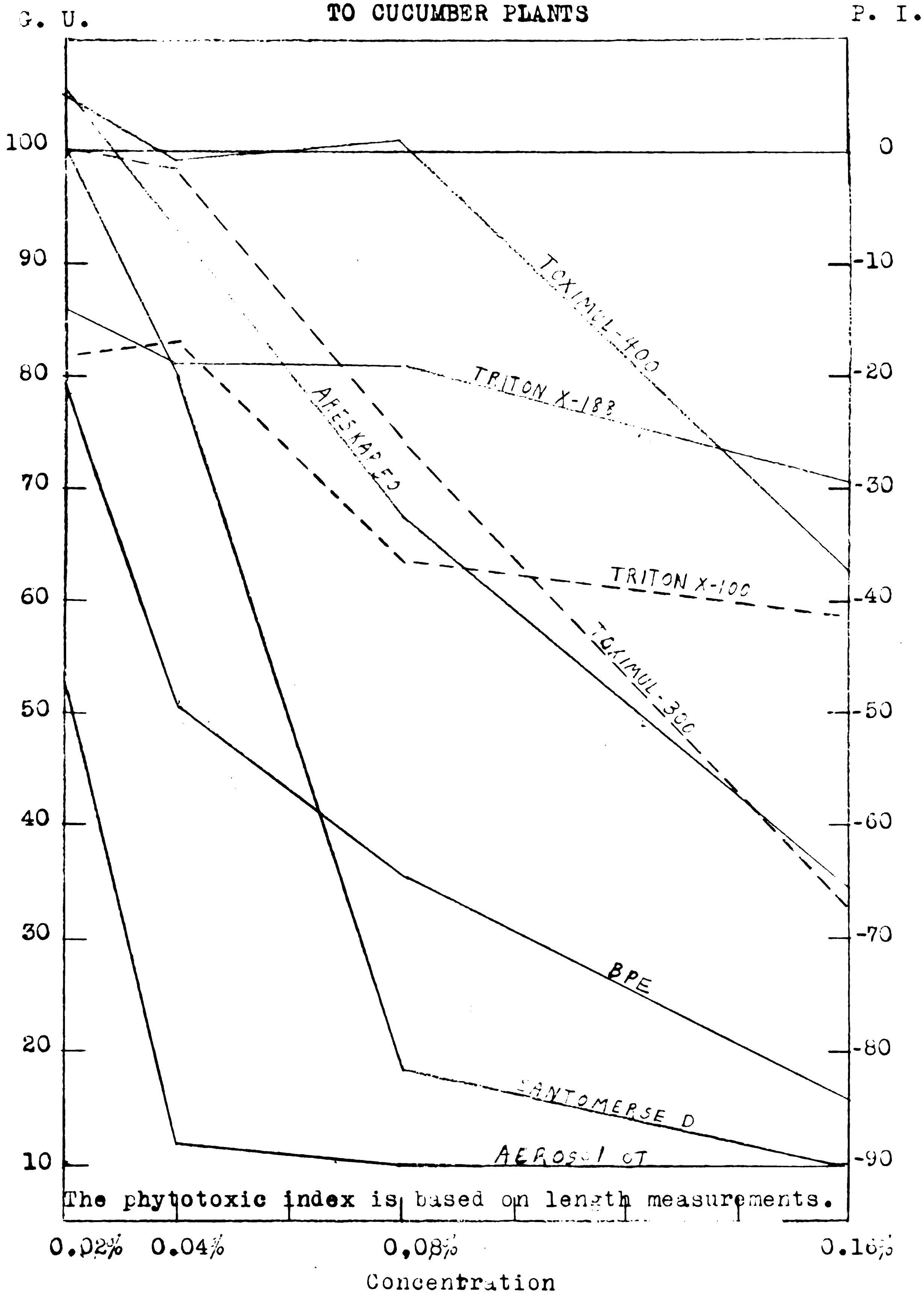


FIG. V. THE PHYTOTOXICITY OF EMULSIFIERS
TO CUCUMBER PLANTS

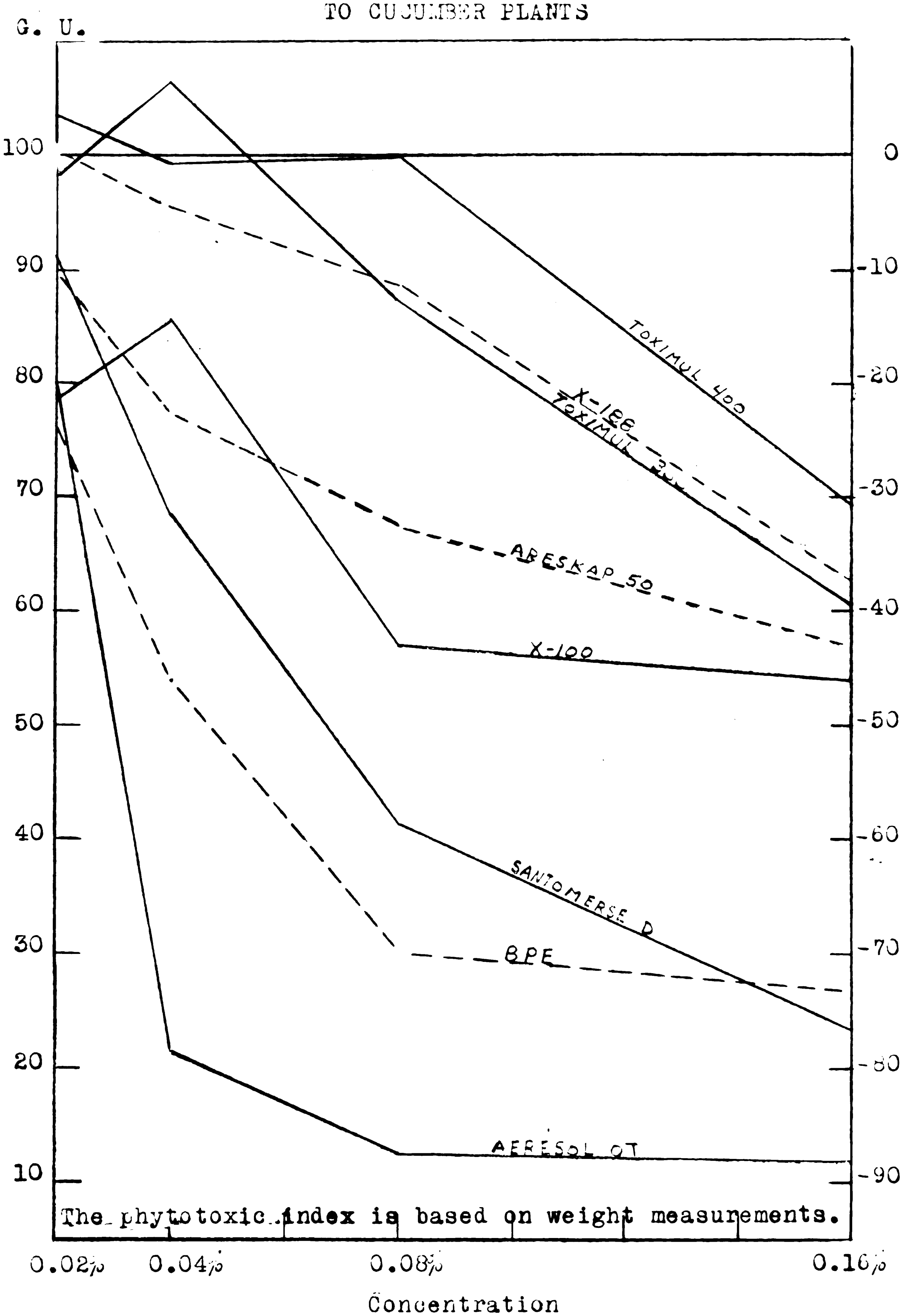


FIG. VI. THE PHYTOTOXICITY OF EMULSIFIERS TO CUCUMBER PLANTS

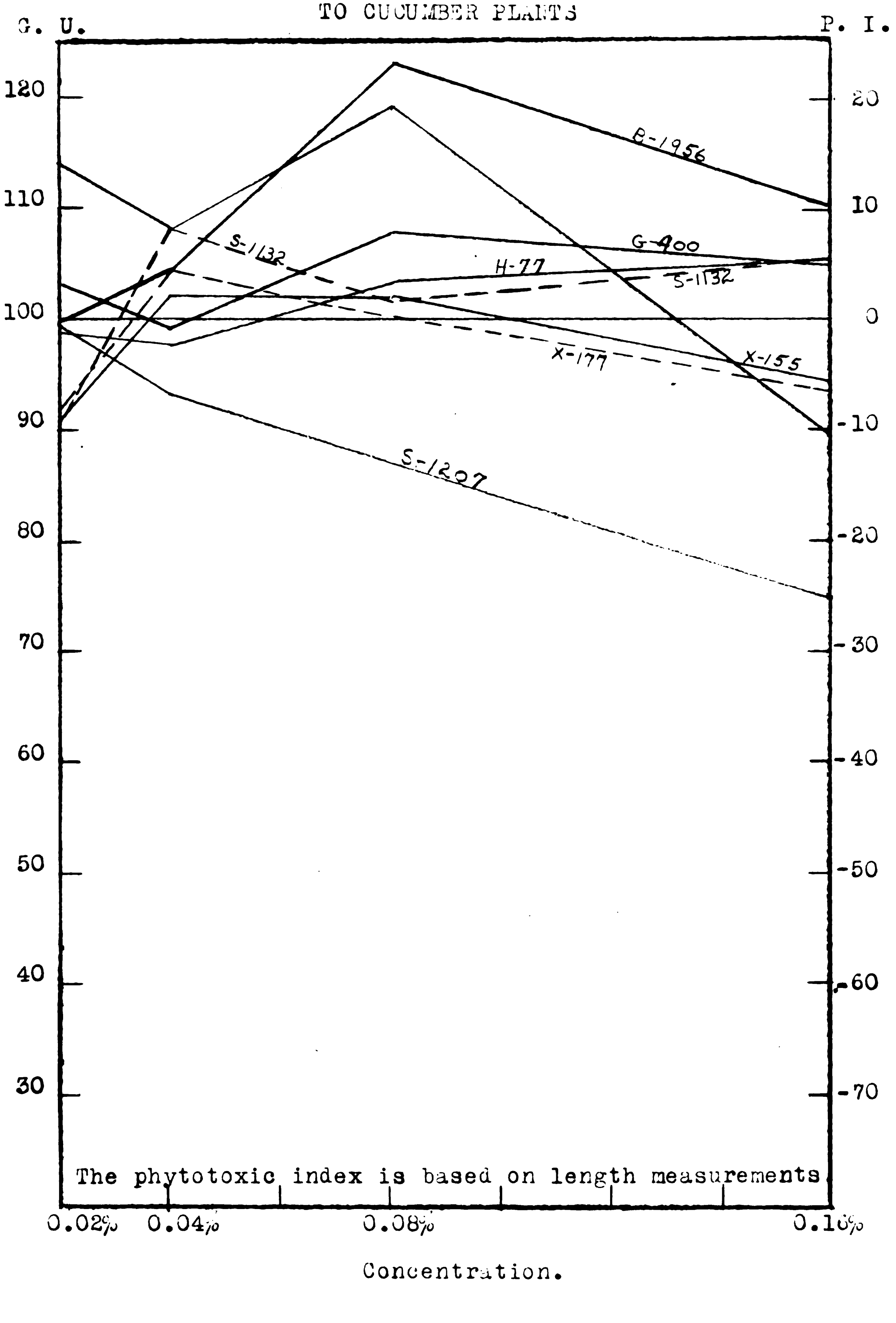


FIG. VII. THE PHYTOTOXICITY OF EMULSIFIERS TO CUCUMBER PLANTS

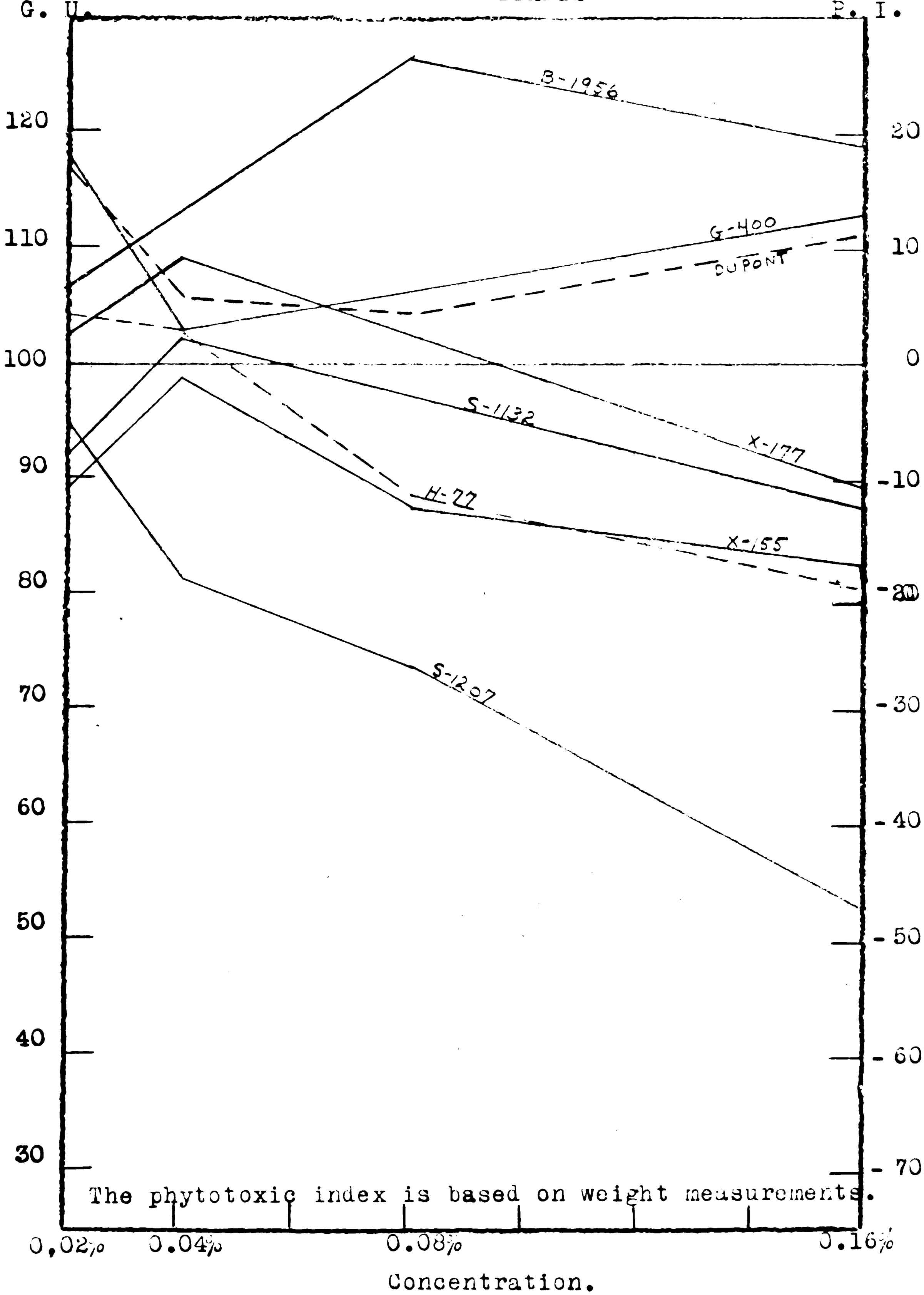


FIG. VIII. THE PHYTOTOXICITY OF DDT FORMULATIONS TO CUCUMBER PLANTS

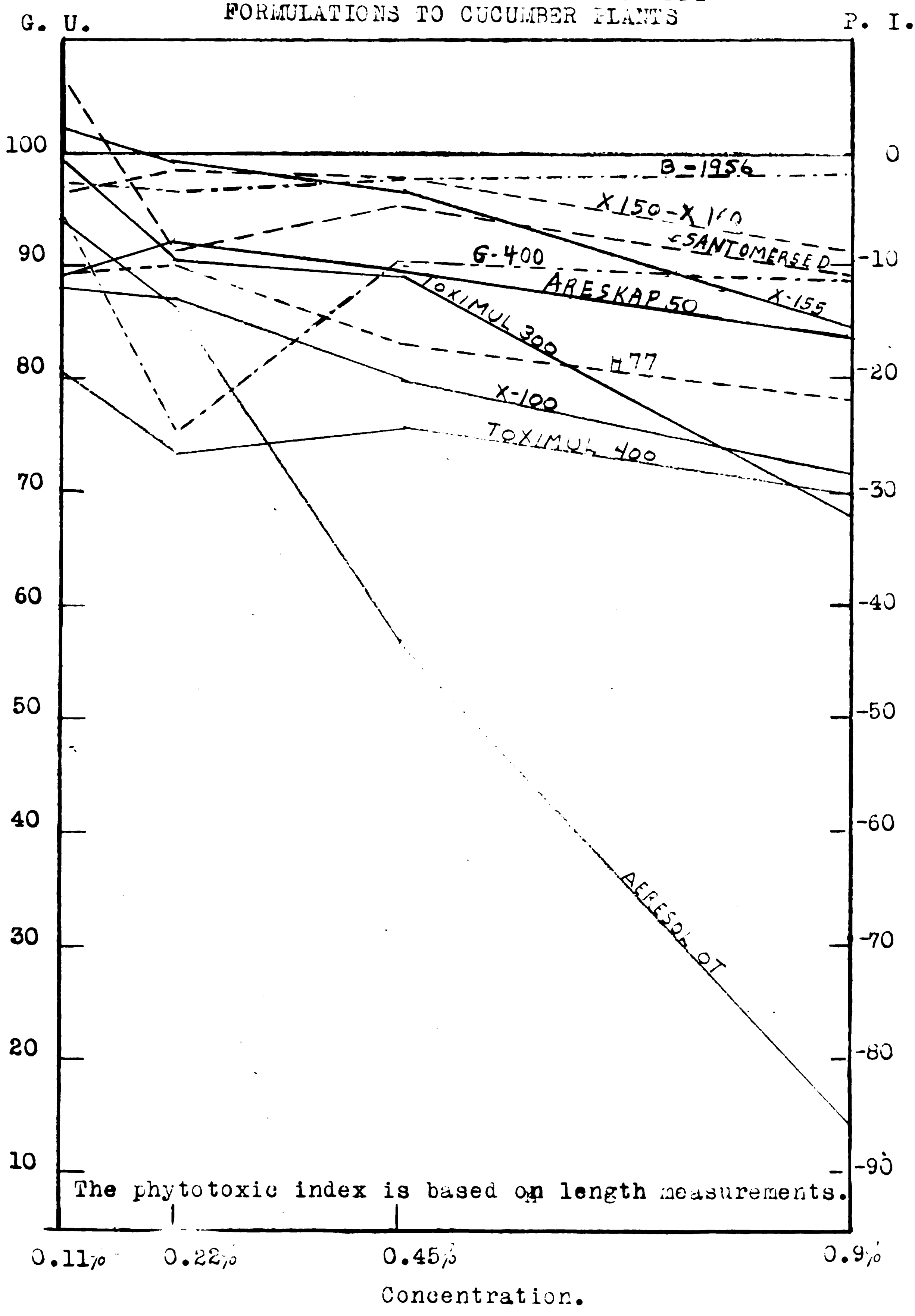


FIG. IX. THE PHYTOTOXICITY OF DDT FORMULATIONS TO CUCUMBER PLANTS

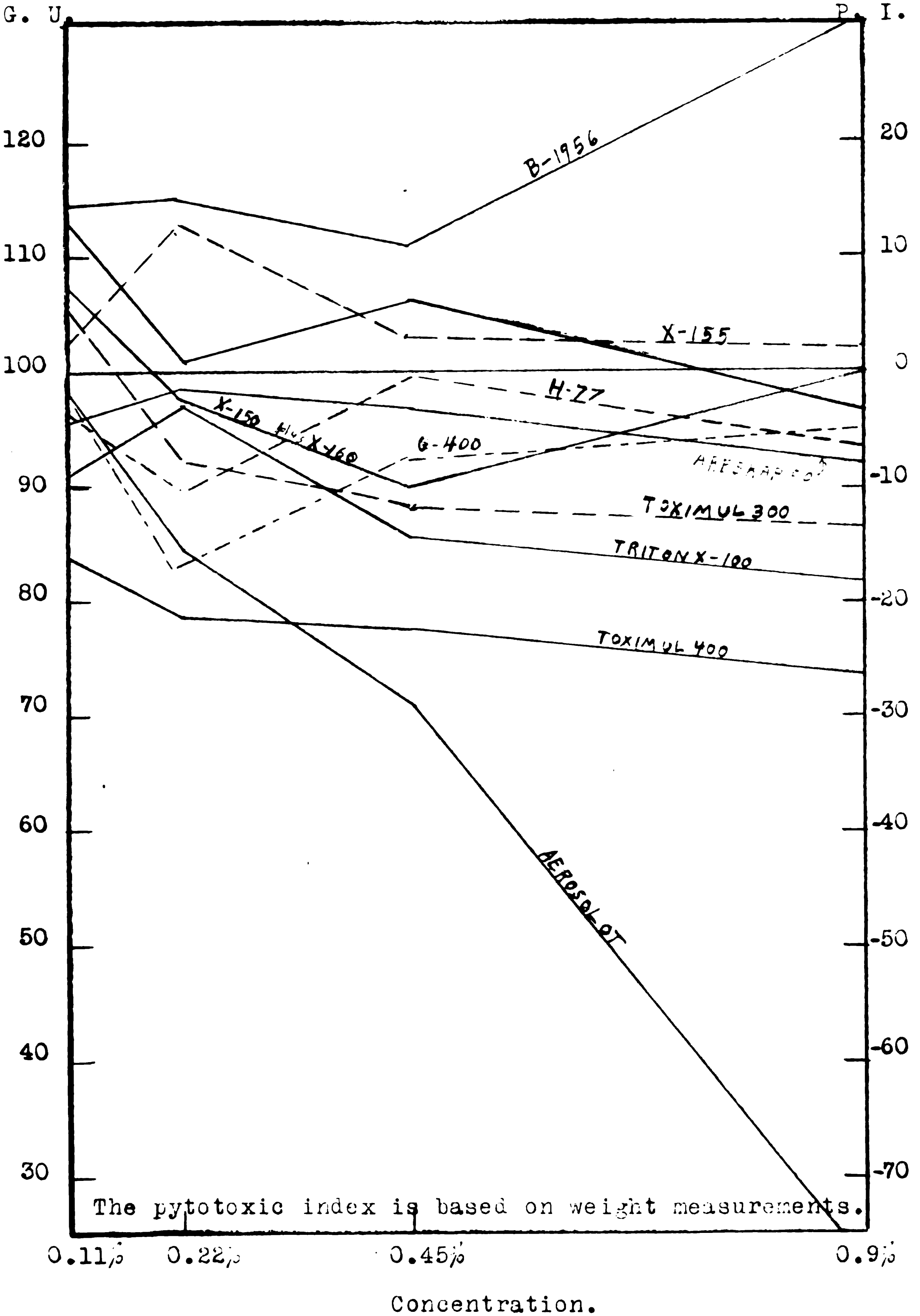


FIG. X. TOXIMUL 400.

Per cent of emulsifier in nutrient solution was .08 per cent.

FIG. XI. TOXIMUL 400.

Per cent of emulsifier in nutrient solution was .08 per cent.

FIG. XII. DDT 25%, XYLENE 71% AND TRITON X- 100.

FIG. XIII. DDT 25%, XYLENE 71% AND TRITON X-100.

Per cent of concentrate in nutrient solution was 0.9 per cent.

FIG. XIV. AEROSOL OT.

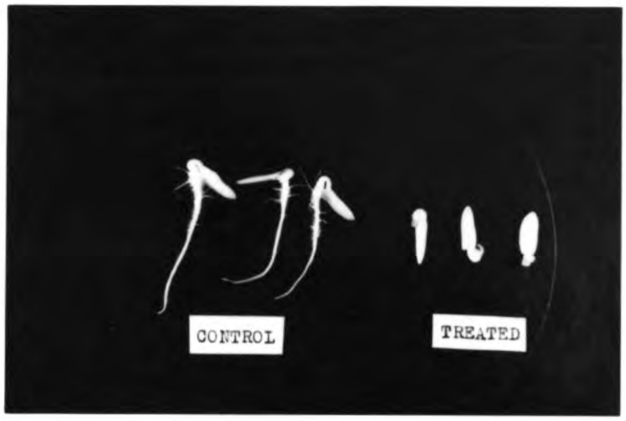
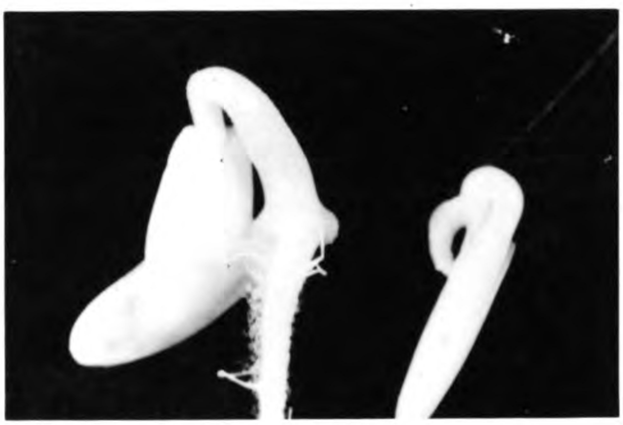


FIG. XV. AEROSOL OT.



Per cent of emulsifier in nutrient solution was 0.16 per cent.

DISCUSSION

Emulsifiers

The emulsifiers were tested separately to determine their specific toxicity to the test plant. As indicated by the summary graphs a wide range of toxicity was found. Aerosol OT and BPE of the American Cyanamid Company were found to be the most toxic materials tested. However, they were not the most toxic emulsifier at every concentration. Santomerse D was the most toxic material at the 0.9% concentration, second in toxicity at the 0.45% concentration, third at the 0.22% concentration and at the lowest concentration non-toxic.

As indicated above, the concentration of the emulsifier is critical in determining the degree of toxicity of a material in relation to the other materials tested. This is due to a difference in the slopes of the toxicity curves of the different chemicals tested. The slope of the toxicity curve was not the same between each concentration but tended to decrease as the concentration increased.

When grouped according to their type and water solubility the anionic emulsifiers were in general more toxic. For a given type of emulsifier the water soluble compounds were found to be the more toxic. Among the water-insoluble chemicals the water-miscible chemicals were most toxic. The four groups

of emulsifiers are given below in the order of their general phytotoxicity rating. The rating is:

over 49.5%.......very toxic
over 25.5%.......toxic
over 9.5%.......slightly toxic
under 9.5%.......non toxic.

For the 0.16% concentration the rating is as follows:

1. Anionic-water-soluble group.......very toxic
2. Anionic-water-insoluble group.....toxic
3. Non-ionic-water-soluble group.....slightly toxic
4. Non-ionic-water-insoluble group...non toxic.

The groups tended to have a lower phytotoxicity rating with a decrease in concentration. The anionic-water-soluble group was very toxic at the 0.08% concentration, toxic at the 0.04% concentration and non toxic at the 0.02% concentration. However, one member of this group, Aerosol OT, could be considered very toxic at every concentration tested. The anionic-water-insoluble group was slightly toxic at the 0.08% concentration and non-toxic at the two lower concentrations. Grasselli Spreader-Sticker, an anionic water insoluble material, was slightly toxic at the 0.16% concentration and non-toxic at the other concentrations tested.

The non-ionic water-soluble group was slightly toxic at all concentrations tested. Several of the chemicals in this group tended to be relatively non-toxic at the lower concentrations. The non-ionic water-insoluble compounds were non-toxic at all concentrations tested. The stimulation in growth might be explained by the increased wetting and the longer contact of IAA with plant surfaces.

A wide range of toxicity was found for chemicals within the same group. Considerable overlapping occurred between the anionic water-insoluble group and the non-ionic water-soluble group. This was due to the very low toxicity of Grasselli Spreader-Sticker.

The relative phytotoxicity of the four groups is based on the emulsifiers actually tested. It is possible that tests of additional emulsifiers of the four groups could alter the ratings given in this paper.

DDT Formulations

As indicated by the graphs of the results a wide range of toxicity was found. The DDT formulations containing anionic emulsifiers were usually more toxic then the formulations containing non-ionic emulsifiers. The toxicity of the formulations at the lower concentrations depended on the stability of the emulsion, a stable emulsion giving the maximum amount of toxicant on the petri dish.

The Aerosol OT formulation was found to be the most toxic emulsion tested at the highest concentration. It was slightly toxic at the 0.45% and 0.22% concentrations and non-toxic at the lowest concentration.

Toximul 400 was second in toxicity at the highest concentration but most toxic at the two lowest concentrations. This formulation could be considered toxic to slightly toxic over the concentration range tested. It contained six percent emulsifier which was twice the amount used in the Aerosol OT formulation. Both the above emulsifiers were of the anionic type.

The most toxic non-ionic emulsifier was Triton X-100. The Triton X-100 formulation rates third in toxicity. Triton X-100 and Toximul 400 were the only emulsions that were toxic in both weight and length relationships at all concentrations tested.

Plants treated with Emcol H-77 and Areskap 50 were inhibited by ten percent or more in length only at all concentrations. The weights of plants treated with Emcol H-77 and Areskap 50 were not altered significantly.

Generally the treated plants were found to have a higher phytotoxicity index in length evaluations. However, there were exceptions. The Triton X-155 plus Triton B-1956 and the Triton X-155 emulsions showed a higher phytotoxic indices in weight. Plants treated with Aerosol OT and Emcol H-77 followed the same pattern at the 0.22% concentration.

The wetting ability of the emulsifier or the DDT formulation could influence the weight evaluations to a great extent.

Evaluation of Method

The fundamental purpose of phytotoxicity studies is to determine the effect of agricultural sprays on host plants. This research is divided into two types - field studies and laboratory investigations. The objective of the laboratory screen test should be to provide a sound basis for field studies. Therefore, there should be no sharp differences between the two types of research and the two should be complementary. The absence of chlorophyll and photosynthesis in the test method and the absence of indole-3-acetic acid in most field tests provides a sharp contrast between this laboratory test and the field test.

Reactions between the nutrient solution and the toxicant provide a large number of unknown and uncontrollable factors which influence in various ways and degrees the results of the experiment. Both antagonisms and synergisms are known for indole-3-acetic acid in the split-pea test and the pea elongation test. Thus conclusions arrived at in this experiment are lacking in accuracy and may be entirely wrong.

The test is a very sensitive one. The presence of light other than those indicated in the literature review inactivates the nutrient solution. The tolerance for many variables is very low. For instance, a difference of a few degrees in temperature may alter the growth of the plants to a great extent. Also the length of time that a plant is exposed to the indole-3-acetic acid will determine the amount of growth resulting from a given experiment. This factor varies greatly with each test and each concentration within a test. Therefore, the author believes that all plant material should be treated for a given length of time in a common growth-promoting solution and then transferred to the toxicant solution. This would eliminate any inactivation of the indole-3-acetic acid and prevent many antagonisms and synergisms possible under the test method used.

The results cannot be extended to any conditions other than those of the test. The growth relationships were found to differ from those reported by Wilson and Sleesman (1948) for field tests of forty varieties of cucumbers. They found that the stunting of the plants progressed in a straight line relationship with each successive doubling of the quantity of the toxicant. Only one material showed a straight line relationship by the test method.

Another problem is the standardization of plant material. A very careful selection of plant material is necessary to lower the variability of plant growth results. Several test concentrations were picked at random and a standard deviation was calculated. The standard deviation averaged about twenty percent of the mean.

The fact that indole-3-acetic acid solution may under certain conditions produce morphological changes, extensive growth or inhibition of growth limits this method as a test for the evaluation of chemicals for agricultural sprays.

Oxidizing agents and lime cannot be used as test materials in this test for they tend to inactivate the auxin.

For the aerial test growth results depend largely on the length of time the plant hormone remains active in the solution. A few seconds difference in the life of the hormone will cause great differences in plant growth. Galston and Hand (1949) report that one minute contact with IAA will cause great growth stimulation.

The transportability of the test chemical within the plant may alter the aerial test unless the entire stem section is exposed to the toxicant solution.

Although the author in the above discussion has objected to this method of evaluating insecticidal phytotoxicity it is nevertheless approved by many biologists. The following quotation is from a letter the author received from Arthur W. Galston, Associate Professor, California Institute of Technology:

> "I have read the article of Casida and Allen, and see no major objections to the method they use. It is possible, by the use of some refinements, to reduce the test to a 4-6 hour assay. This is better, not only from the point of view of convenience but also because it obviates errors due to microbial effects. Nevertheless, I consider these objections not to invalidate the method used."

SUMMARY

1. Eighteen emulsifiers were tested for their toxicity to the National Pickling cucumber. When grouped according to their type and water solubility the following relationship was found for each group:

   anionic water-soluble group.......very toxic
   anionic water-insoluble group.....toxic
   non-ionic water-soluble group.....slightly toxic
   non-ionic water-insoluble group...non-toxic.

   The above grouping indicates the toxicity of each group as a whole. Emulsifiers within a group tended to vary greatly. Several emulsifiers were more or less toxic than the rating given the group to which it belongs.

2. A wide range of phytotoxicity was noted for eleven DDT emulsions. The only variable in each formulation was the emulsifier which varied from two to six percent of the concentrate. The formulations with the anionic emulsifiers were generally more toxic than the formulations with the non-ionic emulsifiers. Generally water-soluble compounds were more toxic than water-insoluble compounds.

3. The test was found to be very sensitive to a number of variables. Standard conditions have been defined and must be carefully followed.

4. Synergisms and antagonisms caused by the toxicant in the nutrient solution may lead to faulty conclusions.

5. The fact that the sensitivity and growth regulating properties of indole-3-acetic acid is not clearly understood limits this test method. Plant responses to the indole-3-acetic acid may lead to the production of roots, excessive cell elongation or inhibition of growth which would alter measurements and conclusions.
6. A sharp division between the laboratory and field conditions exist. This is due to the absence of chlorophyll and photosynthesis in the laboratory test.
7. An evaluation of the results cannot be extended to any conditions other than those actually tested.

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APPENDIX

I. Emulsifier Measurements in Grams and Millimeters.

II. DDT Formulation Measurements in Grams and in Millimeters.

Length Tables

1. Numbers in the columns below each concentration represent the length of a single plant in millimeters.
2. The numbers in the brackets represent the total growth of all plants in one petri dish in millimeters.
3. The line labled Tot. gives the total growth in millimeters for each concentration.
4. The line labled P. I. gives the phytotoxic index for each concentration.
5. Percentage of concentration of material in nutrient solution was by weight.

Table 4

PHYTOTOXIC INDEX AND WEIGHTS
IN GRAMS OF CUCUMBER PLANTS

Emulsifier	Control	Percentage of concentrate in nutrient solution 0.16%	0.08%	0.04%	0.02%	
Aerosol OT	1.665	0.202 87.9%	0.210 87.4%	0.360 78.4%	1.344 19.3%	g. P. I.
BPE	2.360	0.630 73.3%	0.710 69.9%	1.274 46.0%	1.820 22.9%	
Emcol H-77	2.040	1.648 19.2%	1.805 11.5%	2.100 -2.9%	2.126 -4.2%	
Santomerse D	1.780	0.415 76.7%	0.735 58.7%	1.221 31.4%	1.626 8.7%	
Areskap 50	2.040	1.159 43.2%	1.372 32.8%	1.581 22.5%	1.840 9.8%	
Polyethylene Glycol 400	1.240	1.410 -13.7%	1.315 -6.0%	1.280 -3.2%	1.475 -19.0%	
S-1132	1.780	1.552 12.8%	1.720 3.4%	1.819 -2.2%	1.630 8.4%	
S-1207	1.630	0.861 47.2%	1.205 26.1%	1.327 18.6%	1.705 -4.6	
Toximul 300	1.427	0.860 39.7%	1.238 13.2%	1.515 -6.2%	1.405 1.5%	
Toximul 400	1.427	0.984 31.0%	1.452 0.1%	1.415 0.8%	1.475 -3.4%	
Triton X-100	1.620	0.870 46.3%	0.925 42.9%	1.385 14.5%	1.278 21.1%	
Triton X-150	1.710	0.690 59.6%	0.840 50.9%	1.045 38.8%	....	

TABLE 4 CONT.

Emulsifier	Control	Percentage of concentrate in nutrient solution 0.16%	0.08%	0.04%	0.02%	
Triton X-155	1.620	1.336 17.5%	1.414 12.7%	1.600 1.2%	1.437 11.3%	g. P. I.
Triton X-160	1.710	0.860 49.7%	1.145 33.0%	1.190 30.4%	....	
Triton X-177	1.475	1.315 10.8%	1.505 -2.0%	1.610 -9.2%	1.530 -3.7%	
Triton X-188	1.475	0.925 37.3%	1.310 11.2%	1.410 4.4%	1.485 -0.7%	
Triton B-1956	1.240	1.475 -19.0%	1.570 -26.6%	1.411 -13.8%	1.320 -6.5%	
Du Pont Spreader Sticker	1.665	1.475 11.4%	1.745 -4.8%	1.765 -6.0%	1.965 -18.0%	

Each figure represents the weight and phytotoxic index for forty five plants.

Table 5. Aerosol OT

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
28		2		3		5		22	
47		3		4		6		4	
47		4		3		2		7	
28		3		3		5		22	
29		3		4		5		8	
31		2		3		6		10	
30		3		4		3		19	
47		3		4		3		10	
26		5		4		3		24	
53		4		4		4		11	
17		3		14		2		7	
31		4		3		4		21	
26		4		3		6		22	
23		5		2		2		23	
14	(477)	4	(52)	3	(61)	3	(59)	25	(235)
38		2		3		4		25	
29		3		2		2		9	
44		2		2		2		26	
26		2		3		3		26	
51		4		1		3		9	
38		4		2		2		8	
36		2		2		5		13	
43		4		3		3		13	
38		3		4		3		8	
31		2		3		6		18	
47		5		3		5		19	
33		2		2		6		20	
12		4		2		3		8	
31		3		1		2		25	
36	(533)	4	(46)	2	(35)	6	(55)	12	(239)
26		5		3		2		30	
49		3		3		5		19	
46		3		3		2		20	
31		3		3		2		28	
27		2		3		3		24	
31		3		3		3		27	
42		4		3		6		16	
12		3		3		7		21	
35		2		2		6		18	
31		2		4		3		25	
24		3		2		6		8	
28		2		3		4		22	
28		4		4		6		20	
29		3		5		4		21	
4	(443)	2	(44)	2	(46)	5	(64)	12	(311)
Tot.	1453		142		142		178		785
P. I.			90.3%		90.3%		87.8%		46.0%

Table 6. BPE

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
46		8		11		18		46	
60		6		7		23		34	
65		7		8		35		42	
65		11		23		19		21	
46		7		12		28		53	
65		9		16		28		40	
39		4		8		28		44	
61		6		13		21		46	
53		8		11		26		20	
58		12		11		24		26	
64		10		10		26		44	
35		13		26		12		46	
54		9		17		29		50	
55		9		16		37			
43	(809)	2	(121)	8	(197)	30	(376)	21	(570)
58		7		30		20		40	
39		6		33		19		41	
34		10		28		14		33	
54		9		30		21		33	
65		11		26		21		42	
62		7		38		19		27	
58		7		11		34		33	
60		8		13		18		33	
34		5		18		21		41	
33		9		7		16		32	
8		5		31		21		40	
58		3		31		7		35	
66		3		21		6		37	
49		3		13		25		32	
71	(749)	6	(99)	13	(343)	22	(284)	36	(535)
35		6		14		28		55	
33		6		13		22		35	
38		6		14		37		49	
24		6		11		17		51	
37		8		11		23		43	
60		8		11		22		56	
44		5		20		22		44	
38		5		10		16		22	
27		4		15		25		33	
50		7		9		22		33	
40		11		16		36		18	
26		10		12		21		26	
39		9		11		20		51	
38		8		30		50		36	
10	(539)	4	(103)	13	(210)	2	(363)	32	(584)
Tot.	2097		323		750		1023		1689
P. I.			85.6%		64.2%		51.2%		19.5%

Table 7. Toximul 300

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
43		10		35		20		48	
36		4		30		18		35	
37		12		28		13		21	
37		12		39		29		44	
34		11		30		40		37	
32		11		22		30		31	
30		24		25		30		26	
28		17		24		27		50	
29		14		18		35		31	
33		12		19		33		53	
32		10		28		46		51	
33		11		33		26		40	
30		6		14		41		48	
4		31		21		28		39	
24	(462)	14	(199)	11	(377)	44	(460)	42	(596)
48		14		25		30		48	
52		10		29		44		25	
25		9		27		34		26	
31		9		33		29		29	
38		6		24		46		23	
26		9		25		39		45	
45		7		27		29		24	
28		11		36		32		6	
26		7		30		28		35	
21		5		22		41		53	
33		7		15		28		44	
20		11		19		30		56	
36		19		15		25		26	
29		3		34		24		23	
44	(502)	13	(140)	27	(388)	30	(489)	51	(514)
51		3		28		29		23	
37		16		27		26		17	
39		19		30		44		32	
24		19		26		39		24	
57		17		21		43		23	
24		19		25		40		22	
52		9		34		39		22	
27		4		26		10		35	
30		10		18		48		29	
30		5		17		34		28	
36		4		27		32		27	
39		2		25		20		13	
23		7		15		39		16	
30		9		8		36		36	
29	(528)	11	(154)	20	(347)	39	(518)	34	(381)
Tot.	1492		493		1112		1467		1491
P. I.			67.0%		25.5%		1.7%		.07%

Table 8. Toximul 400

Control		Percentage of emulsifier in nutrient solution							
		0.16%		0.08%		0.04%		0.02%	
43		22		48		45		26	
36		27		23		37		42	
37		20		40		33		45	
37		19		39		38		32	
34		17		41		25		20	
32		26		30		41		23	
30		17		24		24		26	
28		29		41		45		57	
29		27		43		28		34	
33		30		40		45		23	
32		23		40		40		42	
33		24		28		29		44	
30		28		23		32		32	
4		12		33		16		44	
24	(462)	16	(337)	27	(520)	3	(481)	36	(526)
48		30		41		26		38	
52		31		33		17		30	
25		23		42		40		44	
31		28		34		36		33	
38		24		39		22		46	
26		21		27		39		29	
45		29		39		35		43	
28		33		23		22		22	
26		24		39		33		36	
21		26		18		32		33	
33		23		40		46		63	
20		22		33		37		30	
36		18		42		43		33	
29		5		38		40		38	
44	(502)	14	(351)	3	(491)	20	(488)	33	(551)
51		29		39		34		45	
37		16		41		35		33	
39		20		40		38		45	
24		13		38		32		30	
57		20		42		43		20	
24		16		21		29		36	
52		19		40		36		35	
27		16		36		41		35	
30		13		33		30		34	
30		30		24		37		29	
36		10		43		34		19	
39		9		8		37		37	
23		7		30		46		30	
30		6		33		4		33	
29	(528)	15	(239)	33	(501)	34	(510)	35	(498)
Tot.	1492		927		1512		1479		1575
P. I.			37.9%		-1.3%		.9%		-5.6%

Table 9. Santomerse D

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
19		2		7		37		21	
30		6		5		35		35	
24		3		2		23		40	
44		3		6		20		39	
54		2		6		31		40	
26		4		21		23		53	
44		2		2		27		45	
40		5		14		26		5	
22		2		8		33		6	
45		3		7		45		21	
23		5		6		29		39	
34		4		4		28		29	
57		4		5		28		32	
23		2		4		43		36	
52	(537)	2	(49)	3	(100)	44	(472)	17	(458)
33		4		8		25		46	
35		3		7		40		25	
27		5		7		19		42	
31		4		12		28		43	
49		4		4		32		21	
37		5		3		38		37	
49		4		5		31		49	
8		3		5		25		35	
27		3		2		45		41	
37		2		7		20		46	
31		4		13		34		49	
29		2		7		39		45	
35		2		5		3		28	
29		2		8		19		37	
42	(499)	2	(49)	10	(103)	31	(429)	44	(588)
51		4		9		25		45	
51		3		16		32		19	
48		6		5		53		29	
31		2		3		26		25	
30		3		3		13		35	
42		4		13		17		44	
47		5		3		31		37	
27		3		3		29		69	
50		3		3		10		42	
31		2		4		4		31	
36		5		4		26		33	
37		4		2		23		39	
12		2		6		33		42	
24		2		12		21		35	
19	(536)	2	(50)	2	(88)	9	(352)	17	(542)
Tot.	1572		148		291		1253		1588
P. I.			90.6%		81.5%		20.3%		-1.0%

Table 10. Areskap 50

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
59		36		32		39		39	
55		12		33		48		57	
44		19		34		55		21	
47		17		27		36		49	
34		19		29		33		70	
53		10		27		28		57	
35		12		42		50		37	
60		14		19		8		67	
48		14		32		43		31	
47		13		38		53		36	
21		5		24		57		67	
45		16		37		55		82	
52		23		23		48		29	
20		11		24		42		22	
25	(645)	18	(239)	17	(438)	25	(620)	12	(676)
33		40		31		30		21	
33		30		32		47		52	
36		6		24		39		37	
30		7		31		23		45	
53		28		39		39		30	
34		20		36		31		52	
56		6		28		19		53	
64		26		35		5		34	
41		3		21		56		19	
36		9		15		30		17	
39		7		15		43		51	
33		11		32		46		32	
28		15		30		47		55	
22		9		21		38		18	
79	(617)	15	(232)	13	(403)	62	(555)	17	(533)
33		11		46		50		65	
31		11		31		25		24	
58		16		30		45		73	
38		3		25		9		49	
47		7		32		49		36	
32		9		24		41		61	
27		15		21		42		64	
61		14		12		37		56	
44		2		37		34		66	
41		16		21		35		46	
38		16		28		36		36	
40		6		8		45		69	
23		10		20		5		33	
33		11		20		25		32	
16	(562)	13	(160)	31	(386)	47	(525)	17	(727)
Tot.	1824		631		1227		1700		1936
P. I.			65.4%		32.7%		6.8%		-6.1%

Table 11. Polyethylene Glycol 400 (Mono) Laurate

Control		Percentage of emulsifier in nutrient solution							
		0.16%		0.08%		0.04%		0.02%	
35		25		25		29		37	
28		22		24		27		9	
23		31		33		38		40	
25		22		36		18		29	
31		39		31		21		31	
26		33		36		34		30	
16		33		15		49		46	
24		30		41		13		30	
39		11		51		34		29	
27		31		23		35		35	
36		32		40		30		32	
33		21		24		4		33	
28		30		29		3		41	
24		25		25		36		37	
8	(403)	36	(421)	15	(448)	15	(386)	11	(470)
30		39		24		27		30	
44		37		33		35		39	
39		26		25		33		25	
32		9		34		26		34	
31		20		33		29		23	
29		42		22		30		4	
39		42		54		29		24	
19		52		45		45		35	
26		7		34		17		22	
18		36		31		23		33	
30		48		26		40		29	
24		30		35		25		27	
29		35		38		30		25	
14		38		28		11		6	
13	(417)	29	(490)	10	(472)	18	(418)	4	(360)
41		10		29		23		35	
30		29		25		20		14	
35		26		16		45		42	
24		16		8		41		21	
31		7		22		35		24	
21		21		35		30		38	
30		35		29		24		25	
20		29		28		43		16	
27		29		39		17		37	
28		39		20		23		8	
28		29		39		18		38	
45		29		33		22		35	
34		33		34		34		45	
20		33		21		34		43	
3	(417)	20	(385)	32	(410)	11	(420)	27	(448)
Tot.	1237		1296		1330		1224		1278
P. I.			-4.8%		-7.5%		1.1%		-3.3

Table 12. S-1132

Control		Percentage of emulsifier in nutrient solution							
		0.16%		0.08%		0.04%		0.02%	
19		25		27		42		32	
30		27		27		41		26	
24		47		36		47		32	
44		45		43		62		29	
54		35		42		42		39	
26		46		30		7		21	
44		61		22		51		32	
40		58		39		54		28	
22		50		6		59		38	
45		56		30		63		37	
23		28		37		24		41	
34		23		31		37		34	
57		25		34		22		52	
23		17		60		24		31	
52	(537)	5	(548)	35	(499)	38	(613)	35	(507)
33		25		43		36		25	
35		20		22		45		25	
27		34		45		47		25	
31		58		31		34		28	
49		35		46		44		51	
37		31		48		30		38	
49		23		3		32		30	
8		18		28		41		26	
27		37		20		36		20	
37		29		2		45		46	
31		34		46		42		21	
29		25		50		43		18	
35		33		41		28		19	
29		51		29		4		2	
42	(499)	47	(500)	32	(486)	2	(509)	3	(377)
51		4		30		41		30	
51		36		29		39		51	
48		32		41		38		45	
31		35		41		36		48	
30		55		31		48		53	
42		42		45		21		45	
47		44		66		43		33	
27		39		40		37		11	
50		44		35		38		55	
31		41		43		41		29	
36		43		58		43		30	
37		33		40		28		30	
12		53		31		49		35	
24		46		40		53		24	
19	(536)	56	(603)	45	(615)	26	(581)	14	(533)
Tot.	1572		1651		1600		1703		1417
P. I.			-5.0%		-1.8%		-8.3%		9.9%

Table 13. S-1207

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
33		52		33		28		27	
37		53		36		51		53	
26		33		42		10		35	
54		31		32		40		23	
34		33		44		30		39	
66		20		4		46		27	
11		4		32		38		47	
38		7		10		57		37	
40		22		35		28		43	
25		2		41		28		54	
34		50		40		54		51	
36		38		40		2		40	
10		2		32		3		65	
20		8		3		8		35	
13	(477)	2	(357)	2	(426)	10	(433)	3	(579)
30		8		34		44		15	
43		3		52		43		31	
22		6		45		57		39	
29		24		13		31		51	
28		39		32		31		51	
38		46		30		42		16	
27		49		46		27		25	
46		49		50		38		55	
60		31		63		30		39	
43		51		63		53		49	
39		35		3		11		43	
38		21		11		17		40	
35		13		34		22		18	
30		4		50		52		36	
29	(537)	25	(404)	32	(558)	51	(549)	4	(512)
35		27		57		67		9	
42		26		49		63		38	
53		22		43		43		51	
51		44		42		41		44	
33		25		54		31		38	
44		44		35		55		50	
28		26		28		5		37	
50		42		3		43		52	
49		37		25		2		30	
45		24		14		3		24	
47		60		23		39		52	
38		20		4		26		5	
31		49		19		37		27	
27		9		16		36		34	
36	(609)	2	(457)	13	(425)	41	(532)	31	(522)
Tot.	1623		1218		1409		1514		1613
P. I.			25.0%		32.7%		6.8%		-6.1%

Table 14. Grasselli Spreader-Sticker

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
28		32		28		29		36	
47		25		42		32		49	
47		31		53		33		29	
28		6		57		46		39	
29		22		45		19		37	
31		28		34		30		23	
30		36		51		31		60	
47		43		48		33		34	
26		33		40		55		37	
53		32		46		18		35	
17		25		39		42		21	
31		26		47		30		23	
26		34		36		30		40	
23		33		28		41		37	
14	(477)	29	(435)	26	(620)	23	(492)	33	(533)
38		11		12		44		32	
29		41		53		55		41	
44		36		29		22		15	
26		47		43		20		48	
51		30		52		32		42	
38		20		36		22		57	
36		36		32		39		26	
43		26		62		33		42	
38		23		32		25		44	
31		27		22		37		38	
47		13		30		44		33	
33		32		21		30		40	
12		17		24		56		25	
31		8		40		33		30	
36	(533)	9	(376)	28	(516)	33	(525)	26	(539)
26		34		41		37		33	
49		38		32		29		45	
46		30		34		36		60	
31		41		38		38		28	
27		37		51		38		41	
31		24		29		40		51	
42		35		67		31		34	
12		22		33		48		44	
35		28		44		31		30	
31		30		31		43		45	
24		38		59		40		40	
28		44		35		29		42	
28		25		42		60		33	
29		30		35		16		30	
4	(448)	34	(490)	25	(596)	40	(556)	38	(594)
Tot.	1453		1300		1732		1573		1661
P. I.			10.5%		-19.2%		-8.3%		-14.3%

Table 15. Triton X-100

Control		Percentege of emulsifier in nutrient solution							
		0.16%		0.08%		0.04%		0.02%	
46		16		19		46		37	
34		27		15		38		41	
50		28		23		35		36	
38		24		36		23		27	
36		25		31		38		31	
65		42		13		29		33	
56		24		16		40		26	
37		21		38		30		37	
56		29		27		29		15	
48		13		12		40		28	
38		18		27		39		27	
44		5		38		22		29	
28		17		32		5		30	
39		6		31		26		33	
29	(644)	8	(303)	10	(368)	41	(481)	23	(453)
34		22		23		55		32	
35		30		27		45		38	
47		26		27		16		23	
45		28		32		43		43	
31		32		27		31		17	
49		9		18		37		29	
26		31		27		25		43	
32		14		19		43		45	
36		11		11		44		32	
51		26		22		40		21	
40		25		14		9		34	
14		20		7		21		44	
33		16		15		30		24	
21		2		22		18		19	
28	(522)	10	(302)	21	(312)	3	(460)	2	(446)
37		30		27		41		30	
37		31		20		35		29	
38		32		33		29		20	
40		23		20		38		31	
39		28		34		35		35	
46		27		33		35		26	
37		35		14		33		42	
42		20		22		40		35	
51		24		28		33		25	
28		24		23		25		31	
45		20		28		35		28	
45		11		30		11		29	
11		31		30		36		41	
3		22		13		13		36	
16	(515)	23	(381)	29	(384)	15	(454)	36	(474)
Tot.	1681		986		1064		1395		1373
P. I.			41.4%		36.7%		17.0%		18.3%

Table 16. Triton X-150

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%	
35		19		20		42	
23		19		30		39	
33		26		30		26	
31		15		30		11	
41		30		28		27	
37		17		9		34	
35		30		36		24	
35		9		39		22	
36		29		13		26	
34		25		25		30	
29		26		14		32	
12		3		15		28	
35		13		28		26	
29		12		28		11	
33	(458)	10	(283)	5	(350)	15	(393)
31		22		31		35	
36		18		32		34	
31		24		21		27	
31		31		26		22	
27		23		18		23	
32		28		27		29	
35		23		28		37	
27		26		20		37	
30		19		5		20	
30		7		21		22	
33		13		33		31	
37		4		15		30	
36		20		22		32	
32		21		23		15	
16	(464)	21	(300)	30	(353)	19	(413)
30		29		29		40	
29		14		37		28	
30		4		22		18	
33		18		14		17	
37		18		17		24	
36		27		28		24	
38		26		17		17	
33		20		19		24	
40		33		23		22	
36		16		13		32	
22		11		25		26	
36		5		23		9	
34		27		3		11	
28		23		4		15	
33	(495)	4	(275)	10	(284)	23	(330)
Tot.	1417		858		987		1136
P. I.			39.5%		30.3%		19.8%

Table 17. Triton X-155

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
46		24		44		46		52	
34		37		50		58		47	
50		30		52		42		51	
38		43		20		43		7	
36		38		19		44		54	
65		40		48		55		38	
56		60		31		38		44	
37		37		45		40		35	
56		34		47		39		23	
48		42		45		40		40	
38		11		31		50		62	
44		38		47		45		28	
28		28		12		19		44	
39		28		2		43		12	
29	(644)	22	(512)	37	(553)	39	(618)	29	(566)
34		7		58		48		50	
35		49		43		48		46	
47		33		43		40		45	
45		22		44		42		2	
31		25		50		20		23	
49		37		13		43		47	
26		43		39		47		43	
32		60		43		44		3	
36		27		47		7		42	
51		34		45		46		47	
40		58		47		62		33	
14		37		55		51		35	
33		42		29		46		48	
21		34		34		33		47	
28	(522)	33	(541)	47	(637)	29	(606)	40	(551)
37		37		23		50		30	
37		35		39		33		46	
38		54		40		39		40	
40		38		49		26		35	
39		14		36		31		39	
46		16		38		28		7	
37		38		40		30		28	
42		40		42		46		40	
51		37		24		28		35	
28		47		25		43		44	
45		43		33		36		19	
45		45		28		32		21	
11		35		45		19		5	
3		40		50		8		6	
16	(515)	9	(528)	13	(525)	45	(494)	7	(402)
Tot. 1681		1581		1715		1718		1519	
P. I.		5.9%		-2.0%		-2.2%		9.6%	

Table 18. Triton X-160

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%	
35		33		45		31	
33		28		30		40	
33		30		28		28	
31		25		36		25	
41		26		27		33	
37		15		18		24	
35		8		30		11	
35		24		20		13	
36		5		33		35	
34		40		6		28	
29		22		36		42	
12		6		28		19	
35		13		30		25	
29		26		10		39	
33	(458)	10	(311)	35	(412)	3	(396)
31		32		33		39	
36		11		36		32	
31		21		38		15	
31		26		31		18	
27		14		13		32	
32		35		31		41	
35		24		37		33	
27		12		33		28	
30		22		25		28	
30		30		24		6	
33		26		39		30	
37		25		44		10	
36		17		42		31	
32		8		46		24	
16	(464)	6	(309)	27	(499)	6	(373)
30		28		49		18	
29		27		29		45	
30		34		28		39	
33		35		36		43	
37		33		29		35	
36		24		33		19	
38		28		9		34	
33		25		23		25	
40		19		32		34	
36		25		16		23	
22		28		26		38	
36		11		31		33	
34		29		41		27	
28		24		31		6	
33	(495)	42	(412)	33	(446)	36	(455)
Tot.	1417		1032		1357		1224
P. I.			27.2%		4.2%		13.6%

Table 19. Triton X-177

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
33		35		46		38		28	
26		36		26		38		38	
38		31		36		27		37	
29		32		39		44		30	
25		27		41		30		14	
30		41		36		13		28	
36		40		40		45		40	
12		16		37		33		32	
34		29		30		33		33	
12		27		27		33		32	
25		28		49		31		34	
28		39		26		40		23	
22		26		32		30		11	
22		33		26		28		30	
43	(415)	29	(469)	19	(510)	22	(459)	30	(440)
38		23		36		12		22	
31		42		37		28		23	
41		29		45		31		26	
40		23		15		34		35	
32		37		35		36		36	
27		9		42		47		33	
43		29		39		30		27	
28		23		29		26		28	
27		38		41		26		29	
17		14		13		44		14	
38		28		27		30		19	
11		27		17		34		29	
37		7		26		43		26	
34		42		22		28		29	
33	(477)	29	(400)	13	(437)	44	(490)	29	(405)
36		40		31		39		42	
38		40		42		43		36	
30		35		43		25		14	
42		34		34		40		34	
31		28		35		30		35	
27		14		38		39		43	
26		30		38		37		15	
49		20		33		32		30	
30		34		37		38		9	
42		29		28		31		29	
46		29		23		39		30	
33		25		21		26		23	
41		34		43		24		38	
11		38		4		37		29	
33	(515)	18	(448)	12	(462)	7	(487)	41	(448)
Tot.	1407		1317		1409		1472		1293
P. I.			6.4%		-0.1%		-4.6%		8.1%

Table 20. Triton X-188

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
33		30		28		35		38	
26		30		19		35		38	
38		28		39		29		29	
29		18		33		30		38	
25		25		9		37		31	
30		10		31		29		30	
36		29		17		35		16	
12		20		16		12		27	
34		25		30		9		26	
12		29		32		23		17	
25		20		28		22		30	
28		28		33		15		38	
22		26		33		19		4	
22		23		33		18		30	
43	(415)	3	(344)	11	(392)	11	(359)	37	(429)
38		5		28		29		37	
31		3		22		37		13	
41		29		24		17		13	
40		27		23		15		32	
32		26		27		27		16	
27		28		27		23		18	
43		21		27		24		40	
28		26		33		26		31	
27		38		33		33		28	
17		27		33		31		22	
38		28		31		38		26	
11		23		20		21		18	
37		35		30		17		12	
34		13		20		25		27	
33	(477)	12	(341)	8	(386)	13	(376)	18	(351)
36		21		29		24		24	
38		12		24		21		42	
30		32		20		25		26	
42		14		31		25		21	
31		30		29		28		25	
27		28		29		32		20	
26		16		30		33		29	
49		15		26		28		34	
30		4		11		27		27	
42		20		32		28		41	
46		31		16		35		28	
33		26		26		30		33	
41		26		27		39		25	
11		21		23		6		26	
33	(515)	11	(307)	9	(362)	23	(404)	33	(434)
Tot.	1407		992		1140		1139		1214
P. I.			29.5%		19.0%		19.0%		13.7%

Table 21. Triton B-1956

Control		Percentage of emulsifier in nutrient solution							
		0.16%		0.08%		0.04%		0.02%	
35		12		42		37		21	
28		43		24		38		11	
23		35		46		36		35	
25		45		27		38		25	
31		25		48		29		24	
26		42		30		33		36	
16		16		35		37		16	
24		21		45		41		39	
39		28		10		27		26	
27		25		39		19		10	
36		24		33		25		19	
33		33		34		14		40	
28		29		42		8		5	
24		33		46		13		2	
8	(403)	32	(443)	11	(512)	3	(398)	38	(347)
30		35		34		36		13	
44		39		37		27		31	
39		38		45		36		37	
32		29		25		40		27	
31		27		60		38		36	
29		28		46		47		35	
39		18		43		41		23	
19		32		21		42		36	
26		45		24		36		41	
18		44		35		38		14	
30		20		10		44		35	
24		36		11		49		46	
29		29		30		35		26	
14		34		49		23		36	
13	(417)	45	(499)	58	(528)	31	(563)	25	(461)
41		36		48		33		43	
30		41		31		18		28	
35		49		34		28		37	
24		28		23		15		24	
31		33		42		23		47	
21		31		28		46		47	
30		37		19		24		23	
20		36		39		27		36	
27		36		37		27		32	
28		39		37		35		26	
28		22		38		22		22	
45		21		39		24		9	
34		4		24		24		30	
20		3		31		22		4	
3	(417)	3	(419)	10	(480)	15	(383)	21	(429)
Tot.	1237		1361		1520		1344		1237
P. I.			-10.0		-22.9%		-8.7%		0.0

Table 22. Emcol H-77

Control		Percentage of emulsifier in nutrient solution 0.16%		0.08%		0.04%		0.02%	
59		54		42		51		52	
55		48		66		51		78	
44		33		35		35		44	
47		65		47		29		61	
34		45		50		45		12	
53		53		33		51		78	
35		53		77		36		4	
60		62		50		52		5	
48		51		35		41		35	
47		61		68		28		46	
21		63		56		40		43	
45		63		27		58		23	
52		68		12		36		27	
20		73		23		34		52	
25	(645)	25	(807)	21	(632)	12	(599)	27	(587)
33		29		43		43		37	
33		27		21		51		35	
36		42		30		51		33	
30		32		44		46		63	
53		20		24		35		18	
34		64		57		53		81	
56		5		25		47		45	
64		33		51		33		46	
41		17		51		54		24	
36		51		35		39		42	
39		6		33		26		53	
33		41		45		22		28	
28		7		56		21		21	
22		35		8		31		17	
79	(617)	64	(473)	65	(566)	48	(600)	46	(589)
33		29		53		31		15	
31		56		59		48		52	
58		16		38		61		31	
38		34		64		29		56	
47		50		40		50		36	
32		49		56		23		36	
27		45		27		40		56	
61		55		59		39		53	
44		49		48		45		56	
41		38		31		61		67	
38		44		40		41		30	
40		46		47		42		10	
23		42		3		8		57	
33		43		5		30		30	
16	(562)	44	(640)	69	(639)	35	(583)	40	(625)
Tot. 1824			1920		1885		1782		1801
P. I.			-5.3%		-3.3%		2.3%		1.3%

Table 23. DDT 25%, Xylene 71%, and Areskap 50 4%

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
52		57		44		47		51	
47		20		37		63		56	
38		53		43		30		23	
44		38		10		43		48	
53		57		61		60		65	
68		70		48		48		50	
46		39		52		30		51	
56		37		40		66		55	
68		12		35		34		66	
48		75		57		40		39	
57		31		45		45		59	
47		34		67		56		54	
43		51		51		13		49	
45		41		53		54		41	
54	(766)	43	(658)	32	(675)	68	(707)	26	(733)
60		50		61		38		55	
60		44		68		74		28	
48		36		70		31		34	
62		47		35		51		46	
40		46		51		56		65	
78		17		43		30		54	
71		31		70		50		25	
65		52		40		75		61	
21		64		33		57		36	
30		36		61		27		42	
49		48		47		59		55	
71		36		67		32		36	
67		56		45		68		29	
39		54		6		54		49	
68	(829)	54	(671)	29	(726)	35	(737)	53	(668)
17		79		51		65		52	
60		18		26		59		58	
57		53		37		56		60	
50		18		67		50		31	
59		42		38		49		48	
68		43		31		46		33	
64		58		35		57		39	
68		45		49		56		50	
58		54		52		53		48	
53		44		49		23		33	
58		24		71		43		39	
61		60		40		26		50	
36		45		43		51		48	
10		19		46		48		52	
20	(739)	44	(646)	60	(695)	24	(708)	58	(699)
Tot.	2334		1975		2096		2152		2100
P. I.			15.4%		10.2%		7.8%		10.0%

Table 24. DDT 25%, Xylene 71% and Polyethylene Glycol 400 (Mono) Laurate

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
33		36		30		28		17	
46		21		27		22		37	
43		27		26		27		25	
30		39		22		25		25	
34		23		25		3		33	
39		57		24		22		25	
38		32		10		27		45	
39		29		28		23		25	
32		13		4		31		36	
31		40		33		5		31	
30		26		30		10		34	
30		18		21		30		28	
21		10		28		28		23	
17		20		26		20		31	
43	(506)	26	(417)	34	(368)	31	(332)	2	(417)
29		34		26		11		35	
29		38		19		21		44	
28		25		25		29		15	
49		5		34		12		39	
35		30		33		28		29	
32		30		30		25		45	
33		40		22		25		31	
18		24		16		25		26	
55		27		26		23		30	
27		39		47		26		35	
25		32		47		31		23	
12		16		21		4		27	
35		32		26		4		29	
27		2		28		21		28	
27	(461)	25	(399)	23	(423)	25	(310)	31	(467)
42		21		34		16		48	
45		24		29		30		7	
43		31		25		32		29	
44		33		39		16		27	
18		29		23		29		24	
43		28		22		2		30	
41		28		23		26		59	
22		4		23		29		24	
32		39		33		41		19	
11		25		24		40		23	
25		40		35		29		29	
12		31		34		17		30	
13		24		40		28		2	
5		29		29		30		27	
5	(401)	10	(396)	31	(444)	25	(390)	36	(414)
Tot.	1368		1212		1235		1032		1298
P. I.			11.4%		9.7%		24.6%		5.1%

Table 25. DDT 25%, Xylene 71% and Triton X-100 4%

Control		Percentege of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
54		19		38		47		34	
59		17		26		34		32	
59		22		32		35		23	
45		15		33		34		36	
47		25		39		31		35	
33		24		23		30		30	
30		16		32		25		39	
42		38		20		31		37	
38		27		30		17		28	
55		22		33		29		33	
29		27		22		42		27	
35		30		37		33		41	
34		29		21		27		26	
34		32		25		24		31	
37	(631)	25	(368)	33	(444)	26	(465)	24	(476)
42		31		30		36		25	
39		30		2		21		33	
36		24		3		34		32	
29		29		35		40		36	
40		26		32		48		32	
37		38		34		23		29	
30		32		34		41		33	
31		29		31		36		32	
33		30		33		33		32	
39		20		45		26		28	
36		13		31		32		26	
37		23		35		43		39	
22		17		33		31		33	
30		20		32		36		35	
25	(506)	22	(384)	27	(437)	29	(509)	21	(466)
31		16		27		41		38	
62		22		27		12		39	
38		27		31		32		39	
35		38		29		36		35	
32		28		33		29		24	
23		24		23		49		40	
33		39		13		28		30	
28		43		7		33		45	
28		34		39		39		34	
32		25		35		30		39	
30		34		36		33		29	
35		26		38		32		18	
35		23		35		26		18	
28		24		22		28		39	
37	(507)	23	(426)	38	(433)	2	(450)	40	(507)
Tot. 1644		1178		1314		1424		1449	
P. I.-		28.3%		20.1%		13.4%		11.9%	

Table 26. DDT 25%, Xylene 71% and Tirton X-155 4%

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
33		26		29		29		30	
46		3		48		28		35	
43		29		29		43		20	
30		23		32		20		30	
34		29		29		31		31	
39		23		34		49		29	
38		17		38		26		36	
39		15		25		28		11	
32		26		36		2		43	
31		38		28		27		28	
30		25		43		26		23	
30		18		26		24		31	
21		24		3		27		39	
17		7		25		29		22	
43	(506)	26	(329)	17	(441)	38	(427)	25	(433)
29		26		28		57		27	
29		29		22		33		37	
28		25		39		25		36	
49		28		24		35		57	
35		5		37		30		42	
32		28		24		35		34	
33		31		43		48		24	
18		38		30		40		24	
55		45		29		28		25	
27		36		42		24		40	
25		45		29		49		4	
12		43		27		27		3	
35		43		44		30		2	
27		22		25		20		37	
27	(461)	29	(473)	10	(453)	34	(515)	27	(419)
42		4		46		5		45	
45		25		48		52		30	
43		3		32		48		25	
44		14		35		37		46	
18		28		24		8		30	
43		28		31		3		26	
41		40		20		39		41	
22		44		29		29		55	
32		10		37		30		34	
11		31		19		30		28	
25		20		12		29		46	
12		30		27		25		46	
13		28		29		26		40	
5		32		30		29		37	
5	(401)	20	(357)	13	(432)	27	(417)	15	(544)
Tot.	1368		1159		1326		1359		1396
P. I.			15.3%		3.1%		0.7%		-2.1%

Table 27. DDT 25%, Xylene 72% and Emcol H-77 3%

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
38		29		36		31		45	
25		32		12		42		25	
49		29		30		30		41	
55		30		30		48		28	
37		35		34		5		23	
41		47		34		42		39	
34		33		43		57		47	
14		39		24		30		35	
12		42		38		43		33	
43		30		38		37		22	
33		40		40		39		35	
22		40		14		38		34	
49		35		34		39		33	
30		31		40		34		33	
48	(530)	16	(508)	43	(490)	33	(548)	21	(494)
37		26		47		45		45	
51		33		23		56		52	
51		29		43		24		45	
43		24		30		46		43	
60		32		61		42		44	
60		45		44		59		47	
37		37		48		39		44	
40		33		40		35		38	
35		30		42		49		43	
52		34		32		54		41	
49		32		33		36		40	
65		30		39		45		46	
38		39		39		55		43	
48		11		10		42		40	
58	(724)	31	(466)	27	(558)	7	(634)	42	(658)
39		39		42		30		32	
51		38		36		35		39	
28		30		9		27		43	
37		30		34		37		11	
29		45		31		35		39	
42		32		29		31		32	
60		40		45		16		35	
49		26		32		29		35	
54		25		36		33		47	
35		38		29		29		34	
39		36		30		37		44	
39		45		28		40		33	
30		4		36		43		29	
40	(611)	20	(484)	44	(504)	35	(501)	35	(515)
Tot.	1863		1458		1552		1683		1667
P. I.			21.4%		16.7%		9.7%		10.5%

Table 28. DDT 25%, Xylene 70% and Triton X-155 2%, Triton B-1956 3%

Control		Percentage of concentrate in nutrient solution 0.9%		0.45%		0.22%		0.11%	
38		40		37		34		30	
25		53		49		51		15	
49		50		30		31		5	
55		35		37		43		31	
37		50		46		41		47	
41		37		43		45		50	
34		50		43		44		41	
14		48		37		34		44	
12		31		26		34		34	
43		45		47		55		40	
33		19		42		35		30	
22		39		34		41		45	
49		47		40		38		31	
30		48		36		35		28	
48	(530)	51	(643)	42	(589)	25	(586)	30	(501)
37		27		31		46		49	
51		44		48		54		50	
51		49		44		50		48	
43		38		48		45		40	
60		39		37		45		49	
60		42		28		41		49	
37		45		43		51		44	
40		50		35		38		52	
35		36		33		26		45	
52		47		32		42		56	
49		36		41		34		46	
65		58		39		39		57	
38		39		42		43		39	
48		34		15		35		60	
58	(724)	49	(633)	26	(542)	42	(631)	59	(743)
39		42		45		36		30	
51		47		46		45		35	
28		40		28		39		11	
37		43		21		45		40	
29		40		45		39		42	
42		40		43		43		41	
60		37		50		38		50	
49		43		26		30		45	
54		22		32		48		58	
35		33		35		49		32	
39		44		38		43		47	
39		34		49		40		46	
39		37		42		45		44	
30		47		33		29		33	
40	(611)	3	(552)	25	(558)	15	(584)	25	(579)
Tot.	1863		1828		1689		1801		1823
P. I.			1.9%		9.3%		3.3%		2.1%

Triton X-150 2%
Table 29. DDT 25%, Xylene 72% and Triton X-160 1%

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
54		43		33		38		38	
59		32		49		45		41	
59		36		52		39		43	
45		51		23		32		56	
47		28		36		55		56	
33		37		31		44		48	
30		23		30		36		41	
42		26		43		33		28	
38		39		39		22		35	
55		40		35		32		22	
29		38		27		32		18	
35		27		35		30		43	
34		37		37		25		33	
34		39		46		35		13	
37	(631)	38	(534)	38	(554)	36	(534)	2	(517)
42		30		28		34		48	
39		42		41		49		51	
36		28		46		48		46	
29		34		34		40		29	
40		40		23		25		22	
37		30		29		33		33	
30		30		56		66		33	
31		32		35		36		23	
33		35		29		39		30	
39		41		38		49		33	
36		57		51		34		27	
37		31		33		36		33	
22		36		61		36		35	
30		32		40		37		31	
25	(506)	13	(511)	29	(573)	37	(599)	49	(523)
31		30		29		31		53	
32		36		29		24		44	
62		42		39		36		48	
38		25		45		30		35	
35		32		35		24		44	
23		54		33		36		49	
33		26		28		43		45	
28		34		28		45		26	
28		17		27		41		35	
32		45		24		36		25	
30		47		32		33		42	
35		23		16		30		30	
35		33		30		23		20	
28		5		55		30		34	
37	(507)	5	(454)	33	(483)	21	(483)	20	(550)
Tot.	1644		1499		1610		1616		1590
P. I.			8.8%		2.1%		1.7%		3.3%

Table 30. DDT 25%, Xylene 72% and Aerosol OT 3%

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
52		3		27		37		55	
71		3		32		33		73	
32		4		16		35		42	
40		2		9		43		48	
37		3		29		29		42	
36		5		42		40		17	
30		4		10		41		34	
37		5		37		45		31	
55		3		30		40		31	
68		3		23		28		44	
43		5		23		25		30	
36		4		19		38		49	
50		5		38		21		46	
44		6		5		29		38	
38	(669)	6	(60)	22	(362)	36	(520)	33	(613)
36		3		13		28		23	
34		8		23		29		26	
44		8		31		35		33	
36		8		36		32		51	
37		7		36		42		30	
36		6		18		47		32	
37		8		9		20		33	
40		7		20		32		52	
46		7		24		34		7	
28		8		34		41		50	
29		3		31		35		32	
38		6		22		16		38	
29		3		12		36		31	
30		6		25		35		26	
29	(529)	3	(91)	25	(359)	7	(469)	29	(493)
50		4		29		33		61	
36		7		17		44		62	
44		6		19		48		41	
45		8		24		40		65	
52		8		31		39		33	
38		10		16		53		29	
47		8		26		40		28	
38		11		25		41		25	
34		7		26		26		43	
31		7		13		54		37	
28		8		21		36		44	
47		2		12		49		44	
40		8		24		39		37	
35		7		7		4		35	
30	(595)	8	(109)	20	(310)	44	(590)	26	(610)
Tot.	1823		260		1031		1579		1716
P. I.			85.6%		43.5%		13.4%		5.9%

Table 31. DDT 25%, Xylene 71% and Toximul 300 4%

Control		Percentage of concentrate in nutrient solution 0.9%		0.45%		0.22%		0.11%	
55		34		68		63		71	
45		19		67		44		68	
79		45		66		70		42	
35		17		58		40		58	
48		42		50		43		51	
33		40		42		65		69	
62		50		44		60		45	
34		38		26		47		52	
66		28		23		39		66	
58		36		48		52		50	
56		26		46		30		49	
23		20		41		6		26	
33		17		65		7		6	
47		20		60		6		6	
30	(704)	25	(427)	9	(713)	11	(563)	23	(682)
60		36		63		51		68	
56		28		51		47		58	
62		36		48		68		72	
44		26		35		59		67	
52		30		35		65		43	
45		46		51		55		71	
61		44		51		38		50	
39		46		64		33		63	
76		32		47		36		66	
52		9		47		55		54	
59		35		14		42		28	
39		47		44		29		30	
31		20		29		37		46	
51		4		3		29		26	
42	(769)	6	(445)	3	(585)	11	(655)	35	(777)
53		40		12		44		40	
45		53		26		44		59	
43		34		23		51		36	
48		30		44		57		28	
56		35		44		47		67	
51		41		12		62		37	
73		37		37		56		46	
39		59		55		45		52	
20		30		65		58		24	
57		32		26		40		68	
45		25		24		44		58	
33		62		49		35		45	
25		17		51		39		41	
14		31		41		17		11	
18	(620)	37	(553)	39	(548)	24	(633)	6	(618)
Tot.	2093		1425		1846		1901		2077
P. I.			31.9%		11.8%		9.2%		.8%

Table 32. DDT 25%, Xylene 69% and Toximul 400 6%

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
49		39		27		39		37	
49		41		54		34		39	
63		32		22		22		35	
53		38		45		41		46	
60		54		35		56		18	
57		39		40		44		30	
53		33		31		53		33	
64		38		45		64		35	
54		17		29		36		30	
28		11		38		58		37	
49		19		39		39		45	
57		35		35		28		30	
42		26		19		36		30	
53		45		20		33		25	
62	(793)	56	(523)	37	(516)	36	(619)	16	(486)
28		34		41		43		30	
60		45		37		37		57	
56		39		7		36		39	
28		37		40		46		57	
60		26		67		36		38	
50		33		28		32		36	
44		26		45		29		51	
64		50		52		42		58	
33		9		39		28		54	
40		32		45		38		38	
12		47		40		32		40	
19		45		43		21		62	
51		10		53		41		56	
56		29		22		15		42	
61	(662)	43	(505)	4	(563)	34	(510)	26	(684)
55		33		50		46		64	
77		41		52		27		43	
59		46		33		39		6	
48		47		14		31		50	
27		26		37		7		37	
58		43		60		34		50	
54		11		51		45		60	
58		8		45		31		54	
32		49		42		55		46	
69		51		48		22		59	
58		40		43		49		19	
45		26		17		30		26	
53		17		45		21		32	
33		56		35		21		29	
30	(756)	19	(513)	24	(596)	42	(500)	39	(612)
Tot.	2211		1541		1675		1629		1782
P. I.			30.3%		24.2%		21.8%		19.4%

Table 33. DDT 25%, Xylene 73% and Santomerse D 2%

Control		Percentage of concentrate in nutrient solution							
		0.9%		0.45%		0.22%		0.11%	
52		27		43		48		61	
71		36		22		33		32	
32		30		45		53		57	
40		31		40		29		54	
37		42		37		29		34	
36		46		52		33		34	
30		35		28		30		45	
37		57		38		60		21	
55		35		40		47		37	
68		41		37		36		45	
43		44		38		57		43	
36		28		27		24		31	
50		44		28		43		32	
44		33		31		38		32	
38	(669)	39	(568)	11	(517)	37	(597)	36	(594)
36		29		35		43		21	
34		35		58		25		41	
44		38		59		38		47	
36		37		46		43		35	
37		33		32		43		46	
36		28		52		58		48	
37		30		65		29		32	
40		24		34		34		38	
46		37		42		32		38	
28		27		43		51		48	
29		28		51		32		56	
38		28		11		25		41	
29		34		19		34		42	
30		30		44		35		51	
29	(529)	25	(463)	23	(614)	28	(550)	39	(623)
50		35		63		38		54	
36		32		38		34		60	
44		33		49		43		68	
45		31		40		46		36	
52		38		33		26		40	
38		35		63		26		71	
47		43		33		23		47	
38		30		22		25		25	
34		32		35		34		37	
31		46		36		35		39	
28		35		15		33		69	
47		47		36		38		39	
40		32		49		31		31	
35		59		31		28		40	
30	(595)	45	(573)	36	(579)	29	(489)	40	(696)
Tot.	1793		1604		1710		1636		1913
P. I.			10.5%		4.6%		8.8%		-6.7%

TABLE 34

PHYTOTOXIC INDEX AND WEIGHTS
IN GRAMS OF CUCUMBER PLANTS

DDT Formulation*	Control	Percentage of concentrate in nutrient solution 0.9%	0.45%	0.22%	0.11%	
Aerosol QT	1.721	.585 79.0%	1.220 29.1%	1.455 15.5%	1.695 1.5%	g. P. I.
Toximul 300	2.321	2.000 13.8%	2.050 11.7%	2.146 7.5%	2.452 -5.7%	
Toximul 400	2.440	1.795 26.6%	1.890 22.5%	1.925 21.1%	2.050 16.0%	
Santomerse D	1.721	1.665 3.2%	1.828 -6.2%	1.741 -1.2%	1.951 -13.4%	
Areskap 50	2.605	2.375 8.8%	2.520 3.3%	2.565 1.5%	2.488 4.5%	
Polyethylene Glyco 400	1.610	1.520 5.6%	1.490 7.5%	1.335 17.1%	1.585 1.6%	
Triton X-100	1.990	1.615 18.8%	1.703 14.4%	1.930 3.0%	1.811 1.6%	
Tritons X-150 & X-160	1.990	1.995 -0.3%	1.790 10.5%	1.920 3.5%	2.140 -7.5%	
Triton X-155	1.610	1.645 -2.2%	1.665 -3.4%	1.834 -13.9%	1.725 -7.1%	
Tritons X-165 & B-1956	2.197	2.860 -30.2%	2.460 -12.0%	2.540 -15.6%	2.510 -14.2%	
Emcol H-77	2.197	2.045 6.[illegible]%	2.194 -0.1%	1.970 10.3%	2.125 3.3%	

*Only the emulsifier used is given for each formulation.

Each figure represents the total for forty five plants.