# THE EFFECT OF VARIOUS CHEMICALS AS SELECTIVE HERBICIDES FOR BRITISH SOVEREIGN STRAWBERRIES (Fragaria chiloensis).

by

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## ABSTRACT

Five experiments in all were carried out with the object of studying the use of selective herbicides on British Sovereign strawberries. Before laying out a large replicated experiment it was felt that (a) the general response of strawberry plants to various herbicides and (b) the effect of these herbicides on both broad-leaved weeds and grasses should be determined. Small plots were laid out on a three year old strawberry plantation and subjected to 34 different treatments (Experiment I). Similar treatments were applied in Experiments II and III to newly seeded and established grasses. These treatments consisted of different concentrations and mixtures of the following:

2,4-dichlorophenoxyacetic acid (2,4-D)
Sodium salt of trichloroacetic acid (TCA)
Ammonium salt of isopropyl N-phenyl carbamate (IPC)
2 methyl-4-chlorophenoxyacetic acid (MCP)
Sodium pentachlorophenate (PCP)
Ammonium salt of dinitro-O-secondary butyl phenol (DNOSBP)
Potassium cyanate
Emulsifiable pentachlorophenol

The effects of these treatments on the strawberry plants, grasses and broad-leaved weeds are reported and discussed.

In the final experiment six treatments (2,4-D and 2,4-D plus IPC) were laid out in three replicates on a maiden British Sovereign strawberry plantation. Treatments of 1, 2, 3 and 4 pounds of 2,4-D per acre and 2 pounds of 2,4-D plus 40 pounds of IPC per acre were compared with a hand-weeded check. It was found from these experiments that (1) the sprays should be applied when the weeds are small and succulent, especially is this true for annuals; and (2) that under conditions of this experiment a mixture of 2 pounds of 2,4-D plus 40 pounds of IPC can be safely recommended for the deweeding of British Sovereign strawberry plantations provided it is not used when the plants are in blossom.

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# THE EFFECT OF VARIOUS CHEMICALS AS SELECTIVE HERBICIDES FOR BRITISH SOVEREIGN STRAWBERRIES (Fragaria chiloensis).

## INTRODUCTION

Information on the use of herbicides for weed control in strawberries is limited, but grower interest has increased to the point where recommendations for safe usage are needed. From the limited investigations (6,13,17,19,23) of the past three years it has been shown that strawberry varietal responses to 2,4-D (this abbreviation will be used for 2,4-dichlorophenoxyacetic acid throughout the paper) are wide and, for that reason, it is imperative that the response of the British Sovereign strawberry to 2,4-D be determined since this variety is used extensively in commercial plantings in the Fraser Valley. In addition a number of new herbicides have made their appearance since 2,4-D and it is possible that some of them may have a place for weed control in strawberries.

With the above points in mind the following experiments were carried out:

1. An exploratory experiment with several herbicides and a large range of concentrations to determine their effect

on British Sovereign strawberry plants.

2. An exploratory experiment with several herbicides and a large range of concentrations to determine their effect on well established grass and weeds.

3. A follow up of experiments 1 and 2 conducted in the greenhouse under controlled conditions to determine the effect of various concentrations of the more promising herbicides on newly germinated grass seedlings.

4. An experiment in the greenhouse with various combinations and concentrations of 2,4-D and Isopropyl N-phenylcarbamate (I.P.C.) to determine the most effective combinations to be used in deweeding of strawberries.

5. An experiment to study the effect of various concentrations of 2,4-D and 2,4-D supplemented with I.P.C, on both weeds and strawberry plants in the field.

## REVIEW OF LITERATURE

Strawberry weed control has long been a laborious and expensive process where mild winters, such as experienced in the Fraser Valley, promote the germination and growth of grasses and weeds throughout the winter months. Annual broad-leaved weeds and grasses are the most troublesome in the first-year bed, while the fruiting bed often becomes infested with perennial weeds and grasses. Growers estimate

that costs of cultivation, hoeing, and hand weeding run up to $100 and more per acre per season.(18)

Various methods and suggestions have appeared from time to time in the literature for easing this problem. However, as mentioned in the introduction, information on the use of herbicides for weed control in strawberries is limited.

Bush (2) describes a method using tar-oil for controlling weeds in strawberry beds. Tar-oil at 8% in water is applied between the rows in autumn, taking care to avoid the strawberry crowns. When the weeds die the soil is lightly turned, leaving a clean bed.

Elder, Elwell and Romshe (8) state that there is some evidence that most strawberry varieties are fairly resistant to 2,4-D. They state it may be used throughout the growing season the first year plants are set, but on older beds it should be used only after the harvest season. Some distortion of leaves and runners will be seen, but the plants usually recover and continue normal growth. Applications three to four days after thorough shallow cultivations are most effective. The suggested rate is one pound (acid equivalent) per acre, with applications not closer than four weeks unless heavy rain should fall in the meantime.

The Division of Horticulture, Dominion Experimental Farm Service, (23) reports that a sodium salt, an amine salt and a butyl ester of 2,4-D each at the rates of one-half, one and two pounds acid equivalent per acre were applied to

the foliage of several varieties of strawberry plants. Included in the test were the varieties: Ambrosia, Big Joe, Crimson Glow, Daybreak, Fairpeake, Gandy, Massey, Maytime, Premier, Red Star, Redwing and a seedling O-374. The one-half pound rate caused slight curvature and twisting of the petioles of all the varieties. Moderate distortion of all the varieties resulted from the two pound rate. Application of the amine resulted in injury similar to that caused by the sodium salt. The degree of distortion, however, was greater and ranged from slight to considerable. The ester was the most injurious and caused distortion ranging in degree from slight to severe. Varietal differences in susceptibility to the 2,4-D were evident. The variety Fairpeake appeared to be the most resistant to the 2,4-D.

Reports (21) from four locations indicate that fruiting plants of three varieties are tolerant of 2,4-D applications up to one pound, acid equivalent, per acre. Higher dosages caused severe distortion of leaves but did not kill the plants nor reduce the production of runner plants. No differences between amine salt, sodium salt and ester formulations were reported. Seedling plants, however, showed a great variation in tolerance. Control of annual weeds was satisfactory, in all cases, but one pound did not control perennial weeds.

Carder (3) reporting on the control of dandelions in strawberries by 2,4-D states that rates of 8,16, and 32 ounces, acid equivalent, per acre of butyl ester of 2,4-D

were applied at three growth stages of Dakota strawberry, viz., just previous to flowering, at time of flowering, and in late summer after harvest. The strawberry plants showed no injury from 8 and 16 ounce rates but exhibited curling of leaves from the 32 ounce spraying at time of flowering. Most complete kill of the dandelions was effected by treating before the strawberry plants were in full flower. Spraying at this time eliminated the dandelions 55, 70 and 80 per cent with the 8, 16 and 32 ounce rates respectively. Many old established dandelions had only their tops killed and later fully recovered.

Nylund (17) studying the use of 2,4-D for weed control in Arrowhead strawberries found that the isopropyl ester at one pound per acre and the sodium salt at one and two pounds per acre, satisfactorily controlled broad-leaved weeds. Some distortion of the leaves and runners of the strawberry plants was noticeable. Leaf counts and runner plant counts indicated no detrimental effect of the 2,4-D on either leaf production or on runner plant formation.

According to Carlson (4) spraying against broad-leaved weeds with 2,4-D at 1,000 parts per million was successful without damage to the strawberry plants at any time in the first season of planting -- in which no crop is required -- and after harvest in the second year.

Carlson and Moulton (5) investigating the use of the ammonium salt of trichloroacetate, the sodium salt of

trichloroacetate, ammonium thiocyanate and herbicide "PB", in the eradication of grasses, and the effect of these chemicals on strawberry and raspberry plants found that both the ammonium and sodium salts of trichloroacetate (TCA) gave slow but effective control of couch grass, Agropyron repens, and Kentucky bluegrass, Poa pratensis, under greenhouse conditions, if applied at the rates of 150 -200 pounds per acre in the case of well established grass and of 40 - 80 pounds per acre in the case of young growth. After a gradual colour change the leaves became chlorotic and withered 4 weeks after treatment. Ammonium thiocyanate proved less effective than the two salts of TCA, and "PB". The latter killed broad-leaved weeds without injuring the grasses. The strawberries were killed by the TCA salts when applied at herbicidal strength.

A preliminary report by Slife and Ball (19) states that TCA was applied to the Premier variety of strawberry, at the rates of 10, 20, 30, 40, and 50 pounds, acid equivalent, per acre. In all plots, plants were severely burned and on a later date, there was no evidence of recovery.

Otis (18) states that good results were obtained with a mixture of water and Diesel oil fortified with Dow General Weed Killer (a concentrate of Dinitro-o-secondary-butylphenol). Proportions used were 1 quart of Dow General, 30 gallons of Diesel oil, and 100 gallons of water. The material was sprayed so as to thoroughly wet the vegetation.

On small weeds 125 to 150 gallons per acre are usually sufficient. The oil-dinitro-water mix kills back top growth but does not injure crowns or root systems of perennials. Hence strawberries treated even after growth was well started were only temporarily "burned" back. By the same token, of course, annual weeds and grasses are eradicated, but established perennial weeds are not.

Much work, the principles of which may prove of value in the weed control of strawberries, has been done by Hitchcock and Zimmerman (12) on the activation of 2,4-D by various adjuvants. They found that mixtures of 2,4-D and certain adjuvants (Benclor 3C, ammonium thiocyanate, ammonium sulphamate, Hammond's Weed Killer, diallyl maleate, sodium bicarbonate, and sodium chloride) were more effective herbicides than any of the individual components used at the same concentration. Adjuvants which functioned as activators of 2,4-D included wetting agents, solubilizers, emulsifiers, penetrants, hormones other than 2,4-D and toxicants commonly used as contact herbicides. Mixtures containing lethal and sub-lethal concentrations of contact herbicides increased the activity of the hormone-like preparations with respect to the induction of hormone-curvature responses, initial injury to foliage, and killing of the entire plant. The herbicidal activity of these mixtures increased with increasing concentrations of the contact weed killer up to the point where the mixture was no more effective than the

contact weed killer used alone at the same concentration as in the mixture. Relatively high concentrations of contact herbicides (1% to 30%) were required to prevent 2,4-D from inducing additive effects. They conclude that it is believed that more effective general-purpose herbicides than those used to date are likely to contain more than one hormone, at least one toxicant, and additional adjuvants which are effective as wetting agents, solubilizers, penetrants, emulsifiers, and stickers.

A description is given by Hance (10) of a method used in the Hawaiian Islands to supplement the herbicidal effect of 2,4-D and at the same time reduce its injurious effect on sugar-cane. It has been found that in certain cases the amount of 2,4-D applied may be reduced to a concentration harmless to germinating sugar-cane -- say two pounds per acre -- while at the same time maintaining for three months or longer its full pre-emergence herbicidal effect on the field, provided that 2,4-D is supplemented with about five times its weight of H.S.P.A. activator (pentachlorophenol, or sodium pentachlorophenate). Some similar method might prove of value in the weed control of strawberries.

# EXPERIMENT I

Object:

To determine the effect of various concentrations of several different herbicides and combinations of herbicides on British Sovereign strawberry plants.

Materials and Methods:

Plots one square yard in area of established British Sovereign strawberry plants were sprayed with the various treatments as shown in table 1. All sprays were applied with a knapsack sprayer. General notes were taken periodically following the applications and the effect of the sprays upon the strawberry plants noted.

Table 1 - Treatments Applied to Established British Sovereign Strawberry Plants. (1949)

| Treat: No. | Material | Rates per acre | Volumes gals/acre | Date sprayed | Temp: F |
|---|---|---|---|---|---|
| 1. | TCA | 25,40,80,100 & 200 pounds | 150 | May 23 v | 72° |
| 2. | TCA plus 2,4-D | 25,40,80,100 & 200 pounds 1000 ppm | 150 | May 23 | 72° |
| 3. | 2.4-D | 1000 ppm | 150 | May 25 | 73° |
| 4. | IPC | 5,10,20,30,40,50, 60,70 & 80 lbs. | 150 | May 25 | 73° |
| 5. | IPC plus 2,4-D | 5,10,20,30,40,50 60,70 & 80 lbs. 1000 ppm | 150 | May 25 | 73° |
| 6. | MCP | 1 & 2 lbs. | 150 | June 7 | 71° |
| 7. | PCP | 24 lbs. | 150 | June 8 | 75° |
| 8. | DNOSBP | 2qt/100 gal $H_2O$ | 75 | June 8 | 75° |
| 9. | Untreated | | | | |

Legend:

TCA - Sodium salt of Trichloroacetic acid
2,4-D - 2,4-Dichlorophenoxyacetic acid
IPC - Ammonium salt of Isopropyl N-phenol carbamate
MCP - 2 methyl-4-chlorophenoxyacetic acid
PCP - Sodium pentachlorophenate
DNOSBP- Ammonium salt of dinitro-O-secondary butyl phenol

## RESULTS

On May 24 (one day following spraying with TCA and TCA plus 2,4-D) TCA at 25 pounds per acre caused marginal browning of the strawberry leaves and this browning increased directly with increased concentration of TCA until at 100 and 200 pounds per acre the leaves were completely browned. Treatment 2 (TCA plus 2,4-D) gave similar results.

On June 17 (twenty-five days following spraying with TCA and TCA plus 2,4-D) new leaves appeared from all plants treated with TCA and TCA plus 2,4-D. The plants sprayed with 2,4-D at 1000 ppm showed slight curvature and twisting of petioles and curling of leaves. Treatment 4 (IPC) regardless of concentration appeared to have no effect upon the strawberry plants. Treatment 5 (IPC plus 2,4-D) affected the plants the same as described above for 2,4-D alone. Treatment 6 (MCP) caused slight curling of the leaves and twisting of petioles. Treatment 7 (PCP) caused slight browning to leaves and blossoms and also caused considerable damage to the fruit. Treatment 8 (DNOSBP) caused partial browning of the leaves.

A final survey was made on August 1 of all plots and complete notes taken. Following are a few brief extracts taken from these notes:

Treatment 1 (TCA)

The majority of the plants in TCA treated plots were dead. The odd plant in plots treated with 25, 40 and 80

pounds of TCA showed a few small green leaves breaking from the crown, but in plots treated with 100 and 200 pounds per acre all plants were completely dead.

Treatment 2 (TCA plus 2,4-D)

The results from these treatments were the same as described above for TCA only the plants were in a worse condition.

Treatment 3 (2,4-D)

The plants in these plots appeared to be developing normally all distortions of petioles and leaves had disappeared.

Treatment 4 (IPC)

All IPC treated plants appeared to be developing normally and were as vigorous as the untreated plants.

Treatment 5 (IPC plus 2,4-D)

Plants under this treatment also appeared to be developing normally though not quite as vigorously as those plants treated with IPC alone.

Treatment 6 (MCP)

Plants treated with MCP at 1 and 2 pounds per acre appeared to be recovering, but leaves were rather small. The plants as a whole appeared sick.

Treatment 7 (PCP)

Plants were recovering, but the leaves appeared smaller than normal. Also no fruit was obtained from these plants after spraying since as mentioned previously this treatment dried up the blossoms and fruit.

Treatment 8 (DNOSBP)

Plants treated with DNOSBP had recovered though in general the plants were smaller than those treated with IPC.

## DISCUSSION

The results with TCA in this experiment are in agreement with those obtained by Carlson and Moulton, (5) who report that strawberries were killed by the TCA salts when applied at herbicidal strength. The Fifth Annual North Central Weed Control Conference Research Report (21) states that TCA, at a rate as low as 10 pounds, acid equivalent, per acre caused severe injury to strawberry plants. Thus in light of these reports and the results obtained in this experiment it appears that TCA is worthless as a weedicide for strawberries.

On the other hand, IPC apparently did not have any effect upon the strawberry plants. Lachman (14) found that IPC was valuable as a selective herbicide in that it effectively kills grasses with little or no harm to broad-leaved plants. Thus IPC should prove useful as a control for grasses in strawberry plantings.

From the results of this experiment it is also seen that 2,4-D at 1000 ppm and IPC plus 2,4-D apparently did not have any lasting detrimental effects upom the strawberry plants. The Fifth Annual North Central Weed Control

Conference Research Report (21) states that reports from four locations indicate that fruiting plants of three varieties of strawberries are tolerant to 2,4-D applications up to one pound, acid equivalent, per acre. Higher dosages caused severe distortion of leaves but did not kill the plants nor reduce the production of runner plants. No differences between amine salt, sodium salt and ester formulations were reported. Carder (3) reported that strawberry plants showed no injury from 8 and 16 ounce rates of 2,4-D, but exhibited curling of leaves from 32 ounce spraying. According to Davidson (6) 16 ounce concentrations of 2,4-D caused slight formative effects on the new strawberry foliage (variety Premier), which emerged immediately after treatments. Nylund (17) states that leaf counts and runner plant counts indicated no detrimental effect of 2,4-D on either leaf production or on runner plant formation (variety Arrowhead). Slife and Ball (19) report that Premier strawberry was sprayed with 0.50, 0.75, 1.0, 2.0, and 3.0 pounds per acre of the amine preparation of 2,4-D. The twisting and curling effect was slight on the 0.50 and 0.75 pound application, but rather severe on the 1, 2 and 3 pound rates. Within one month from application, all plots appeared normal and showed no apparent effects of treatment. According to Klein (13) the premier strawberry tolerated a weed-killing spray of 1,400 ppm of 2,4-D in July and August; two applications were made, three weeks apart. It is apparent from the results of this experiment and of those quoted that 2,4-D and 2,4-D plus IPC

hold promise as selective weedicides for British Sovereign strawberries.

From the results of this experiment it is easily seen that PCP, MCP and DNOSBP are all too injurious to actively growing strawberry plants. It is possible that these chemicals may prove useful as weedicides if applied after harvest or when the plants are dormant.

## CONCLUSIONS

Of the various chemicals tested in this exploratory experiment it appears that 2,4-D and 2,4-D supplemented with IPC offer the greatest promise as selective herbicides for British Sovereign strawberries during the growing period. Furhher experimentation is definitely warranted in order that complete information as to most effective concentrations and combinations of these chemicals can be determined.

## EXPERIMENT II

Object:

To determine the effect of various concentrations of several different herbicides and combinations of herbicides on well established grass and weeds.

Materials and Methods:

Plots one yard square were laid out on a weed

Table 2 - Treatments Applied to Well Established Grass and Weed Plots. (1949)

| Treat: No. | Material | Rates per acre | Volumes gals/acre | Date sprayed | Temp: F |
|---|---|---|---|---|---|
| 1. | TCA | 25,40,80,100 & 200 lbs. | 150 | May 26 | 71° |
| 2. | TCA plus 2,4-D | 40 & 100 lbs. 1000 ppm | 150 | May 26 | 71° |
| 3. | IPC | 10,30,50 & 80 lbs. | 150 | May 26 | 71° |
| 4. | IPC plus 2,4-D | 10,50 & 80 lbs. 1000 ppm | 150 | May 26 | 71° |
| 5. | MCP | 1 & 2 lbs. | 150 | June 7 | 71° |
| 6. | PCP | 24 lbs. | 150 | June 8 | 75° |
| 7. | DNOSBP | 2 qt/100 gal $H_2O$ | 75 | June 8 | 75° |
| 8. | Untreated | | | | |

Legend:

TCA - Sodium salt of Trichloroacetic acid
2,4-D - 2,4-Dichlorophenoxyacetic acid
IPC - Ammonium salt of Isopropyl N-phenol carbamate
MCP - 2 methyl-4-chlorophenoxyacetic acid
PCP - Sodium pentachlorophenate
DNOSBP- Ammonium salt of dinitro-O-secondary butyl phenol

infested piece of turf. Grasses present were couch grass, Agropyron repens, Kentucky bluegrass, Poa pratensis, and a scattering of other miscellaneous grasses. These plots provided a more extreme grass and weed condition than would normally be encountered in a strawberry plantation. The potential herbicidal value of these sprays could be best determined under such conditions. The plots were treated as shown in table 2. Heavy rains followed within 12 hours after applications of treatments 1, 2, 3 and 4. All sprays were applied with a knapsack sprayer. General notes were taken periodically following the applications and the effect of the sprays upon the grass and weed growth recorded.

## RESULTS

Extracts from the general notes taken on June 1 are as follows:

Treatment 1 (TCA)

- at 25 pounds per acre - no apparent effect.
- at 40 pounds per acre - slight browning of the grass.
- at 80 pounds per acre - browning of the grass slightly more than 40 pounds.
- at 100 pounds per acre - appeared the same as the 80 pound treatment.
- at 200 pounds per acre - appeared to be hitting

dandelion, plantain, etc., more severely than the lower concentrations. The grass was only slightly browner than in the plots of lower concentrations.

Treatment 2 (TCA plus 2,4-D)

- at 40 pounds per acre plus 2,4-D - browning of grass and marginal browning of broad-leaved weeds. Some curling of plantain leaves.
- at 100 pounds per acre plus 2,4-D - There appeared to be less browning of the grass foliage as compared to 50 pounds per acre plus 2,4-D.

Treatment 3 (IPC)

- no apparent effect from any of the concentrations on the grass or the weeds.

Treatment 4 (IPC plus 2,4-D)

- all concentrations show slight 2,4-D effect on broad-leaved weeds, but no effect apparent on the grass.

Further notes were taken on June 17, extracts of which follow:

Treatment 1 (TCA)

- at 40 pounds per acre grass slightly burned and as the concentration increases burning of grass increases until at 200 pounds per acre some of the grass is definitely dead.

Treatment 2 (TCA plus 2,4-D)

- at 40 pounds per acre plus 2,4-D - plantain dying, dandelion showing effects, grass browning.

- at 100 pounds per acre plus 2,4-D 1000 ppm as above but damage more severe.

Treatment 3 (IPC)

- no apparent effect from any of the concentrations on the grass or weeds.

Treatment 4 (IPC plus 2,4-D)

- only 2,4-D effect on broad-leaved weeds apparent.

Treatment 5 (MCP)

- little effect on the grass.

Treatment 6 (PCP)

- grass showed browning.

Treatment 7 (DNOSBP)

- grass showed some browning.

An extract from notes taken on June 30 follows:

Treatments 3 & 4 (IPC & IPC plus 2,4-D)

- all plots at this time were showing the following effects: grass stunted and browned; broad-leaved weeds showed typical 2,4-D damage.

A final survey was made of all the plots on August 1, and brief extracts follow:

Treatment 1 (TCA)

- in all plots treated with TCA above 25 pounds per acre all grasses appeared dead. The broad-leaved weeds, however, spread rapidly.

Treatment 2 (TCA plus 2,4-D)

- This treatment in addition to killing the grass

also controlled the broad-leaved weeds to a degree -- plantain appeared to be completely eradicated, whereas the well established dandelion and yellow cress showed recovery.

Treatments 3 & 4 (IPC & IPC plus 2,4-D)

- In all plots, grasses were partially killed and stunted. Broad-leaved weeds were growing in all plots, but to a lesser extent in plots treated with IPC plus 2,4-D.

Treatments 5, 6 & 7 (MCP, PCP & DNOSBP)

- Plots treated with these chemicals all showed partial and stunting of the grass.

## DISCUSSION

From the above results it is apparent that TCA will effectively control well established couch grass, Kentucky bluegrass and other grasses if applied at 40 pounds per acre. TCA plus 2,4-D appears promising as a weedicide for land infested with both perennial grasses and broad-leaved weeds.

Carlson and Moulton (5) report that both ammonium and sodium salts of trichloroacetate (TCA) gave slow but effective control of couch grass and Kentucky bluegrass under greenhouse conditions, if applied at the rates of 150 - 200 pounds per acre in the case of well established grass and 40 - 80 pounds per acre in the case of young growth.

Barrons (1) obtained good kills of couch grass from as little as 40 pounds per acre.

In this experiment IPC required approximately a month before effect upon the grass was apparent. However, as seen from the results IPC finally gave a fairly effective control of the grasses present though not as absolute a control as was obtained from TCA. Broad-leaved weeds were apparently not harmed except in those plots to which 2,4-D had been added.

Lachman (14) found that IPC was valuable as a selective herbicide in that it effectively kills grasses with little or no harm to broad-leaved plants.

Mitchell and Marth (16) report that when IPC was applied at relatively high rates (50 and 100 pounds per acre) to potted soil in which crab grass had become established and had developed leaves extending about 1 - 2 cm. above the surface of the soil, the plants failed to grow further and died within a period of two weeks following treatment.

In light of the results obtained in Experiment 1 it would appear that a suitable combination of IPC and 2,4-D should offer promise as a weed-killer in plantations of actively growing British Sovereign strawberries where weeds and grasses are plentiful.

PCP, MCP and DNOSBP gave no better control of grasses than did IPC under conditions of this experiment. Since the results of Experiment 1 show they cause considerable

harm to actively growing British Sovereign plants it can be concluded that they offer little promise as weedicides for strawberries during the growing period.

## CONCLUSIONS

Of the various herbicides tested in this exploratory experiment it appears that IPC plus 2,4-D offers the greatest promise as a selective weedicide for British Sovereign strawberries during the growing period in plantations where both broad-leaved weeds and grasses are plentiful.

## EXPERIMENT III

Object:

To determine the effect of various concentrations of the more promising herbicides (as previously determined from Experiments I and II) on newly germinated grass seedlings.

Materials and Methods:

Plots one square foot in area were laid out in flats in the greenhouse and sown to perennial rye grass on June 8. The following treatments were applied on June 20 at which time the grass was 2½ inches tall.

| Treatment No. | Material | Rate/acre |
|---|---|---|
| 1. | PCP | 10 lbs. |
| 2. | IPC | 10,40 & 80 lbs. (as a spray) |
| 3. | IPC | 40 & 80 lbs. (as a dust with sand) |
| 4. | IPC plus 2,4-D | 40 lbs.<br>1000 ppm |
| 5. | Untreated | |

Note:

PCP - Sodium pentachlorophenate
IPC - Ammonium salt of Isopropyl N-phenol carbamate

General notes were taken periodically following treatments and the effect of the sprays upon the grass recorded.

## RESULTS

A final survey of the flats was made on July 18, and cpmplete notes taken. Extracts from these notes follow:

Treatment 1 (PCP)

- partial kill and stunting of the grass.

Treatment 2 (IPC)

- at 10 pounds per acre - partial kill and stunting of the grass.
- at 40 pounds per acre - partial kill and stunting.
- at 80 pounds per acre - complete kill.

Treatment 3 (IPC dust)

- at both 40 and 80 pounds per acre - complete kill.

Treatment 4 (IPC plus 2,4-D)

- partial kill and stunting.

## DISCUSSION

From an examination of the above results it is seen that 40 pounds of IPC in sand gave complete kill of the perennial rye grass whereas only partial kill and stunting was obtained from 40 pounds of IPC in water; this may be due to the greater residual effect of dust. There was little difference in effect upon the grass between IPC (spray) at 10 pounds, 40 pounds or 40 pounds per acre plus 2,4-D. But IPC at 80 pounds per acre gave complete kill. Thus it would appear that the higher concentrations are required when IPC is applied as a spray. Mitchell and Marth (16) found that IPC is inactivated in the presence of moist, fertile soil.

PCP at 10 pounds per acre gave only partial kill and stunting. Therefore, it appears to be no better than IPC at 10 pounds per acre for killing perennial rye grass seedlings

and further from Experiment 1 it was shown that PCP was detrimental to the strawberry plants at higher concentrations. IPC would appear, therefore, to be the most promising herbicide for the control of grasses in strawberries.

## CONCLUSIONS

Further experimentation is required to determine the most effective combination of IPC and 2,4-D for use as a selective herbicide for British Sovereign strawberries.

## EXPERIMENT IV

Object:

To study the effects of various combinations and concentrations of 2,4-D and IPC and other promising herbicides on several kinds of newly germinated grass seedlings and British Sovereign strawberry plants in the greenhouse.

Materials and Methods:

Grass Seedlings

Three randomized blocks were laid out on the greenhouse benches. Each block consisted of 23 flats so that one flat constituted a plot. Each flat was 4 inches deep and 1 foot wide by 1½ feet long. One block of flats was filled

with composted soil while the flats of the other two blocks were filled with garden soil (sandy loam). On August 18, 1949, the 69 flats were sown with the following grasses: creeping red fescue (Festuca rubra; perennial rye (Lolium perenne); orchard (Dactylis glomerata) and hog millet (Panicum miliaceum). Thus each flat contained the four species of grass seed sown so that each specie was in a separate band 4½ inches wide across the flat. Therefore, the effect of the various treatments upon each specie of grass could be easily studied.

Strawberry Plants

On August 18, 1949, sixty-nine uniform, young, British Sovereign strawberry plants were lifted from the field and planted in composted soil contained in tin pots 7 inches in diameter and 8 inches deep, with bottom drainage. The pots were then arranged in three randomized blocks on the greenhouse benches so that one pot constituted a plot (see figure 1 for general layout).

Treatments:

Both the grass seedlings and the strawberry plants were given the following treatments:

| Treatment No. | Material and Rates |
|---|---|
| 1 | ½ lb. 2,4-D per acre. |
| 2 - 6 | ½ lb. 2,4-D plus 10,20,40, 60 and 80 lbs. IPC per acre. |
| 7 | 1 lb. 2,4-D per acre. |

| | |
|---|---|
| 8 - 12 | 1 lb. 2,4-D plus 10,20,40 60 & 80 lbs. IPC per acre. |
| 13 | 2 lbs. 2,4-D per acre. |
| 14 - 18 | 2 lbs. 2,4-D plus 10,20,40, 60 & 80 lbs. IPC per acre. |
| 19 | 75 gal. per acre of emulsifiable Pentachlorophenol. |
| 20 | 150 gal. per acre of emulsifiable Pentachlorophenol. |
| 21 | 1% aero cyanate |
| 22 | 2% aero cyanate |
| 23 | Untreated |

Note:

2,4-D -- Sodium salt of 2,4-Dichlorophenoxyacetic acid. (Dow-Deweed).

IPC -- Ammonium salt of Isopropyl N-phenol carbamate.

Aero-cyanate -- 91% potassium cyanate prepared by American Cyanamide Co.

Emulsifiable pentachlorophenol -- oil-in-water. emulsion of pentachlorophenol prepared by Monsanto Chemical Co.

On August 30 all treatments were applied with a hand sprayer of one-pint capacity. Cardboard shields were held along the sides of each area being sprayed to avoid drift of the mixture (See figure 2.)

General notes, measurements and photographs were taken periodically following the applications and the effect of the sprays upon the various species of grasses and strawberry plants noted.

Figure 1 - General View Showing the Layout of the Plots in the Greenhouse.

Figure 2 - Method of Spraying Greenhouse Plots. Note the Cardboard Shields held along the sides of each area being sprayed to avoid drift of the mixture.

# RESULTS

Twelve days following application of the treatments the height of the Hog Millet was recorded. These were the only measurements made at this time since the Hog Millet appeared to be representative of the effects of the treatments on all the grasses. These measurements are shown in table 3 and figure 3.

On October 30, (two months after sprays had been applied) the grasses remaining were harvested (by clipping at the soil level) and weighed. The clipping results are presented in table 4 and in figures 6, 7, 8 and 9.

A complete statistical analysis of the results was made. However, only minimum significant differences at the .05 level will be shown here, but the complete analysis will be found in the appendix.

The treatment heights (from table 3) are listed below in descending order and entered alongside each is the amount of the difference from the previous value (M.S.D. 1.08).

| Treatment | Mean Height (cms) | Difference from prev.value. |
|---|---|---|
| 23 - Untreated | 14.3 | |
| 2 - ½lb. 2,4-D + 10lb. IPC | 12.7 | 1.6 |
| 1 - ⅛ lb. 2,4-D | 12.3 | 0.4 |
| 8 - 1 lb. 2,4-D + 10lb. IPC | 11.7 | 0.6 |

Table 3 - The Height of Hog Millet at Twelve Days following the Treatments. (1949)

| Treatment No. | Treatments (per acre) | Mean Height (cms) |
|---|---|---|
| 1. | ½ lb. 2,4-D | 12.3 |
| 2. | ½ lb. 2,4-D + 10 lbs. IPC | 12.7 |
| 3. | ½ lb. 2,4-D + 20 lbs. IPC | 11.3 |
| 4. | ½ lb. 2,4-D + 40 lbs. IPC | 10.7 |
| 5. | ½ lb. 2,4-D + 60 lbs. IPC | 10.0 |
| 6. | ½ lb. 2,4-D + 80 lbs. IPC | 8.3 |
| 7. | 1 lb. 2,4-D - | 11.3 |
| 8. | 1 lb. 2,4-D + 10 lbs. IPC | 11.7 |
| 9. | 1 lb. 2,4-D + 20 lbs. IPC | 10.3 |
| 10. | 1 lb. 2,4-D + 40 lbs. IPC | 9.0 |
| 11. | 1 lb. 2,4-D + 60 lbs. IPE | 8.0 |
| 12. | 1 lb. 2,4-D + 80 lbs. IPC | 7.7 |
| 13. | 2 lb. 2,4-D | 9.0 |
| 14. | 2 lb. 2,4-D + 10 lbs. IPC | 11.7 |
| 15. | 2 lb. 2,4-D + 20 lbs. IPC | 8.3 |
| 16. | 2 lb. 2,4-D + 40 lbs. IPC | 7.7 |
| 17. | 2 lb. 2,4-D + 60 lbs. IPC | 7.3 |
| 18. | 2 lb. 2,4-D + 80 lbs. IPC | 5.7 |
| 19. | 75 gal. Pentachlorophenol | 0.3 |
| 20. | 150 gal. Pentachlorophenol | 1.7 |
| 21. | 1 % aero cyanate | 3.0 |
| 22. | 2 % aero cyanate | 3.7 |
| 23. | Untreated | 14.3 |

M.S.D. = 1.08 cms.
for treatments (.05 level)

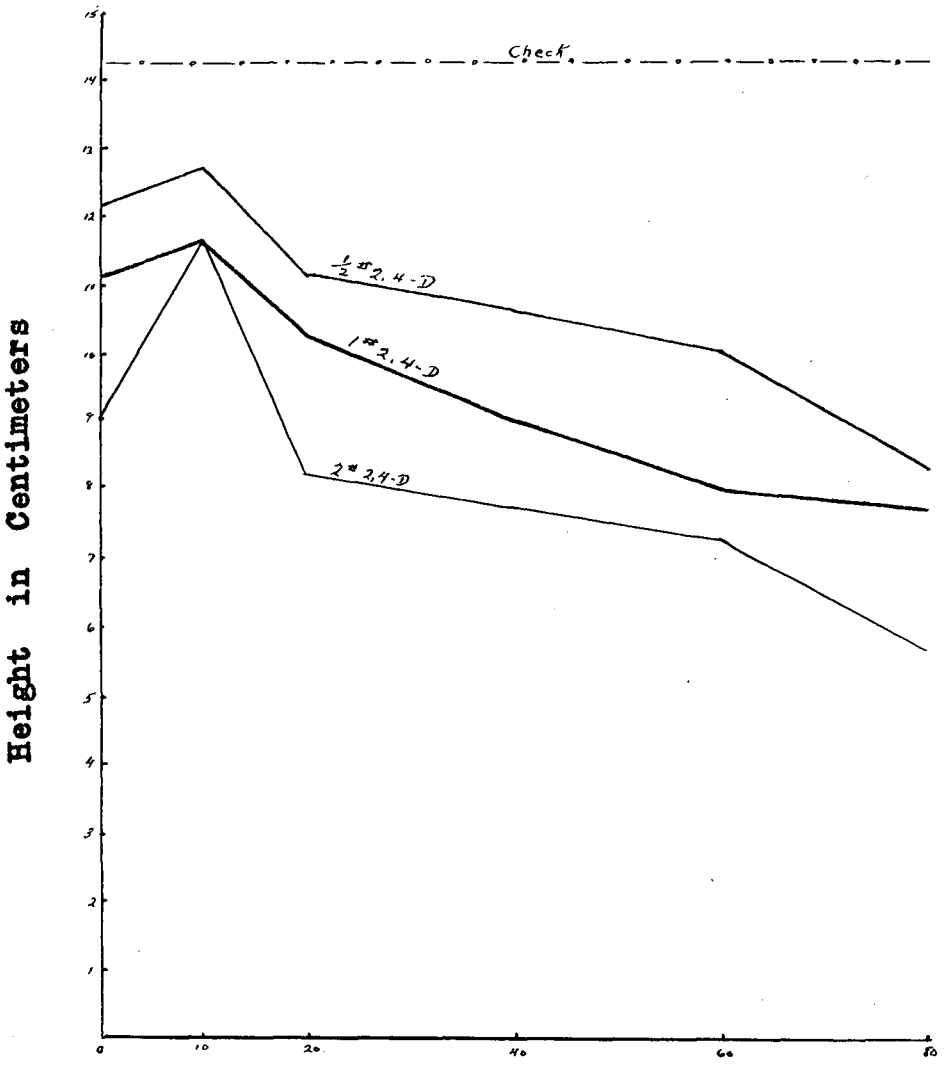


Figure 3 - Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the Height of Hog Millet (Panicum miliaceum) as at September 11, 1949.

| | | |
|---|---|---|
| 14 - 2 lb. 2,4-D + 10 lb. IPC | 11.7 | 0.0 |
| 3 - ½ lb. 2,4-D + 20 lb. IPC | 11.3 | 0.4 |
| 7 - 1 lb. 2,4-D | 11.3 | 0.0 |
| 4 - ½ lb. 2,4-D + 40 lb. IPC | 10.7 | 0.6 |
| 9 - 1 lb. 2,4-D + 20 lb. IPC | 10.3 | 0.4 |
| 5 - ½ lb. 2,4-D + 60 lb. IPC | 10.0 | 0.3 |
| 10 - 1 lb. 2,4-D + 40 lb. IPC | 9.0 | 1.0 |
| 13 - 2 lb. 2,4-D | 9.0 | 0.0 |
| 6 - ½ lb. 2,4-D + 80 lb. IPC | 8.3 | 0.7 |
| 15 - 2 lb. 2,4-D + 20 lb. IPC | 8.3 | 0.0 |
| 11 - 1 lb. 2,4-D + 60 lb. IPC | 8.0 | 0.3 |
| 12 - 1 lb. 2,4-D + 80 lb. IPC | 7.7 | 0.3 |
| 16 - 2 lb. 2,4-D + 40 lb. IPC | 7.7 | 0.0 |
| 17 - 2 lb. 2,4-D + 60 lb. IPC | 7.3 | 0.4 |
| 18 - 2 lb. 2,4-D + 80 lb. IPC | 5.7 | 1.6 |
| 22 - 2% aero cyanate | 3.7 | 2.0 |
| 21 - 1% aero cyanate | 3.0 | 0.7 |
| 20 - 150 gal. Pentachlorophenol | 1.7 | 1.3 |
| 19 - 75 gal. Pentachlorophenol | 0.3 | 1.4 |

Now any difference or cumulative difference greater than 1.08 the M.S.D. proves a significant decrease in height (repression of growth) over treatments higher up on the list. On this basis, treatment 19 is significantly better than any of the treatments. It follows that treatments 20, 21, and 22 in that order are significantly better than any of the remaining treatments. However, these treatments severely

damaged the strawberry plants (see figure 4) and thus are of no value as selective herbicides for actively growing strawberry plants.

The remaining treatments (2,4-D and 2,4-D + IPC) caused no apparent damage to the strawberry plants and thus can be considered. Now if the above list is studied along with figure 3 it will be noted that treatment 18 is significantly better than any other of the remaining treatments. There is no significant difference between treatments 17, 16, 12, 11, 15 or 6. However, treatments, 17, 16 and 12 are all significantly better than treatment 13 (see figure 5). There is no significant difference between treatment 13 or 5. But treatment 13 is significantly better than treatment 9. There is no significant difference between treatments 9, 4 and 7. Treatment 9 is significantly better than treatment 14. There is no significant difference between treatments 7, 3, 14, 8 and 1. Treatments 7 and 3 are significantly better than treatment 2. Finally, treatment 2 is significantly better than treatment 23.

It is also noted from the above list and figure 3 that the addition of only 10 pounds IPC to 2,4-D has a reverse effect i.e., in all cases 10 pounds of IPC caused an increase in the height of the millet over those treated with 2,4-D alone. Almost 20 pounds of IPC is required to increase the effect of 2,4-D. With each additional increase in IPC the growth is further repressed.


Figure 4 - The Effect of Pentachlorophenol and Potassium Cyanate upon British Sovereigh Strawberry Plants and Grass Seedlings as at Sept. 6, 1949. The numbers refer to treatments as follows:

No. 21 - 1% Aero Cyanate

No. 23 - Untreated

No. 19 - 75 gal. per acre of emulsifiable pentachlorophenol.


Figure 5 - The Effect of 2,4-D and 2,4-D plus IPC upon the Various Grasses as at Sept. 11, 1949.

The Numbers refer to treatments as follows:

No. 23 - Untreated

No. 13 - 2 lbs. 2,4-D per acre

No. 18 - 2 lbs. 2,4-D plus 80 lbs. IPC per acre.

All plots were harvested two months after treatments were applied. The clippings from each specie of grass in each plot were weighed and the weights recorded. The results are summarized in table 4 and figures 6, 7, 8 and 9.

Creeping red fescue (Festuca rubra)

An examination of table 4 and figure 6 shows that an application of ½ pound 2,4-D per acre caused a significant increase in weight of clippings over the untreated plot. There is no significant difference between treatment 7 (1 pound 2,4-D) and the unsprayed plot. However, 2 pounds 2,4-D per acre did cause a significant reduction in the grass as compared to the untreated plot. The addition of IPC further reduced the amount of grass. In general this reduction in grass increases with an increase in IPC. However, it will be noted especially for the mixtures containing ½ pound 2,4-D and 2 pounds 2,4-D that there is only a slight difference between the mixture containing 40, 60 and 80 pounds of IPC per acre.

Perennial rye grass (Lolium perenne)

An examination of table 4 and figure 7 shows that both ½ pound 2,4-D and 1 pound 2,4-D per acre very significantly increased the amount of grass in comparison with the unsprayed plots. No significant difference was found between the plots sprayed with 2 pounds 2,4-D per acre and the unsprayed plots. In general the amount of grass present

Table 4 - The amount of grass remaining one month after treatments were applied (weight of clippings).

| Grasses | Creeping red fescue (Festuca rubra) | Perennial rye (Lolium perenne) | Orchard grass (Dactylis glomerata) | Hog millet (Panicum miliaceum) |
|---|---|---|---|---|
| Treatments | | Mean weight in grams | | |
| 1. | 10.1 | 26.7 | 13.8 | 34.7 |
| 2. | 5.3 | 13.7 | 12.3 | 48.7 |
| 3. | 2.5 | 3.8 | 5.0 | 43.8 |
| 4. | 2.2 | 4.7 | 2.8 | 45.7 |
| 5. | 1.5 | 4.0 | 1.7 | 51.7 |
| 6. | 1.5 | 4.0 | 1.7 | 55.3 |
| 7. | 8.8 | 26.8 | 10.5 | 36.8 |
| 8. | 4.0 | 10.7 | 6.3 | 45.7 |
| 9. | 5.8 | 15.7 | 6.8 | 34.0 |
| 10. | 3.8 | 7.7 | 2.8 | 41.7 |
| 11. | 2.7 | 4.7 | 2.3 | 26.5 |
| 12. | 1.7 | 4.3 | 1.7 | 39.5 |
| 13. | 6.2 | 15.5 | 6.7 | 36.2 |
| 14. | 5.0 | 14.2 | 6.5 | 29.7 |
| 15. | 3.7 | 12.5 | 6.2 | 29.0 |
| 16. | 2.2 | 5.7 | 2.3 | 30.0 |
| 17. | 1.8 | 6.8 | 2.2 | 33.7 |
| 18. | 1.7 | 3.8 | 1.5 | 23.5 |
| 19. | 8.7 | 28.7 | 5.7 | 1.5 |
| 20. | 3.8 | 13.0 | 1.7 | 9.2 |
| 21. | 8.0 | 11.7 | 10.0 | 12.3 |
| 22. | 9.0 | 18.4 | 18.0 | 14.3 |
| 23. | 9.2 | 15.7 | 12.7 | 44.5 |
| M.S.D. (.05 level) (gms) | 0.5 | 3.7 | 2.8 | 6.9 |

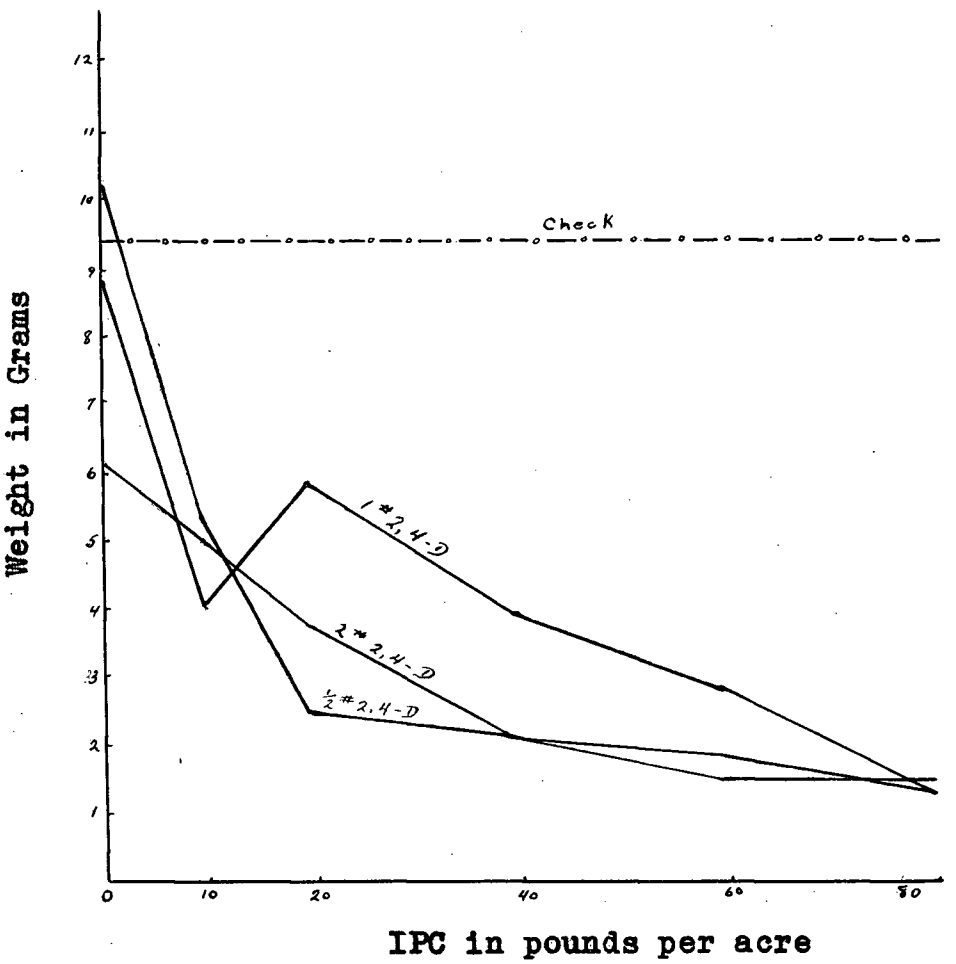


Figure 6 - Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Creeping Red Fescue (Festuca rubra) as at Sept. 30, 1949.

(M.S.D. at .05 level = 0.5)

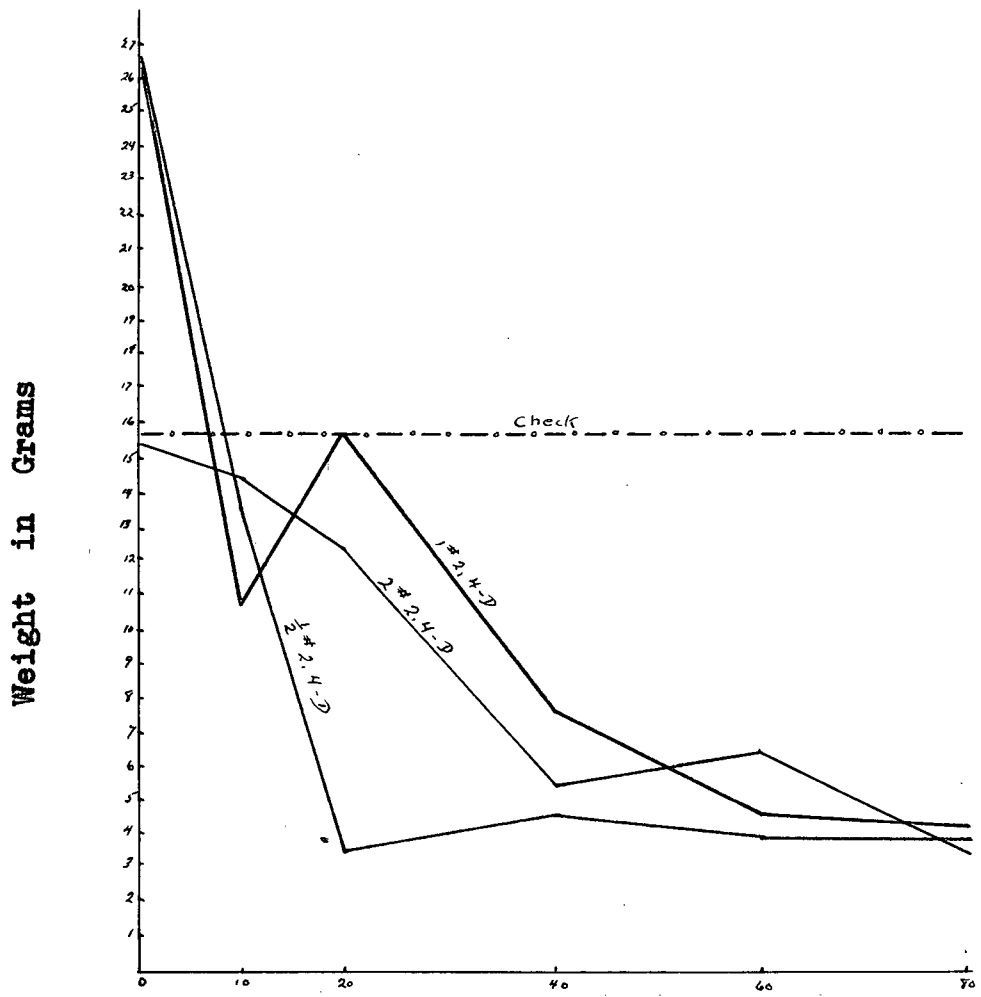


Figure 7 - Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Perennial Rye Grass (Lolium perenne) as at Sept. 30, 1949.

(M.S.D. at .05 level = 3.7)

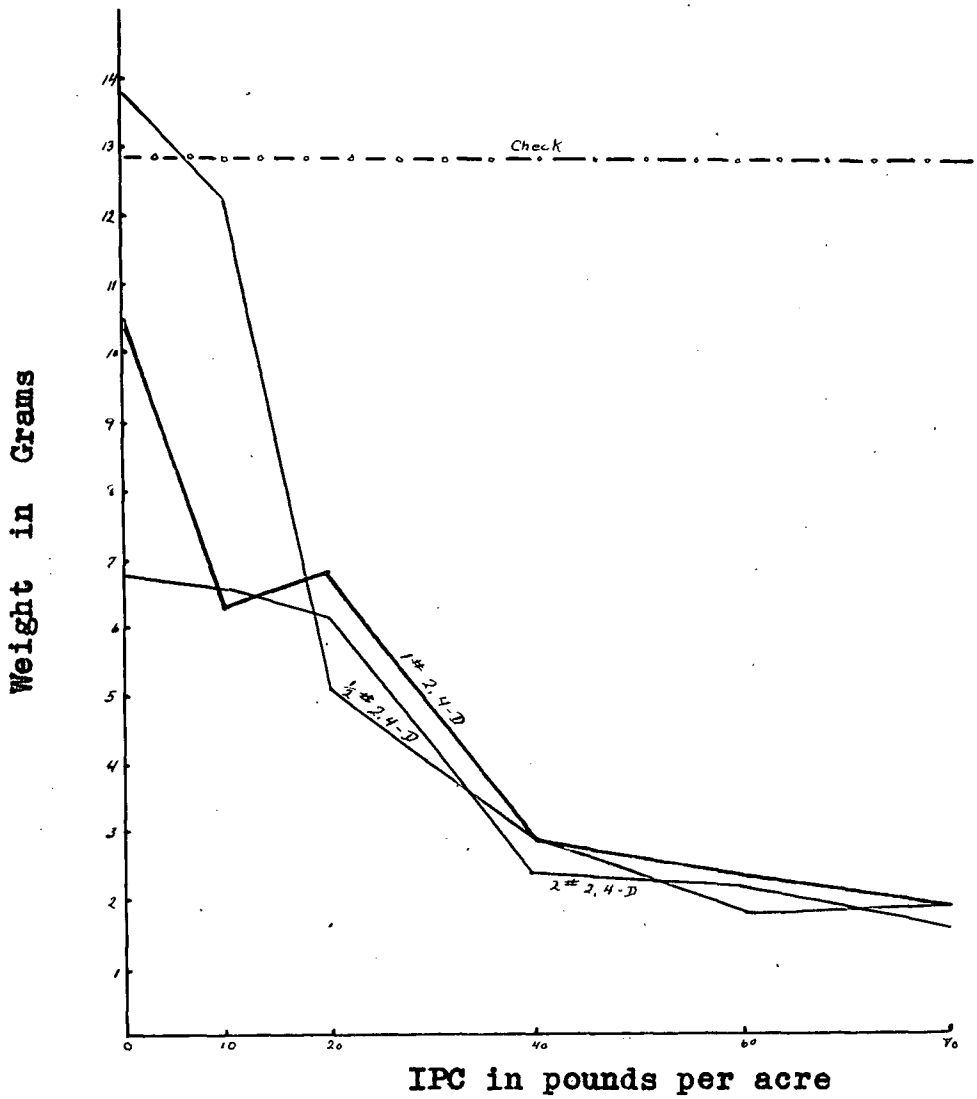


Figure 8 - Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Orchard Grass (Dactylis glomerata) as at Sept. 30, 1949.

(M.S.D. at .05 level = 2.8)

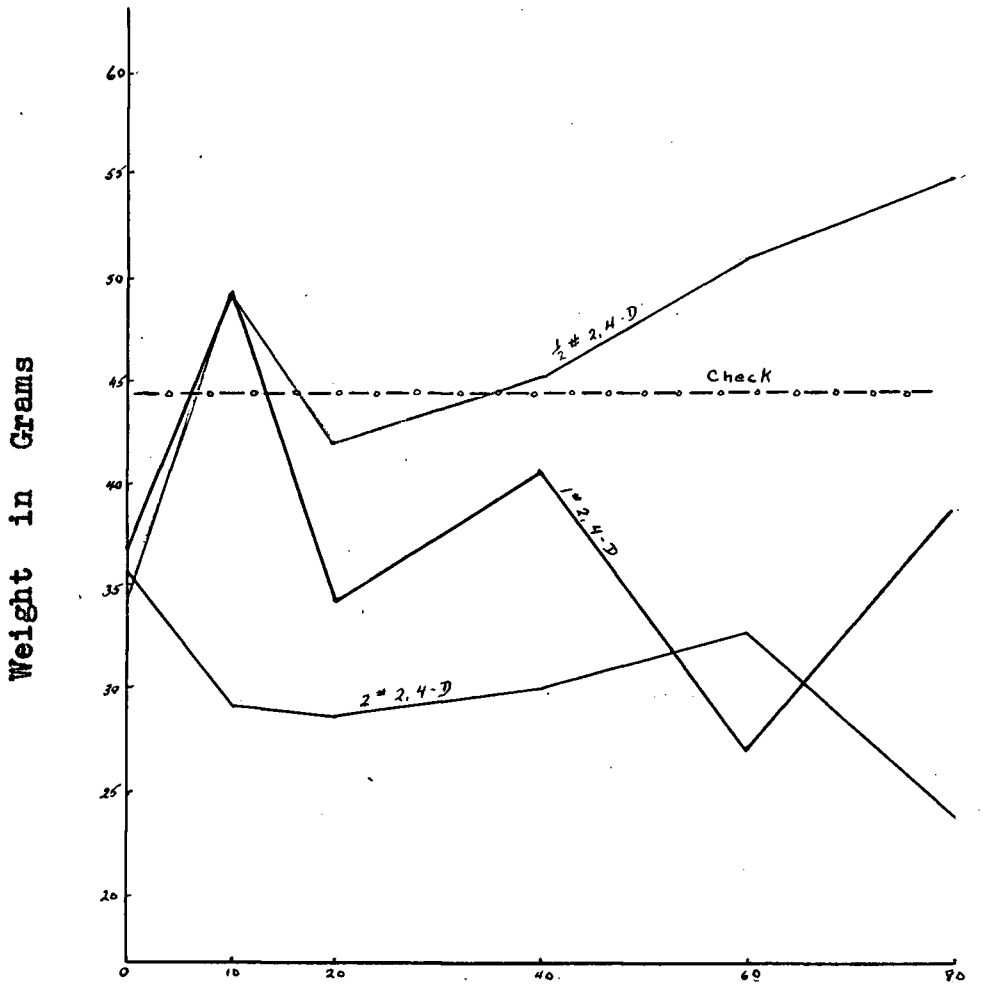


Figure 9 - Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Hog Millet (Panicum miliaceum), as at Sept. 30, 1949.

M.S.D. at .05 level = 6.9)

was directly related to the concentration of IPC. However, as with the fescue there is little difference between the plots sprayed with mixtures containing 40, 60 or 80 pounds of IPC.

Orchard grass (Dactylis glomerata)

An examination of table 4 and figure 8, shows that ½ pound 2,4-D increased the amount of grass slightly as compared to the unsprayed plot. There is no significant difference between treatment 7 (1 pound 2,4-D) and the unsprayed plots. However, 2 pound 2,4-D per acre gave a significant reduction in the amount of grass present as compared to the unsprayed plots. As in the above two grasses the addition of IPC caused a decrease in the amount of grass present. It is also noted that there is no significant difference between the treatments containing ½ pound 2,4-D plus 40, 60 or 80 pounds IPC; 1 pound 2,4-D plus 40, 60 or 80 pounds IPC; or 2 pounds 2,4-D plus 40, 60, or 80 pounds IPC.

Hog millet (Panicum miliaceum)

On examination of table 4 and figure 9 it will be noted that the ½, 1 and 2 pounds 2,4-D per acre all caused a significant reduction in the millet as compared to the unsprayed plots. However, there is no significant difference between the three concentrations of 2,4-D. Again as pointed out previously re: figure 3 (height of millet) the treatments containing ½ pound and 1 pound of 2,4-D plus 10 pounds IPC

per acre caused an increase in the weight of clippings as compared to the untreated plots, however, this increase is not significantly greater than the unsprayed plots. It is also noted that plots treated with a mixture of ½ pound 2,4-D plus IPC tend to increase in weight of clippings with concentration of IPC, this result is in direct reverse to that obtained by the same mixtures with the other grasses. The results of plots treated with 1 pound 2,4-D per acre plus IPC have no definite trend and with the exception of 60 pounds IPC no mixture is better than the 1 pound of 2,4-D alone. The treatments containing 2 pounds 2,4-D all gave a significant reduction in weight of clippings. There is no significant difference between 2 pounds 2,4-D alone and 2 pounds 2,4-D plus 10, 20, 40 and 60 pounds IPC per acre. There is, however, a significant difference between 2 pounds 2,4-D alone and 2 pounds 2,4-D plus 80 pounds IPC per acre.

Effect on Strawberry Plants

The treatments consisting of 2,4-D or of 2,4-D plus IPC caused no apparent detrimental effects to the strawberry plants. However, treatments 19 and 20 (Pentachlorophenol) caused excess burning and finally death to the plants. Treatments 21 and 22 (Aero cyanate) caused marginal burning of the leaves and finally complete browning, but the crowns were not killed as in the pentachlorophenol treatments. See figure 4 showing the effects of treatments 19, 21 and 23 on the strawberry plants and grasses.

# DISCUSSION

This experiment was designed to study the various combinations and concentrations of 2,4-D, IPC and other promising herbicides on several kinds of newly germinated grass seedlings and British Sovereign strawberry plants in the greenhouse.

An examination of figure 3 and table 3 on the effects of 2,4-D and various mixtures of 2,4-D and IPC on the height of Hog Millet twelve days after the application of the treatments shows that 2,4-D alone caused a significant decrease in height and that this stunting increased with increase in the concentration of 2,4-D. At this time all the grasses present (Creeping red fescue, Perennial rye grass, Orchard grass) appeared to respond in the same manner.

Mitchell and Marth (15) obtained somewhat similar results. They found that the growth of well-established creeping bentgrass was depressed by spraying with a water mixture of 2,4-D at rates equivalent to $\frac{3}{4}$, $1\frac{1}{2}$, $2\frac{1}{4}$ and 3 pounds of the acid per acre. Plants sprayed at rates equivalent to $\frac{3}{4}$ and $1\frac{1}{2}$ pounds per acre recovered during a period of 3-4 months following treatment.

Further from table 3 and figure 3 it is noted that the addition of only 10 pounds of IPC in all cases caused an increase in the height of the grass over those treated with 2,4-D alone. It would appear at this point that 10 pounds of

IPC had a slight inactivating effect upon the 2,4-D. However, even this mixture resulted in a significant suppression of growth of the grass as compared to the untreated plots. Almost 20 pounds of IPC are required before this inactivating effect is overcome and the mixture of 2,4-D and IPC is made more effective than the 2,4-D alone. With each additional increase in IPC stunting is further increased. The mixture containing 2 pounds 2,4-D and 80 pounds of IPC per acre was significantly better than any of the other 2,4-D and 2,4-D plus IPC mixtures. It is interesting to note that there is no significant difference between treatments 6, 11, 12, 15, 16 and 17 (i.e. ½ pound 2,4-D plus 80 pounds IPC, 1 pound 2,4-D plus 60 pounds IPC, 1 pound 2,4-D plus 80 pounds IPC, 2 pounds 2,4-D plus 20 pounds IPC, 2 pounds 2,4-D plus 40 pounds IPC, and 2 pounds 2,4-D plus 60 pounds IPC) and these treatments are second best. There appears to be a tendency towards definite optimum combinations of 2,4-D and IPC. From these results and using the above combinations the following generality appears feasible: beginning with ½ pound 2,4-D plus 80 pounds IPC we may say that as the IPC is reduced by 20 pounds it is necessary to double the amount of 2,4-D to obtain the same effects i.e., 1 pound 2,4-D plus 60 pounds IPC or 2 pounds 2,4-D plus 40 pounds IPC gives the same effects as ½ pound 2,4-D plus 80 pounds IPC. Therefore, it would appear that both chemicals have a supplementing value for one another in the depressing of grass growth. Such a relationship is of value for it means that the herbicidal

effect of 2,4-D can be supplemented with IPC and at the same time reduce the injurious effect of 2,4-D on crop plants.

On examination of table 4 and figures 6, 7, 8 and 9, on the weight of clippings of the various grasses one month after treatments were applied it is readily seen that the various grasses responded somewhat differently from one another. An application of ½ pound of 2,4-D per acre to Creeping red fescue caused a significant increase in weight of clippings over the unsprayed plot. It took 2 pounds of 2,4-D to significantly decrease the weight. Both the ½ pound 2,4-D and the 1 pound 2,4-D per acre to perennial rye grass caused very significant increases in weight of clippings over the unsprayed plot. The 2 pounds 2,4-D was not significantly different from the unsprayed plot whereas in the orchard grass there was no significant differences in weight of clippings between the plots sprayed with ½ pound 2,4-D or 1 pound 2,4-D and the unsprayed plot. But 2 pounds of 2,4-D reduced the weight of clippings significantly. In the case of the millet it is noted that the ½ pound, 1 pound and 2 pounds of 2,4-D per acre all caused a significant reduction in the clipping weight of millet as compared to the unsprayed plots. The increases in growth over the unsprayed plots, as noted in creeping red fescue and perennial rye grass when lesser amounts of 2,4-D are used, may be due in part to the elimination of weed competition in the sprayed plots.

Mitchell and Marth (15) sprayed a water mixture containing 0.1% 2,4-D and 0.5% Carbowax 1500 at rates equivalent to ¾, 1½, 2¼ and 3 pounds of acid per acre on potted soil in which Kentucky blue-grass, redtop, and creeping red fescue grass seeds had been planted. The treatments reduced the number of redtop seedlings that appeared by 28, 83, 83, and 95% respectively. A slightly greater number of fescue seedlings emerged from the soil sprayed at rates equivalent to ¾ and 1½ pounds of acid per acre, while the heavier applications reduced emergence by 10 and 17%, in comparison with the unsprayed soil. Fourteen per cent more bluegrass seedlings appeared in the soil sprayed at a rate equivalent to ¾ of a pound per acre than emerged in the unsprayed soil. The heavier applications reduced the emergence of bluegrass by as much as 32% below that of the untreated soil.

In general the addition of IPC to the plots containing the perennial grasses reduced the weight of clippings and this reduction increased with concentration of IPC. From figures 6, 7, 8 and 9 it is seen that the curves tend to level out from 40 pounds of IPC on. Thus 40 pounds of IPC in the mix appears to be the most practical; it depresses the growth of grass almost as completely as do the higher concentrations of 60 and 80 pounds per acre. Also, it must be mentioned at this point that concentrations of IPC over 40 pounds per acre at the usual rates of application tend to precipitate and clog the spray nozzle. Lachman (14) also had

the same trouble he states that the solubility of IPC is only about 250 p.p.m. and is only attained after vigorous shaking or stirring. He has found that IPC is readily soluble in Carbowax 1500, ethyl alcohol, isopropyl alcohol, acetone, and glacial acetic acid and as cosolvents these compounds are helpful in attaining the maximum concentration in a shorter time. However, in concentrations greater than 250 p.p.m. the IPC is precipitated upon the addition of water to the IPC and solvent. Doxey (7) studying the effect of IPC on mitosis in rye and onion found that 200 p.p.m. solution closely approached saturation. The chemical companies have recognised this problem and are developing more soluble forms of IPC.

From table 4 and figure 9 it is seen that the response of annual hog millet to 2,4-D and mixture of 2,4-D and IPC is quite different from that obtained in the perennial grasses. As mentioned earlier, even the lesser concentrations of 2,4-D alone significantly depressed the growth in comparison with the unsprayed plot. Therewas no significant difference between the three concentrations of 2,4-D. Again, in the case of $\frac{1}{2}$ pound 2,4-D and 1 pound 2,4-D the addition of 10 pounds IPC appears to inactivate the 2,4-D. The millet appeared to more or less recover from the mixtures of 2,4-D and IPC, especially was this true with the lesser amounts of 2,4-D. In general though, as the concentration of the 2,4-D was increased the greater was the depression of growth. The 2,4-D at the concentration of 2 pounds per acre

is only made slightly more effective with the addition of IPC. Although these plots are significantly different from the unsprayed plots, the results are not too satisfactory since the control is only about 50% as compared to 80 and 90% control obtained with the perennial grasses.

Differences in the sensitivity of grasses to IPC were also noted by Mitchell and Marth (16) who found that when crabgrass and bluegrass seeds were planted in soil containing known amounts of IPC that emergence of bluegrass seedlings was greatly reduced in soil that contained as little as 3.4 mg. of IPC per pound of soil, while the emergence percentage for crab grass (Digitaria sanguinalis) increased with the addition of IPC to the soil. Although the emergence percentage of partially dormant crab grass was apparently stimulated by IPC in this experiment, the subsequent growth of the plants was greatly inhibited.

Mitchell and Marth (16) studied the sensitivity of several other monocotyledonous plants and have constructed a table showing the sensitivity of these plants to IPC. This table has been reproduced here (see table 5). An examination of table 5 shows that rye grass, red top, and orchard grass are all very sensitive to IPC while millet is only slightly sensitive. Thus these results are confirmed by those obtained by the writer.

They further add that the effect of IPC when applied at the rates of 30-60 pounds per acre on the growth of less

sensitive species (sorghum, Sudan grass) was prolonged so that plants grew above the surface of the soil for a distance of 1-3 cm. and then failed to develop further. Microscopic examination revealed that these plants remained alive but stunted after appearing above the surface. These stunted plants failed to produce seeds.

As an Experiment 1, 2,4-D and 2,4-D plus IPC apparently did not cause any detrimental effects to the strawberry plants. Such was not the case with pentachlorophenol and potassium cyanate. Pentachlorophenol caused excess burning and death while cyanate caused considerable marginal browning of the leaves though it did not appear to harm the strawberry crown. Therefore though these chemicals gave excellent control of the grass they are, however, of no use as weedicides for strawberries during the growing season.

## CONCLUSIONS

The results of this experiment which was laid out in the greenhouse using mixtures of three levels of 2,4-D and five levels of IPC, two levels PCP and two levels of cyanate on four species of grass and British Sovereign strawberries shows that:

1. There is considerable difference in sensitivity between the different species of grass to 2,4-D and IPC.

Table 5 - Sensitivity of some Monocotyledonous Plants to IPC when Applied to the Soil at a Rate Equivalent to 5 pounds per acre.#

(after Mitchell and Marth)

| Plant | Emergence Index | Plant | Emergence Index |
|---|---|---|---|
| Bermuda grass | 130 | Fescue | 0 |
| Amber sorghum | 99 | Ryegrass | 0 |
| Sudan grass | 88 | Red top | 0 |
| Millet | 86 | Timothy | 0 |
| Bluegrass | 4 | Orchard grass | 0 |
| Barley | 0 | Quack grass | 0 |

# Values represent relative emergence from seeds planted in treated soil calculated on the basis that emergence in comparable untreated soil equalled 100 per cent.

2. A mixture of 2 pounds of 2,4-D and 40 pounds of IPC per acre gives very satisfactory control of perennial rye grass, creeping red fescue, and orchard grass (all perennial grasses) but not of the annual hog millet.

3. Mixtures of 2 pounds of 2,4-D and up to 80 pounds of IPC per acre apparently did not cause any detrimental effects to the British Sovereign strawberry plants.

4. Pentachlorophenate and potassium cyanate are not suitable herbicides for strawberries during the growing season. The pentachlorophenate caused extreme burning and finally death. The cyanate, however, only caused marginal to severe browning, but apparently did not injure the crown and, therefore, may be of value as an after harvest or dormant spray.

## EXPERIMENT V

Object:-

To study the effect of various concentrations of 2,4-D and 2,4-D supplemented with IPC on both weeds and British Sovereign strawberry plants under field conditions.

Materials and Methods:

Plots 18½' x 21' were laid out in three randomized blocks. Strawberries were planted in rows 3½ feet apart and 18 inches between plants. Young, certified, British Sovereign plants were planted out in the spring of 1949.

The treatments were as follows:

1. 1 lb. 2,4-D per acre.
2. 2 lbs. 2,4-D per acre.
3. 3 lbs. 2,4-D per acre.
4. 4 lbs. 2,4-D per acre.
5. 2 lbs. 2,4-D plus 40 lbs. IPC per acre.
6. Hand weeded.

Note:

The amounts of 2,4-D refer to acid equivalent.

Treatments were to have been applied to the young plants as weed growth dictated possibly three or four times during the season. However, the first application was delayed due to rainy weather until July 2, and consequently the weeds were 7-8 inches tall and very dense.

Both a knapsack sprayer and a Hudson sprayer were used in applying the first application of sprays. See figure 10 for general layout of experiment and method of applying sprays. Temperature recorded was 68.5°F. Soil samples were taken of the area to be sprayed before the first application. The results of the analysis appear in table 6. General notes, measurements and photographs were taken periodically following the applications of treatments on the following:

1. Weed control, effects on various species noted.
2. Effects on strawberry plants noted.

Table 6 - Soil Analysis of Strawberry Plots Obtained by Spurway Chemical Tests.

| | Ppm. | Lb. a/6 in. | Remarks |
|---|---|---|---|
| Nitrates | 10 | 80 | Medium |
| Phosphorus | ½ | 4 | Low |
| Potassium | 3 | 24 | Low |
| Calcium | 40 | 320 | Low |
| Magnesium | 1 | 8 | Low |
| Reaction | pH 6.0 | | |

3, Plant growth measured by leaf counts, runner counts, and observation ratings.

Fertilizer (4-10-10) was broadcasted alongside of the rows on July 4 at 700 pounds per acre. A second application of fertilizer was made on August 1, at the same rate. On July 29, after notes had been taken on weed control, etc., all plots were hoed and raked off. Leaf counts and growth ratings were taken on September 1. Second application of sprays was applied on September 1, with a knapsack sprayer. All materials were applied at the rate of 100 gallons of solution per acre. Temperature recorded at this time was 78°F.

## RESULTS

Control of Various Weed Species:

The various weed species present in the strawberry plots and their approximate percentage at time of spraying were as follows:

Polygonum Persicaria L. (Lady's Thunb) .. 60-65%.
Chenopodium album L. (Lamb's Quarters) .. 10%.
Spergula arvensis L. (Corn Spurrey) ..... 10%.
Echinochloa crusgalli (L) Beaux (Wild Millet) ..10%.

All other weeds combined made less than 10 per cent of the total weed population. They are listed below:

Roripa polustria (L) Bess. (Yellow Cress)

Amaranthus retroflexus L. (Red-root Pigweed)

Convolvulus arvensis L. (Field Bindweed)

Agropyron repens (L) Beauv. (Couch Grass)

Raphanus Raphanistrum L. (Wild Radish)

Rumex Acetosella L. (Sheep Sorrel)

Gnaphalium uliginosum (Cudweed)

Following are extracts of notes taken on the effect of the treatments on the weeds:

July 2

- Curling of leaves of weeds noticeable within an hour after spraying even with 1 pound per acre of 2,4-D.

July 4 (2 days following sprays)

- All weeds showing typical 2,4-D injury such as curling of leaves, twisting and curling of petioles.

Treatment 5 (2 lb. 2,4-D plus IPC)

- no effect of IPC on grass as yet
- 2,4-D injury as in other plots.

July 8 (6 days following sprays)

Treatment 5 (2 lbs. 2,4-D plus IPC)

- Weeds browning more than in other plots.
- Wild radish practically dead.

- Field Bindweed - browned.
- Lady's Thumb - browned.

Treatment 4 (4 lbs. 2,4-D)

- Some browning, but not near as noticeable as Treatment 5 -- more of a yellowing.

Treatments 1, 2, & 3 (1, 2 & 3 lbs. 2,4-D)

- Damage to weeds appears to be progressively less with lower concentrations.

July 28 (26 days following sprays)

General observations on the effect of the sprays on broad-leaved weeds and grasses were recorded numerically as shown in table 7.

Effect on Strawberry Plants

Extracts of notes taken on the effect of the various treatments on the strawberry plants follows:

July 4 (2 days following sprays)

- In all plots the strawberry plants are exhibiting curling of leaves, twisting and curling of petioles to some degree (see figure 11).

July 8

Treatment 4 (4 lbs. 2,4-D per acre)

- Strawberry plants at present appear poorest of lot.
- Curling and crisping of leaves.

Table 7 - Effect of the Various Treatments upon the Broad-Leaved Weeds and Grasses as at July 28, 1949.

| | TREATMENTS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 (1 lb. 2,4-D) | | 2 (2 lb. 2,4-D) | | 3 (3 lb. 2,4-D) | | 4 (4 lb. 2,4-D) | | 5 (2 lb. 2,4-D -40 lb. IPC) | |
| | B | G | B | G | B | G | B | G | B | G |
| BLOCK | | | | | | | | | | |
| I | 2 | 1.5 | 4 | 2 | 4.5 | 2 | 5 | 1 | 5 | 2 |
| II | 3 | 2 | 4 | 1 | 3 | 2 | 5 | 3 | 5 | 2 |
| III | 3 | 1 | 4 | 2 | 5 | 3 | 5 | 3 | 4 | 2 |
| Sum. | 8 | 4.5 | 12 | 5 | 12.5 | 7 | 15 | 7 | 14 | 6 |

Legend:

B -- Broad-leaved weeds.

G -- Grass

Rating -- 1 = nil control

5 = complete control

Condition of Strawberry Plants:

Leaf counts were made on ten plants per plot making 30 plants per treatment. Plants were selected from the same position in each plot. The results obtained were of no value since the variations within plots was great also the leaf count gave no indication as to the size of leaf. For example, many plants were found to have a large number of leaves but in many cases the leaves were small, while other plants had fewer leaves, but very frequently these leaves were larger. Other methods were tried such as the spread of the plant, height of plant, production of runners, etc., but all were found unsatisfactory since none of these methods or combinations of these methods gave a complete picture of the true condition of the plants. Thus it was decided that the best measure of the condition of the strawberry plants was to rate the plants from observation. The writer obtained the cooperation of the Horticulturist and the Head Gardener of the Dominion Experimental Farm, Agassiz, B.C., in rating the plants. Both gentlemen rated the plants independently and the results obtained are summarized in table 8.

Weed Control:

General observations were again made on October 30, 1949 on the effect of the treatments on weeds and as before a numerical rating for each treatment was recorded as shown in table 9. The weeds at this time were mainly grasses such as oats, millet, Kentucky blue, and couch grass.

Figure 10 - Showing a General View of the Layout of Experiment V and the Method of Spraying with a Knapsack Sprayer.

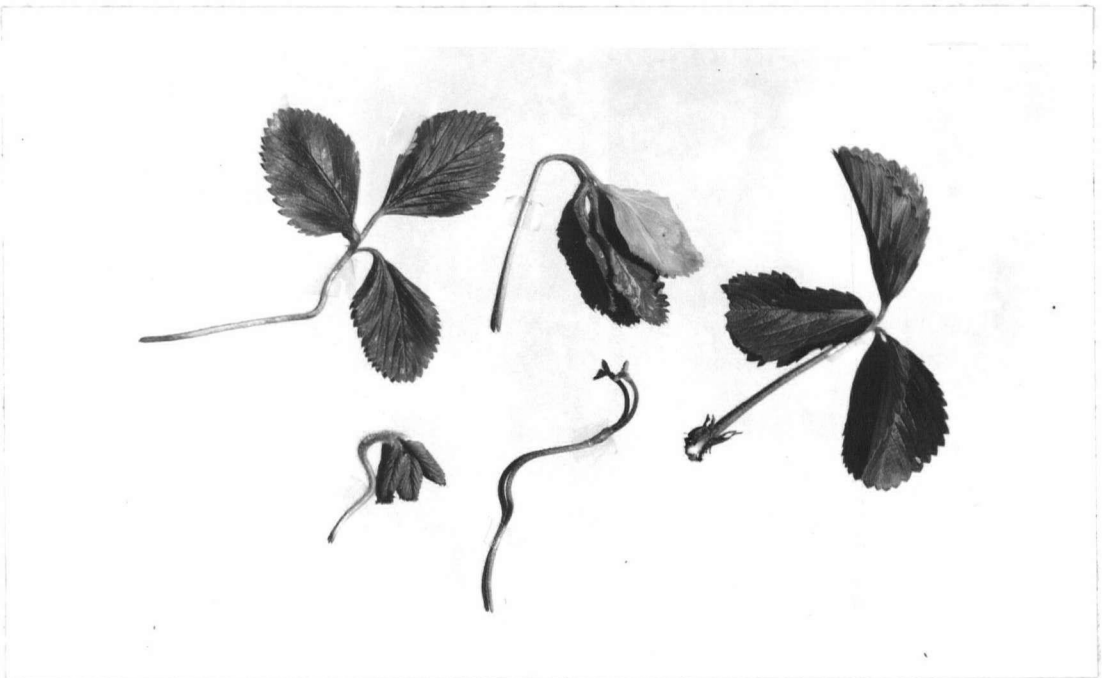

Figure 11 - Showing the Effects of 2,4-D upon the Leaves and Petioles of British Sovereign Strawberry Plants. The centre leaf shows the "burning" or "crisping" effect caused by 4 lbs. and over of 2,4-D per acre.

Table 8 - The condition of the Strawberry Plants as at September 1, 1949.

| | TREATMENTS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1. (1 lb. 2,4-D) | | 2. (2 lb. 2,4-D) | | 3. (3 lb. 2,4-D) | | 4. (4 lb. 2,4-D) | | 5. (2 lb. 2,4-D + 40 lb. IPC | |
| | A | B | A | B | A | B | A | B | A | B |
| BLOCK | | | | | | | | | | |
| I | 4 | 4 | 4 | 4 | 3 | 2 | 3 | 3 | 2# | 3# |
| II | 5 | 4 | 4+ | 3 | 3 | 3 | 3 | 3- | 4+ | 4 |
| III | 5 | 4+ | 4 | 3 | 3 | 3+ | 2 | 2 | 4 | 4 |
| Sum. | 14 | 12+ | 12+ | 10 | 9 | 8+ | 8 | 8- | 10+ | 11- |

Legend:

Rating: 1 to 5

(poorest to best condition)
(hand-weeded plots = 5)

A. By Head Gardener.

B. By Horticulturist.

#Difficult to assess condition of plants in this plot since many of the plants appeared to be damaged by other than sprays (carelessness of a laborer).

Table 9 - Effect of the Various Treatments upon the Weeds as at October 30, 1949.

| | TREATMENTS | | | | | |
|---|---|---|---|---|---|---|
| | 1. (1 lb. 2,4-D) | 2. (2 lb. 2,4-D) | 3. (3 lb. 2.4-D) | 4. (4 lb. 2,4-D) | 5. (5 lb.2,4-D +40 lb.IPC) | 6. (Check) |
| BLOCK | | | | | | |
| I | 2 | 3 | 3 | 2 | 4 | 5 |
| II | 1 | 1⁻ | 2 | 4 | 5 | 4 |
| III | 1 | 1 | 3 | 3⁻ | 5 | 5 |
| Sum. | 4 | 5⁻ | 8 | 9⁻ | 14 | 14 |

Legend:

Rating: 1 to 5

(poor to good control)

# DISCUSSION

This experiment was designed to study the effect of various concentrations of 2,4-D and 2,4-D supplemented with IPC on both weeds and British Sovereign strawberry plants under field conditions. The treatments used in this experiment were determined in part from the results of the four preceding experiments.

Weed Control:

From the results it is noted that curling of leaves was apparent on the broad-leaved weeds within an hour after spraying even in those plots sprayed with 1 pound per acre. Within two days all the broad-leaved weeds present were showing typical 2,4-D injury such as curling of the leaves, twisting and curling of the petioles.

Harvey and Robbins (11) state that the first noticeable effect of 2,4-D is in the stems and leaves which become twisted and bent, with the leaves showing varying epinastic conditions. The stems and leaves may remain green for several weeks after treatment before dying, or they may recover if the treatment was light. Carlson (4) reporting on the control of weeds in strawberry plantings by the use of 2,4-D states that many weeds showed deformative effects at the low concentrations of 400 and 800 parts per million and yellow dock, dandelion and field violets were killed. Canada thistle

was injured severely at these concentrations but slowly recovered. Alsike clover was not severely affected at the low concentrations (400 to 800 parts per million), but was killed at 2,000 to 2,400 parts per million. According to Warren and Hernandez (20) 2,4-D at the rates of 2, 3 and 4 pounds of the acid equivalent per acre gave generally good control of pigweed, lambsquarters, purslane, shepherds-purse, witchgrass and foxtail for a period of 4 to 6 weeks, but annual smartweeds were only slightly affected. The weed Committee of the B.C. Agronomists' Association (22) states that weed species vary considerably in their reaction to 2,4-D, ranging from very susceptible to highly resistant. Furthermore the stage of growth is an important factor. A species of weed may be highly susceptible at one stage while at a later stage it may become quite resistant. Soil and climatic conditions also give marked differences in the effect of 2,4-D on weeds. Most annual weeds, other than those belonging to the grass family, are generally susceptible at the young succulent stage of growth, while many become quite resistant at the flowering or seed stage. Perennial weeds show greater variation in susceptibility to 2,4-D than do annual weeds. In general, the perennial weeds require somewhat higher rates of application of 2,4-D than do the annuals. Susceptible perennial weeds respond more readily to the action of 2,4-D from bud stage to flower stage rather than at earlier stages of growth.

Six days after treatment the weeds in the plots sprayed with a mixture of 2,4-D and IPC were showing the greatest injury with many weeds practically dead. Even the weeds sprayed with 4 pounds of 2,4-D were not showing as much injury. This would appear to be further evidence of the supplementing value of these chemicals for one another as mentioned in the preceding experiment.

An examination of table 7 shows that the control of the broad-leaved weeds increased with increase in the concentration of 2,4-D until at 4 pounds per acre the broad-leaved weed control is 100 per cent. However, it will be noted that this improvement in weed control is not in proportion to the increase in amount of 2,4-D applied. These results are in agreement with those obtained by Warren and Hernandez (20) in weed control in certain vegetable crops with soil applications of 2,4-D. Of particular interest is treatment 5 (2 lbs. 2,4-D plus 40 lbs. IPC) which shows a broad-leaved weed control of 93.9 per cent. Again, further evidence of supplementing value of these chemicals.

The control of grass at this time was not too encouraging as can be seen from table 7. Control of grass improved with increase in 2,4-D but as with the broad-leaved weeds this improvement is not in proportion to the increase in amount of 2,4-D applied. It will be noted that 2 and 3 pounds of 2,4-D gave the same result. The plots sprayed with the mixture of 2 pounds of 2,4-D and 40 pounds IPC showed a

slight improvement in grass control over plots treated with 2 pounds of 2,4-D alone, but the improvement was slightly less than that obtained by use of 3 and 4 pounds of 2,4-D alone. However, since much of the grass present in the plots at this time was annual hog millet, such results are as expected in view of the results obtained with this grass in Experiment IV. This provides further evidence of the high degree of resistance of annual hog millet to IPC in comparison with the other grasses present.

Now an examination of table 9, on the effect of the various treatments upon the weeds as at October 30, two months following the second application of treatments, shows that weed control improved with increase in the concentration of 2,4-D. The plots treated with 2 pounds of 2,4-D plus 40 pounds of IPC show extremely good control of the weeds. It is also noted that the weeds present in the plots at this time were mainly grasses. The broad-leaved weeds were practically extinct. Treatment 5 made a much better showing this time; possibly because the broad-leaved weeds and grasses were much more immature at the time of the second spraying than the weeds were for the first spraying. It must be remembered that the plots were cleaned up and weeds raked off after complete results were recorded on the first spraying. According to Freed (9) IPC acts principally as a mitotic poison (prevention of cell division), which means it is most effective during early growth. Another

explanation for the disappointing results obtained from the first spraying is the possibility that the IPC was inactivated by the excess moisture in the soil at the time of spraying. As mentioned earlier, there had been considerable rainy weather before the first sprays were applied. According to Mitchell and Marth (16) IPC is inactivated in the presence of moist, fertile soil as is the case with 2,4-D.

The Effect on Strawberry Plants:

Two days following application of the sprays typical 2,4-D injury was noted on the strawberry plants in all treated plots. This injury was the same as described previously for the broad-leaved weeds; namely, curling of leaves and twisting and curling of the petioles. Four days later the plants sprayed with 4 pounds of 2,4-D showed a much more extreme 2,4-D injury. The leaves had extreme curling and were becoming crisp.

Carlson (4) having sprayed Premier strawberries with 1000 parts per million of 2,4-D reported that about two weeks after application of 2,4-D the strawberry plants in the second-year planting took on a darker green colour, and younger actively growing leaves showed twisting of the petioles. The larger plants showed no deformative effect. The spring planting which was producing runners showed similar responses. There was some indication of curling of the young tender shoots but this was of short duration.

In the same paper Carlson reports on another experiment in which he used various concentrations of 2,4-D after harvest and found that the low concentrations 400 and 800 parts per million had no effect on the strawberry plants. Concentrations of 1200, 1600 and 2000 parts per million resulted in slight to moderate twisting of the strawberry petioles, and at 2400 parts per million the petioles were badly twisted. The deformative effects caused by the higher concentrations soon disappeared from the strawberry plants and after 4 to 5 weeks they appeared normal. He further states that when flowers of the everbearing varieties were hit with the spray small and misshapen fruits were produced.

Many methods were tried in an attempt to find an accurate estimation of the condition of the strawberry plants. But as pointed out in the results such measurements as leaf counts, spread of plant, production of runners, etc., either singly or in combination left much to be desired. Observation ratings appeared to be the best method of recording the condition of the strawberry plants. These ratings are summarized in table 8 and an examination of this table shows that in all treated plots the strawberry plants were less vigorous than in the hand-weeded plots. The vigour decreased as the concentration of 2,4-D was increased. As expected from previous experiments, the IPC apparently did not affect the strawberry plants to any appreciable degree. It would appear from these results that three or four pounds of 2,4-D

per acre is too much for British Sovereign strawberry plants. This injurious effect was much less with the lower concentrations of 2,4-D. It must be appreciated that this loss in vigour is not necessarily due entirely to the 2,4-D, but in part, at least, some loss would be due to competition with weeds. For it must be remembered that due to rainy weather the weeds were allowed to become tall and dense before sprays were applied. Further these herbicides required considerable time to affect the more mature annual weeds. During this time the weeds were still competing with the strawberry plants. While, on the other hand, in the hand-weeded plots the weeds were removed immediately. Thus, the importance of applying the herbicides when the weeds are small and succulent.

## CONCLUSIONS

Six treatments (2,4-D and 2,4-D plus IPC) were laid out in three replicates on a maiden British Sovereign strawberry plantation, and 1, 2, 3 and 4 pounds of 2,4-D per acre and 2 pounds of 2,4-D plus 40 pounds of IPC per acre were the spray treatments compared with a hand-weeded check. It was found that up to 2 pounds of 2,4-D per acre did not seriously damage strawberry plants and gave satisfactory control of both broad-leaved weeds and grasses. All plots treated with herbicides resulted in slightly less vigorous strawberry plants than the hand-weeded check. It was

explained that this decrease in vigour was a result, in part, at least, of allowing the weeds to become tall and very dense before applying the sprays (unavoidable in this experiment due to weather conditions). Thus these weeds competed with the strawberry plants for a considerable time after sprays were applied while in the hand-weeded plots the weeds were removed immediately. It is appreciated that 2 pounds of 2,4-D and 40 pounds of IPC per acre will not be required for weed control in all strawberry plantations. The amounts to be used will depend upon the age and species of weeds present. In this experiment it will be remembered that 60 - 65% of the total weed population consisted of Lady's thumb (Polygonum Persicaria L.) which is very resistant to 2,4-D. Also wild millet (Echinochloa crusgalli L. Beaux) made up 10% of the total weed population and this grass shows considerable resistance to IPC. In addition it must be pointed out that there are many new formulations of IPC coming on the market which are effective at much lower concentrations than the formulation used in this experiment. Of the herbicides available to-day there appears to be no close rival for the mixture of 2,4-D and IPC as a selective herbicide for strawberries.

Under conditions of this experiment a mixture of up to 2 pounds of 2,4-D plus 40 pounds of IPC can be safely recommended for the deweeding of British Sovereign strawberry plantations, provided it is not used when the plants are in blossom.

## SUMMARY

Information on the use of herbicides for weed control in strawberries is limited, but grower interest has increased to the point where recommendations for safe usage are needed. It has been shown that strawberry varietal responses to 2,4-D are wide and therefore it is necessary to determine the concentration of 2,4-D suitable for each variety. Some newer herbicides, toxic to grasses, have recently been introduced which might have a place either alone or in a mixture with 2,4-D in a weed control program for strawberries. With these two points in mind the following experiments were conducted on British Sovereign strawberry plants and various grasses at the Dominion Experimental Farm, Agassiz in 1949.

Five experiments in all were carried out with the object of studying the use of selective herbicides on strawberries. Before laying out a large replicated experiment it was felt that (a) the general response of strawberry plants to various herbicides and (b) the effect of these herbicides on both broad-leaved weeds and grasses should be determined. Small plots were laid out on a three year old strawberry plantation and subjected to 34 different treatments (Experiment I). Similar treatments were applied in Experiments II and III to newly seeded and established grasses. These treatments consisted of different concentrations and mixtures of the following:

2,4-dichlorophenoxyacetic acid (2,4-D)

Sodium salt of trichloroacetic acid (TCA)

Ammonium salt of Isopropyl N-phenyl carbamate (IPC)

2 methyl-4-chlorophenoxyacetic acid (MCP)

Sodium pentachlorophenate (PCP)

Ammonium salt of dinitro-O-secondary butyl phenol (DNOSBP)

Potassium cyanate

Emulsifiable pentachlorophenol

Effect on Strawberry Plants

IPC at 5 to 80 pounds per acre had no effect on established strawberry plants. 2,4-D at 150 gallons per acre of 1000 ppm, either alone or with IPC, left the plants normal after 2 months although there was slight curvature of petioles produced after 3 weeks. All other treatments either killed the strawberry plants or left them in a very weakened condition. A mixture of 2,4-D and IPC appeared promising.

Effect on Grasses

As reported by other workers, all herbicides but 2,4-D controlled grasses while 2,4-D controlled the broad-leaved weeds. IPC at 80 pounds per acre in a spray alone and with 2,4-D controlled or seriously stunted the grass species present. It took 4 weeks to become completely effective. Applied as a dust, 40 pounds per acre gave complete kill of seedling grass mixture.

Experiment IV was laid out in the greenhouse with mixtures of three levels of 2,4-D and five levels of IPC on four species of grass. This experiment has shown that 2 pounds of 2,4-D and 40 pounds of IPC gives very satisfactory control of perennial rye grass, creeping red fescue, and orchard grass (all perennial grasses), but not of the annual hog millet. Millet, fortunately, is rarely found as a weed, but was present in the plots of the experiment to follow.

In the final experiment six treatments (2,4-D and 2,4-D plus IPC) were laid out in three replicates on a maiden British Sovereign strawberry plantation. Treatments of 1, 2, 3 and 4 pounds of 2,4-D per acre and 2 pounds of 2,4-D plus 40 pounds of IPC per acre were compared with a hand-weeded check. It was found that up to 2 pounds of 2,4-D per acre did not seriously damage strawberry plants and gave satisfactory control of the broad-leaved weeds. A mixture of 2 pounds of 2,4-D and 40 pounds of IPC per acre gave satisfactory control of both broad-leaved weeds and grasses. All plots treated with herbicides resulted in slightly less vigorous strawberry plants than the hand-weeded check. It was explained that this decrease in vigour was a result, in part, at least, of allowing the weeds to become tall and very dense before applying sprays (unavoidable in this experiment due to weather conditions). Thus, these weeds competed with the strawberry plants for a considerable time after sprays were applied while in the

hand-weeded plots the weeds were removed immediately.

In general, the conclusions from these experiments are: (1) that the sprays should if possible be applied when the weeds are small and succulent, especially is this true for annuals; (2) under conditions of this experiment a mixture of up to 2 pounds of 2,4-D plus 40 pounds of IPC can be safely recommended for the deweeding of British Sovereign strawberry plantations provided it is not used when the plants are in blossom.

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# APPENDIX

Following are complete statistical analyses of the effect of applications of various amounts of 2,4-D and mixtures of 2,4-D and IPC on the height of hog millet (Panicum miliaceum) as at September 11, 1949, and of the effect of applications of various amounts of 2,4-D and mixtures of 2,4-D and IPC on the weight of clippings from the various grasses, as shown, as at September 30, 1949. Data obtained from Experiment IV.

Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the Height of Hog Millet (Panicum miliaceum) as at September 11, 1949.

| Treatments | Block I | II | III | Sum. | Treatment Mean |
|---|---|---|---|---|---|
| 1 | 13 | 10 | 14 | 37 | 12.3 |
| 2 | 11 | 13 | 14 | 38 | 12.7 |
| 3 | 9 | 10 | 15 | 34 | 11.3 |
| 4 | 8 | 12 | 12 | 32 | 10.7 |
| 5 | 8 | 12 | 10 | 30 | 10.0 |
| 6 | 8 | 8 | 9 | 25 | 8.3 |
| 7 | 11 | 14 | 9 | 34 | 11.3 |
| 8 | 12 | 12 | 11 | 35 | 11.7 |
| 9 | 8 | 11 | 12 | 31 | 10.3 |
| 10 | 7 | 9 | 11 | 27 | 9.0 |
| 11 | 8 | 8 | 8 | 24 | 8.0 |
| 12 | 8 | 9 | 6 | 23 | 7.7 |
| 13 | 8 | 10 | 9 | 27 | 9.0 |
| 14 | 9 | 11 | 15 | 35 | 11.7 |
| 15 | 9 | 9 | 7 | 25 | 8.3 |
| 16 | 10 | 7 | 6 | 23 | 7.7 |
| 17 | 5 | 7 | 10 | 22 | 7.3 |
| 18 | 6 | 6 | 5 | 17 | 5.7 |
| 19 | 0 | 1 | 0 | 1 | 0.3 |
| 20 | 0 | 4 | 1 | 5 | 1.7 |
| 21 | 2 | 4 | 3 | 9 | 3.0 |
| 22 | 4 | 4 | 3 | 11 | 3.7 |
| 23 | 14 | 14 | 15 | 43 | 14.3 |
| Blk.Totals | 178 | 215 | 205 | | |
| Blk.Mean | 7.7 | 9.3 | 8.9 | | |

Grand Total ..... 598

General Mean ..... 8.7

## ANALYSIS OF VARIANCE

| Source of Variation | Degrees of Freedom | Sum of Squares | Variance | Variance ratio in F. | Table value F at P = .05 |
|---|---|---|---|---|---|
| Total | 68 | 847 | | | |
| Treatment | 22 | 662 | 30.1 | 8.60 | 1.81 |
| Blocks | 2 | 32 | 16.0 | 4.57 | 3.21 |
| Error | 44 | 153 | 3.5 | | |

M.S.D. for Treatments at .05 level = 1.08

Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Creeping Red Fescue (Festuca rubra) as at Sept. 30, 1949. (M.S.D. at .05 level = 0.5)

| Treatments | Block I | II | III | Sum. | Treatment Mean |
|---|---|---|---|---|---|
| 1 | 7.0 | 6.2 | 17.0 | 30.2 | 10.1 |
| 2 | 4.5 | 2.5 | 9.0 | 16.0 | 5.3 |
| 3 | 1.0 | 2.5 | 4.0 | 7.5 | 2.5 |
| 4 | 0.5 | 4.0 | 2.0 | 6.5 | 2.2 |
| 5 | 0.5 | 0.9 | 3.0 | 4.4 | 1.5 |
| 6 | 1.0 | 0.5 | 3.0 | 4.5 | 1.5 |
| 7 | 11.5 | 5.0 | 10.0 | 26.5 | 8.8 |
| 8 | 1.0 | 8.0 | 3.0 | 12.0 | 4.0 |
| 9 | 10.0 | 3.5 | 4.0 | 17.5 | 5.8 |
| 10 | 8.0 | 1.5 | 2.0 | 11.5 | 3.8 |
| 11 | 4.0 | 4.0 | 0.0 | 8.0 | 2.7 |
| 12 | 2.0 | 1.0 | 2.0 | 5.0 | 1.7 |
| 13 | 9.0 | 5.5 | 4.0 | 18.5 | 6.2 |
| 14 | 8.0 | 3.0 | 4.0 | 15.0 | 5.0 |
| 15 | 5.5 | 1.5 | 4.0 | 11.0 | 3.7 |
| 16 | 4.0 | 1.5 | 1.0 | 6.5 | 2.2 |
| 17 | 2.0 | 1.5 | 2.0 | 5.5 | 1.8 |
| 18 | 3.5 | 1.5 | 0.0 | 5.0 | 1.7 |
| 19 | 9.0 | 6.0 | 11.0 | 26.0 | 8.7 |
| 20 | 3.0 | 2.3 | 6.0 | 11.3 | 3.8 |
| 21 | 7.0 | 5.0 | 12.0 | 24.0 | 8.0 |
| 22 | 13.0 | 6.0 | 8.0 | 27.0 | 9.0 |
| 23 | 11.5 | 9.0 | 7.0 | 27.5 | 9.2 |
| Blk.Totals | 126.5 | 82.4 | 118.0 | | |
| Blk.Mean | 5.5 | 3.6 | 5.1 | | |

Grand Total ..... 326.9

General Mean ..... 4.7

## ANALYSIS OF VARIANCE

| Source of Variation | Degrees of Freedom | Sum of Squares | Variance | Variance ratio in F. | Table value F at P =.05 |
|---|---|---|---|---|---|
| Total | 68 | 914 | | | |
| Treatment | 22 | 528 | 24 | 3.12 | 1.81 |
| Blocks | 2 | 48 | 24 | 3.12 | 3.21 |
| Error | 44 | 338 | 7.7 | | |

M.S.D. for Treatments = 0.507
at .05 level.

Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Perennial Rye Grass (Lolium perenne) as at Sept.30, 1949. (M.S.D. at .05 level = 3.7)

| Treatments | Block I | II | III | Sum. | Treatment Mean |
|---|---|---|---|---|---|
| 1 | 33.0 | 10.0 | 37.0 | 80.0 | 26.7 |
| 2 | 8.0 | 8.0 | 25.0 | 41.0 | 13.7 |
| 3 | 1.5 | 4.0 | 6.0 | 11.5 | 3.8 |
| 4 | 1.0 | 6.0 | 7.0 | 14.0 | 4.7 |
| 5 | 1.5 | 3.5 | 7.0 | 12.0 | 4.0 |
| 6 | 1.5 | 0.5 | 10.0 | 12.0 | 4.0 |
| 7 | 40.0 | 18.5 | 22.0 | 80.5 | 26.8 |
| 8 | 8.0 | 12.0 | 12.0 | 32.0 | 10.7 |
| 9 | 23.5 | 8.5 | 15.0 | 47.0 | 15.7 |
| 10 | 10.5 | 2.0 | 10.5 | 23.0 | 7.7 |
| 11 | 9.0 | 3.0 | 1.0 | 13.0 | 4.7 |
| 12 | 5.5 | 2.5 | 5.0 | 13.0 | 4.3 |
| 13 | 20.0 | 11.5 | 15.0 | 46.5 | 15.5 |
| 14 | 13.0 | 10.5 | 19.0 | 42.5 | 14.2 |
| 15 | 19.0 | 6.5 | 12.0 | 37.5 | 12.5 |
| 16 | 13.0 | 2.5 | 1.5 | 17.0 | 5.7 |
| 17 | 9.0 | 2.5 | 9.0 | 20.5 | 6.8 |
| 18 | 7.0 | 3.5 | 1.0 | 11.5 | 3.8 |
| 19 | 22.5 | 13.5 | 50.0 | 86.0 | 28.7 |
| 20 | 13.5 | 13.5 | 12.0 | 39.0 | 13.0 |
| 21 | 7.0 | 11.2 | 17.0 | 35.2 | 11.7 |
| 22 | 27.5 | 14.8 | 13.0 | 55.3 | 18.4 |
| 23 | 18.0 | 10.0 | 19.0 | 47.0 | 15.7 |
| Blk.Totals | 312.5 | 178.5 | 326.0 | | |
| Blk. Mean | 13.6 | 7.8 | 14.2 | | |

Grand Total ..... 817

General Mean ..... 11.9

## ANALYSIS OF VARIANCE

| Source of Variation | Degrees of Freedom | Sum of Squares | Variance | Variance ratio in F. | Table value F at P =.05 |
|---|---|---|---|---|---|
| Total | 68 | 6390.33 | | | |
| Treatment | 22 | 3965.21 | 180.24 | 4.29 | 18.1 |
| Blocks | 2 | 578.18 | 289.09 | 6.89 | 3.21 |
| Error | 44 | 1846.94 | 41.98 | | |

M.S.D. for Treatments = 3.7
at .05 level.

Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Orchard Grass (Dactylis glomerata) as at Sept.30, 1949. (M.S.D. at .05 level = 2.8)

| Treatments | Block I | II | III | Sum. | Treatment Mean |
|---|---|---|---|---|---|
| 1 | 20.5 | 6.0 | 15.0 | 41.5 | 13.8 |
| 2 | 25.0 | 2.0 | 10.0 | 37.0 | 12.3 |
| 3 | 4.0 | 4.0 | 7.0 | 15.0 | 5.0 |
| 4 | 1.0 | 2.5 | 5.0 | 8.5 | 2.8 |
| 5 | 1.0 | 2.0 | 2.0 | 5.0 | 1.7 |
| 6 | 1.0 | 1.0 | 3.0 | 5.0 | 1.7 |
| 7 | 16.5 | 5.0 | 10.0 | 31.5 | 10.5 |
| 8 | 9.0 | 5.0 | 5.0 | 19.0 | 6.3 |
| 9 | 14.0 | 4.5 | 2.0 | 20.5 | 6.8 |
| 10 | 5.5 | 2.0 | 1.0 | 8.5 | 2.8 |
| 11 | 2.0 | 4.0 | 1.0 | 7.0 | 2.3 |
| 12 | 2.0 | 2.0 | 1.0 | 5.0 | 1.7 |
| 13 | 11.0 | 5.0 | 4.0 | 20.0 | 6.7 |
| 14 | 9.5 | 4.0 | 6.0 | 19.5 | 6.5 |
| 15 | 11.5 | 3.0 | 4.0 | 18.5 | 6.2 |
| 16 | 4.0 | 2.0 | 1.0 | 7.0 | 2.3 |
| 17 | 3.5 | 1.0 | 2.0 | 6.5 | 2.2 |
| 18 | 1.5 | 2.0 | 1.0 | 4.5 | 1.5 |
| 19 | 4.5 | 2.5 | 10.0 | 17.0 | 5.7 |
| 20 | 1.5 | 0.5 | 3.0 | 5.0 | 1.7 |
| 21 | 6.0 | 7.0 | 17.0 | 30.0 | 10.0 |
| 22 | 38.0 | 7.0 | 9.0 | 54.0 | 18.0 |
| 23 | 18.0 | 9.0 | 11.0 | 38.0 | 12.7 |
| Blk.Totals | 210.5 | 83.0 | 130.0 | | |
| Blk.Mean | 9.15 | 3.61 | 5.65 | | |

Grand Total ..... 423.5

General Mean ..... 6.1

## ANALYSIS OF VARIANCE

| Source of Variation | Degrees of Freedom | Sum of Squares | Variance | Variance ration in F | Table value F at P =.05 |
|---|---|---|---|---|---|
| Total | 68 | 2876.94 | | | |
| Treatment | 22 | 1456.11 | 66.19 | 2.75 | 1.81 |
| Blocks | 2 | 361.53 | 180.77 | 7.51 | 3.21 |
| Error | 44 | 1059.30 | 24.08 | | |

M.S.D. for Treatments = 2.8
at .05 level.

Effect of Applications of Various Amounts of 2,4-D and Mixtures of 2,4-D and IPC on the weight of Clippings from Hog Millet (Panicum miliaceum) (M.S.D. at .05 level = 6.9)

| Treatments | Block I | II | III | Sum. | Treatment Mean |
|---|---|---|---|---|---|
| 1 | 44.0 | 16.0 | 44.0 | 104.0 | 34.7 |
| 2 | 42.0 | 35.0 | 69.0 | 146.0 | 48.7 |
| 3 | 42.0 | 17.5 | 72.0 | 131.5 | 43.8 |
| 4 | 44.0 | 29.0 | 64.0 | 137.0 | 45.7 |
| 5 | 45.0 | 28.0 | 82.0 | 155.0 | 51.7 |
| 6 | 49.0 | 37.0 | 80.0 | 166.0 | 55.3 |
| 7 | 33.0 | 42.5 | 35.0 | 110.5 | 36.8 |
| 8 | 50.0 | 38.0 | 49.0 | 137.0 | 45.7 |
| 9 | 26.0 | 19.0 | 57.0 | 102.0 | 34.0 |
| 10 | 26.0 | 34.0 | 65.0 | 125.0 | 41.7 |
| 11 | 33.0 | 14.5 | 32.0 | 79.5 | 26.5 |
| 12 | 39.0 | 38.5 | 41.0 | 118.5 | 39.5 |
| 13 | 31.0 | 20.5 | 57.0 | 108.5 | 36.2 |
| 14 | 24.0 | 24.0 | 41.0 | 89.0 | 29.7 |
| 15 | 34.5 | 18.5 | 34.0 | 87.0 | 29.0 |
| 16 | 33.0 | 25.0 | 32.0 | 90.0 | 30.0 |
| 17 | 20.0 | 20.0 | 61.0 | 101.0 | 33.7 |
| 18 | 31.5 | 9.0 | 30.0 | 70.5 | 23.5 |
| 19 | 0.0 | 4.5 | 0.0 | 4.5 | 1.5 |
| 20 | 1.5 | 22.0 | 4.0 | 27.5 | 9.2 |
| 21 | 5.5 | 18.5 | 1.3 | 37.0 | 12.3 |
| 22 | 26.0 | 10.0 | 7.0 | 43.0 | 14.3 |
| 23 | 49.0 | 30.5 | 54.0 | 133.5 | 44.5 |
| Blk.Totals | 729 | 551.5 | 1023.0 | | |
| Blk. Mean | 31.7 | 23.9 | 44.5 | | |
| Grand Total ..... | | | | 2303.5 | |
| General Mean ..... | | | | 33.3 | |

## ANALYSIS OF VARIANCE

| Source of Variation | Degrees of Freedom | Sum of Squares | Variance | Variance ratio in F. | Table value F at P = .05 |
|---|---|---|---|---|---|
| Total | 68 | 24,144.08 | | | |
| Treatment | 22 | 12,931.58 | 587.8 | 4.12 | 1.81 |
| Blocks | 2 | 4,931.23 | 2465.6 | 17.26 | 3.21 |
| Error | 44 | 6,281.27 | 142.8 | | |

M.S.D. for Treatments = 6.9
at .05 level.