T H E S I S

THE INFLUENCE OF HERBICIDES ON MICROBIAL ACTIVITY IN THE SOIL

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY DONALD B. BAKES

ENTITLED THE INFLUENCE OF HERBICIDES ON MICROBIAL ACTIVITY IN THE SOIL

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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INTRODUCTION

Present day trends in agriculture indicate that farmers must cut production costs if they are to realize a profit. For example, to produce a crop of field onions in Colorado four to five hand weedings are required. This may cost as much as one hundred dollars per acre. The use of herbicides is one effective way of cutting production costs. Much empirical data are available on the effects of herbicide applications on weed control. This type of data answers many of the questions raised by growers such as type of herbicide to use, rates and dates of applications and whether it will increase or decrease yields. Previous investigations in this department (22) have answered some of these questions; however other fundamental questions remain unanswered. Two examples follow: does the application of herbicides to the soil alter the exchange complex by the replacement of an ion adsorbed on the soil colloid with an herbicide ion? What possible effects do herbicides have on soil microorganisms?

Fundamental information is necessary if we are to eliminate some of the hazards which accompany the use of agricultural chemicals. The scope of this study will be limited to that portion of the problem which involves the production of nitrate nitrogen by microorganisms in the soil as it is influenced by temperature, soil type, kind and rate of herbicide application as a function of time.

The nature of the biological medium into which herbicides are placed needs to be clearly understood before intelligent cultural practices can be utilized efficiently. The soil is a dynamic heterogeneous medium consisting of very many different kinds and numbers of organisms, the numbers and kinds depending upon the soil environment and man's treatment. A system of checks and balances imposed by physical, chemical, and biological variations within the soil serves to decide the kind and number of the active population at a given time. Thus the application of an herbicide to the soil would change the environment and alter the biological composition of the soil. This poses the question: is the magnitude of the change brought about by herbicides enough to alter the nitrate nitrogen produced by microorganisms? One important group of microorganisms is the chemosynthetic autotrophs which change the ammonia nitrogen produced by the heterotrophs from the soil organic matter, into nitrate nitrogen. This group is sensitive to change in the soil environment and hence the nitrate produced by them may be used as an indication of the effect of a given herbicide on one segment of the soil microbial population. Since all higher plants, including onions, are dependent on the production of nitrate nitrogen, it would be desirable to know whether or not the herbicides may in any way effect this fundamental process.

If the herbicides used in weed control on onions affect the nitrate nitrogen producing bacteria, then the value of the herbicide must be correlated with the changes in amounts of nitrate nitrogen. For this reason the investigation was undertaken.

Problem

Do herbicides influence microbial activity in the soil?

Problem analysis.--In order to answer the main problem it was found necessary to obtain answers to the following four questions:

1. What is the effect of herbicides on microbial activity when applied to the soil?

2. What is the effect of rate of application of herbicides on microbial activity as measured by production of nitrate nitrogen?

3. What is the duration of the effect of herbicides as measured by microbial activity?

4. What is the duration of the effect of herbicides on microbial activity as measured by nitrate nitrogen?

Delimitations.--This investigation has been limited to (1) three soil types: Gilcrest sand, Rocky Ford loam and Las Animas clay; (2) three herbicides: Calcium cyanamide ($CaCN_2$), o-isopropyl n-(3 chlorophenyl) carbamate (chloro IPC) and 2 chloro 4,6-bis (diethylamino)-s triazine (444E); (3) three soil temperatures: 13°, 25°, and 35° Centigrade; (4) four dates of sampling: 5, 10, 20, and 30 days after the start of incubation; (5) microbial activity to be measured by changes in nitrate nitrogen; (6) four herbicide rates.

REVIEW OF LITERATURE

Herbicide residues in soils have received much less consideration than the effects of their applications to plants. This placement of emphasis can be attributed to the readily observable effect of the herbicide on plant growth, whereas the effects of herbicide residues in soils may not be readily apparent. Studies of herbicides in soils have dealt primarily with the persistence of the herbicide as it may effect subsequent crops and with the effect of herbicides on microorganisms.

Effects of 2,4-dichlorophenoxyacetic acid on soil microorganisms have been investigated. Koike and Gainey (12) state 2,4-D is non-toxic to most microorganisms at concentrations used in the field for weed control. Fults and Payne (10) and other investigators (5,11,17,24, 25) report inhibitory effects on organisms by 2,4-D at concentrations used for weed control.

Aldrich (1) states that all microorganisms are not affected to the same degree by a particular herbicide, just as all higher plants do not react the same. He also states that the selective action of 2,4-D on microorganism population may change with repeated herbicide application. The rate of 2,4-D decomposition in soil indicates slight decomposition immediately after treatment, followed by rapid decomposition. Presumably a lag period is necessary for build-up of organisms capable of breaking down 2,4-D, indicating that the number of such organisms is limited at a given time. Audus (3) and Newman (17) working with 2,4-D and 2-methyl-4-chlorophenoxyacetic acid (MCP) report that pretreatment with these compounds results in more rapid decomposition of subsequent applications of the compounds. This suggests an accumulation of organisms capable of using such compounds as a source of carbon. However, Audus (2) was not able to culture the organism responsible for 2,4-D decomposition in the absence of 2,4-D. Therefore, he concludes that 2,4-D is the only source of carbon utilizable by these organisms.

Norman and Newman (21) state that the build-up of organisms capable of decomposing a particular herbicide may reduce the effectiveness of subsequent soil applications of the herbicide.

Aldrich (1) states that herbicides may be removed from the soil by one or more of the following ways: (1) leaching, (2) fixation by the soil colloids, (3) decomposition, and (4) volatilization. Conditions that affect these means of removal determine the persistence of an herbicide in the soil.

It appears that decomposition of herbicides in the soil is accomplished through the action of soil organisms. A number of investigations (2,3,8,9,13,14, 15,18,19,20,23,28,30) have shown that soil moisture, soil temperature, organic matter content, and other factors most conducive to microbial activity are also most conducive to herbicide decomposition. ZoBell (31) states that aliphatic hydrocarbons are oxidized more readily than aromatic or naphthenic compounds. Within certain limits, long-chain hydrocarbons are attacked more readily than similar compounds of small molecular weight. The addition of aliphatic side chains increases the susceptibility of cyclic compounds to microbial attack.

The reports of decomposition of herbicides by microorganisms indicate that small differences in chemical structure have a pronounced effect on decomposition by soil organisms. Isopropyl N-(3-chlorophenyl)-carbamate is readily attacked by microorganisms in soil (19,23,27), while 3-p-chlorophenyl-1,1-dimethylurea is extremely resistant to attack.

Audus (2) found that the organisms capable of breaking down 2,4-D were able to breakdown 2 methyl-4-chlorophenoxyacetic acid at a lower rate. The organism involved in 2,4-D decomposition did not affect decomposition of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid).

Early workers believed that microorganisms were responsible for the change from cyanamide to ammonia in the soil. Crowther and Richardson (7) state that although some bacteria and fungi are able to attack cyanamide, many inorganic catalysts for the cyanamide to urea reaction were discovered by Ulpiani, Kappen, and others. Cowie (6) showed that in sterile soils urea was rapidly formed and accumulated; in partially sterilized soils the urea disappeared again after a few days and ammonia and nitrates accumulated.

Temme (29) found that the speed with which the cyanamide in the soil is being converted appears to be connected with the humidity of the soil and the temperature whereby the conversion takes place. He concluded that the conversion of calcium cyanamide to urea is accomplished by physico-chemical means, while the conversion of urea to nitrate nitrogen is accomplished biologically.

Mukerji (16) measuring the microbiological activity of the soil treated with calcium cyanamide found no relationship between bacterial numbers as determined by plate counts and the changes in the amounts of simple nitrogen compounds. He states that since the plating method is highly selective, the rate of carbon dioxide production was used as a general integration of microbiological activity. The results of Mukerji's investigation show that in two different experiments calcium cyanamide when compared with ammonium sulfate increased the carbon dioxide evolution 18 per cent.

METHODS AND MATERIALS

One hundred pound samples of the three soil types were collected in the field and brought to Fort Collins. These samples were air-dried then sieved, the soil passing through a 2 mm. sieve was reserved for the study.

A tension equal to 70 cm. of water (near ideal moisture content) for the Gilcrest sand from Weld county, was 1.55 ml. per 25 g. of soil; for the Rocky Ford loam from Otero county, 6.55 ml. per 25 g. of soil; and for the Las Animas clay from Otero county, 7.14 ml. per 25 g. of soil. Other properties of these soils are given in Table 1.

Table 1.--COOPERATIVE SOILS LABORATORY ANALYSIS REPORT.

Soil class	Depth	pH 1:5	Per cent soluble salts	Per cent O.M.	Per cent lime	lb./A. P_2O_5	lb./A. K_2O
Sand	0-6"	6.8	0.07	1.2	0.0	280	397
Loam	0-6"	7.9	0.13	1.4	7.7	47	370
Clay	0-6"	8.0	0.16	2.4	13.1	96	689

Twenty-five gram samples of the air-dry soil were weighed and placed into 25 ml. erlenmeyer flasks. The herbicides used in this experiment were added to these flasks at rates equivalent to rates used in field applications as indicated by Table 2.

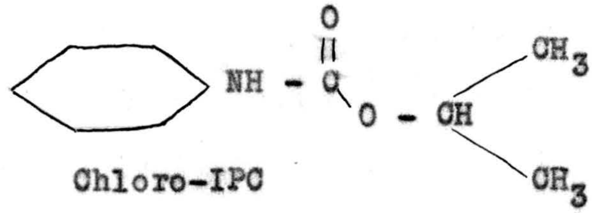
Table 2.--HERBICIDE RATES AS EXPRESSED IN POUNDS, KILOGRAMS, AND MICROGRAMS.

Herbicide	Pounds per acre	Kilo g. per 25 g. soil	Micrograms per 25 g. soil
CIPC	3	1.36	37.5
CIPC	3 + 3	2.72	75.0
CIPC	6	2.72	75.0
444E	10	4.54	97.5
444E	15	6.80	146.2
444E	20	9.07	195.0
$CaCN_2$	100	45.36	1250.0
$CaCN_2$	200	90.72	2500.0
CaCN	400	181.44	5000.0

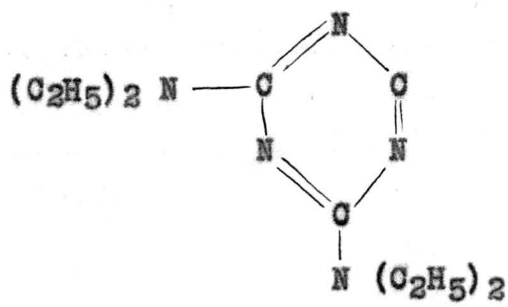
The three herbicides used in this experiment were calcium cyanamide ($CaCN_2$), Chloro-IPC or CIPC (o-isopropyl n- (3 chlorophenyl) carbamate, and 444E (4,6-bis (diethylamino) -s triazine. The structural formula for each herbicide is presented.

$Ca{=}N - C{\equiv}N$

Calcium cyanamide



Chloro-IPC



444E

The materials soluble in water (CIPC) and 444E were dissolved in water in such an amount that the water required to bring the soil to a water content equal to that at 70 centimeters of water tension would contain the proper amount of herbicide. The solutions were applied by means of a burette. The insoluble calcium cyanamide was mixed with a diluent of quartz sand to pass a 200 mesh sieve. The herbicide-diluent mixture equivalent to recommended rates for weed control in onions was weighed and mixed with each soil sample. Water in proper amount was then added to these samples.

Three incubation temperatures were used: 13°C., 25°C., and 35°C. These temperatures were maintained in an insulated chamber by means of thermostatically controlled infrared heat lamps. A high relative humidity was maintained in the chambers by a pan of water which was just slightly smaller than the dimensions of the bottom of the box. Temperature and humditiy were recorded on a weekly hydro-thermograph. All erlenmeyer flasks were stoppered with one-holed rubber stoppers to minimize changes in moisture content.

One hundred and forty-four erlenmeyer flasks containing 25 grams of soil plus the herbicide treatment were placed in three different temperature chambers. One-fourth of all the samples from each chamber were removed at the end of 5, 10, 20, and 30 days. Upon removal from the chambers, all samples were immediately oven-dried and stored prior to analysis.

Explanation of chemical analysis

1. Nitrate nitrogen was removed from each 25 g. soil sample by extraction with an 80 ml. solution of silver sulfate and copper sulfate (2 g. $AgSO_4$ - 30 g. $CuSO_4$ per 12 liters distilled water).

2. Shake 10 minutes.

3. Add about 0.6 g. precipitating mixture (10 parts $MgCO_3$ and 4 parts $Ca(OH)_2$).

4. Shake 10 minutes.

5. Filter (Whatman 42) and catch extract in 50 ml. erlenmeyer flasks.

6. Pipet aliquot of 2 ml. into 100 beaker.

7. Dry aliquot in oven (80 to 85°C).

8. Add 2 ml. phenoldisulfonic acid reagent (dissolve 25 g. pure white phenol in 150 ml. concentrated H_2SO_4, add 75 ml. fuming H_2SO_4, 13 to 15 per cent SO_3. Heat at 100°C. for two hours.

9. Allow to stand for 10 minutes, making sure that all residue in the beaker has been contacted.

10. Add 16 ml. of distilled water.

11. Add 20 ml. of 1:1 NH_4OH.

12. Cool and read per cent transmission using a Cenco Photelometer and a filter of 410 to 440 mu.

The transmission data was converted to micrograms of nitrate nitrogen from a calibration curve, and the data is recorded in appendices I and II.

STATISTICAL ANALYSIS OF DATA

Biological data is highly variable and well designed experiments always provide a means of assessing the magnitude of this variation. Conventionally, replicates of each treatment accomplish this objective with two replicates being the minimum and a much larger number being more desirable. The major limitation of this technique is that large numbers of samples must be processed. In the present experiment 432 individual analyses were made and the experiment had but one replication. The necessary precision was achieved by using a statistical technique for analyzing the data. This technique is described in the succeeding paragraph.

The statistical tool or technique used to evaluate an experiment of this type without the use of replicates is based on the fact that when an analysis of variance is interpreted it is impossible, to a large degree, to interpret third and higher order interactions. These higher order interactions are lumped with the error term and as a result increase the overall and individual item precision accordingly. In the experiment described five main effects were considered; temperature, soil type, rate of herbicide, kind of herbicide, and sampling dates: 10 first order interactions, 10 second order interactions; third and higher order interactions were lumped with the error term.

The statistical technique by which the data were handled is given in detail in appendices I and II. The data were analyzed in two different manners with identical results. A $3^3 \times 2^4$ factorial design was used in the experiment and the production of nitrate nitrogen as influenced by time, temperature, soil type, rate of herbicide, kind of herbicide and their interactions were measured.

In the succeeding discussion it is to be understood that whenever the term nitrate nitrogen is used it will refer to the average amount of nitrate nitrogen produced.

The analysis of the data shows that a significant increase in nitrate was obtained as a result of the action of all of the major variables under consideration. The effect of temperature on nitrate production was linear; the higher the temperature, the higher the nitrate production (see Table 4). Since the temperatures used were well within the range normally found in these soils, the data confirm predictions which could have been made from theory.

The effect of soil type was very significant. The data show that the soils studied nitrify at different and characteristic rates. The major factor involved in the differences between the soils appears to be the amount of clay which the soils contain. The Gilcrest sand produced less nitrate than the Rocky Ford loam which in turn produced less than the Las Animas clay. Microbial populations also increase with the clay content of the soil and hence one explanation of this effect of soil type may be that a higher number of nitrifying bacteria is associated with the increase in clay content (see Tables 6 and 7).

Nitrate nitrogen increased in all of the soils as a function of time. This is as would be expected and is a direct result of the build up and adaptation of the microbial population.

The main effect of herbicides indicates that there is no statistical difference in the amount of nitrate nitrogen produced by soils treated with either Chloro-IPC or 444E. Soils treated with these materials however, produced significantly less nitrate nitrogen than those to which calcium cyanamide had been added. There was no difference in the amount of nitrate nitrogen produced by soils treated with Chloro-IPC or 444E and the nontreated soil.

When the effect of herbicide rates were compared, it was noted that there was no statistical difference between the untreated control, and the first rates. There was no statistical difference between the second and third rates, however, the amount of nitrate nitrogen produced by both the second and third rates was significantly higher than in the nontreated soil.

An examination of the first and second order interactions showed that with the exception of herbicide by herbicide rate, and herbicide by sampling date, none of the interactions showed changes in effect. That is, the soils studied did not act differently at different temperatures, times or with different herbicides or herbicide rates. Some of the more important interactions are shown in Tables 4, 5, 6, 7, 8 and Figs. 1 and 2.

Table 3 shows the relationship between temperature and herbicide. The amount of nitrate nitrogen produced in soils treated with 444E and Chloro-IPC increased with temperature. The difference between the two herbicides was slight but significant at 25° and 35°C.

The relation between rate of herbicide application and temperature is shown in Table 4. This data shows that there was no significant increase in nitrate nitrogen production at any temperature when the untreated soil and the first rate are compared. The data in Table 4 also indicates that there was a significant increase in nitrate nitrogen production over the check at all temperatures and at all other herbicide rates.

The relationship between kind of herbicide and soil type as these variables affect nitrate accumulation is shown in Table 5. This data indicates that the herbicides did not act differently in the soils studied. The overall effect of the different herbicides was most pronounced in the Las Animas clay.

The effect of the rate of herbicide application when combined with the effect of soil type is shown in Fig. 2 and also in Table 6. Table 6 points out that the soils react similarly at all rates of herbicide application and nitrate nitrogen production increases (in general) with rate of herbicide application and with increase in the clay content of the soil.

The data arranged to show the relationship between soil type and sampling date are shown in Table 7. The data indicates that all soils react similarly to produce increasing amounts of nitrate nitrogen as the length of incubation of the soil sample increases.

The effect of sampling dates when combined with herbicides is given in Table 8. These data indicate that calcium cyanamide increased the amount of nitrate nitrogen in the sample at all sampling dates significantly over 444E and Chloro-IPC. The latter two herbicides do not react similarly at all sampling periods, but the differences are small.

As indicated in Fig. 1, there is some interaction between herbicide rate and kind of herbicide when the nontreated samples are compared with the first rate of all herbicide. Between the first and second and second and third rates the herbicides act similarly with $CaCN_2$ producing the most nitrate nitrogen, and 444E producing slightly but not significantly less than Chloro-IPC.

The remaining undiscussed first order interactions may be examined in the tables in appendix II. The second order interactions are also given. In general the first order interactions show significant changes in the magnitude of nitrate nitrogen production but do not show any appreciable changes in effect. The second order interactions show a great deal of variation, some show no significance, some barely significant, and two are highly significant. In general, no additional information was obtained from the second order interactions. More data is necessary to interpret accurately these three factor interactions. As noted previously, the degrees of freedom for the third and higher order interactions were lumped and included in the error term so no attempt was made to explain these interactions.

Table 3.--TEMPERATURE BY HERBICIDE INTERACTION.

Herbicides	13°C	25°C	35°C	L.S.D. .05 level	L.S.D. .01 level
	μg NO_3/1 g of soil				
Check	9.82	12.59	15.76	0.66	1.09
$CaCN_2$	14.06	19.66	26.74	0.66	1.09
CIPC	13.50	16.50	20.80	0.66	1.09
444E	12.74	16.06	21.82	0.66	1.09

Table 4.--TEMPERATURE BY HERBICIDE RATE INTERACTION.

Herbicide rate	13°C	25°C	35°C	L.S.D. .05 level	L.S.D. .01 level
	μg NO_3-n/1 g of soil				
0	13.12	16.80	21.02	0.67	1.02
1	12.80	16.45	21.42	0.67	1.02
2	14.80	17.78	23.60	0.67	1.02
3	13.02	18.62	26.45	0.67	1.02

Table 5.--HERBICIDE BY SOIL TYPE INTERACTION.

Soil class	Check	$CaCN_2$	CIPC	444E	L.S.D. .05 level	L.S.D. .01 level
	μg NO_3-N/1 g of soil					
Sand	9.14	13.63	12.77	12.19	0.67	1.02
Loam	13.23	18.80	16.62	16.96	0.67	1.02
Clay	15.82	28.03	21.39	21.46	0.67	1.02

Table 6.--SOIL TYPE BY HERBICIDE RATE INTERACTION.

Herbicide rate	Sand	Loam	Clay	L.S.D. .05 level	L.S.D. .01 level
	$\mu g\ NO_3$/1 g of soil				
0	12.18	17.65	21.12	0.67	1.02
1	12.45	15.87	22.35	0.67	1.02
2	13.60	18.58	24.00	0.67	1.02
3	13.25	17.78	27.07	0.67	1.02

Table 7.--SAMPLING DATE BY SOIL TYPE INTERACTION.

Sampling date	Sand	Loam	Clay	L.S.D. .05 level	L.S.D. .01 level
	$\mu g\ NO_3$/1 g of soil				
5 days	10.35	14.62	18.45	0.67	1.02
10 days	11.90	17.38	22.45	0.67	1.02
20 days	14.50	18.50	24.53	0.67	1.02
30 days	14.70	19.38	29.12	0.67	1.02

Table 8.--HERBICIDE BY SAMPLING DATE INTERACTION.

Sampling date	$CaCN_2$	CIPC	444E	L.S.D. .05 level	L.S.D. .01 level
	$\mu g\ NO_3$/1 g of soil				
5 days	15.60	13.90	13.90	0.67	1.02
10 days	19.06	16.98	15.68	0.67	1.02
20 days	22.13	17.15	18.21	0.67	1.02
30 days	23.81	19.68	19.68	0.67	1.02

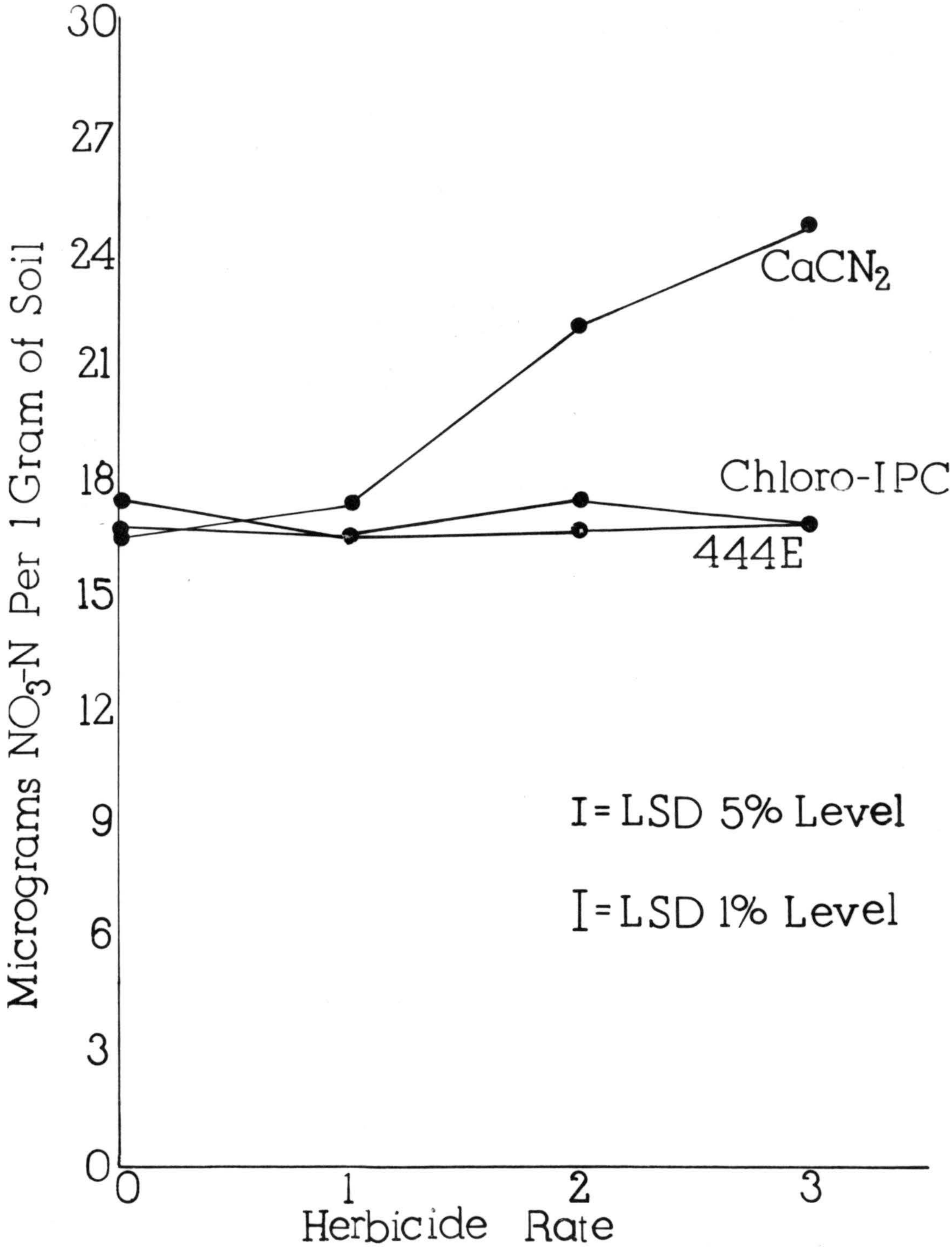


Fig. 1.--Herbicide by herbicide rate interaction.

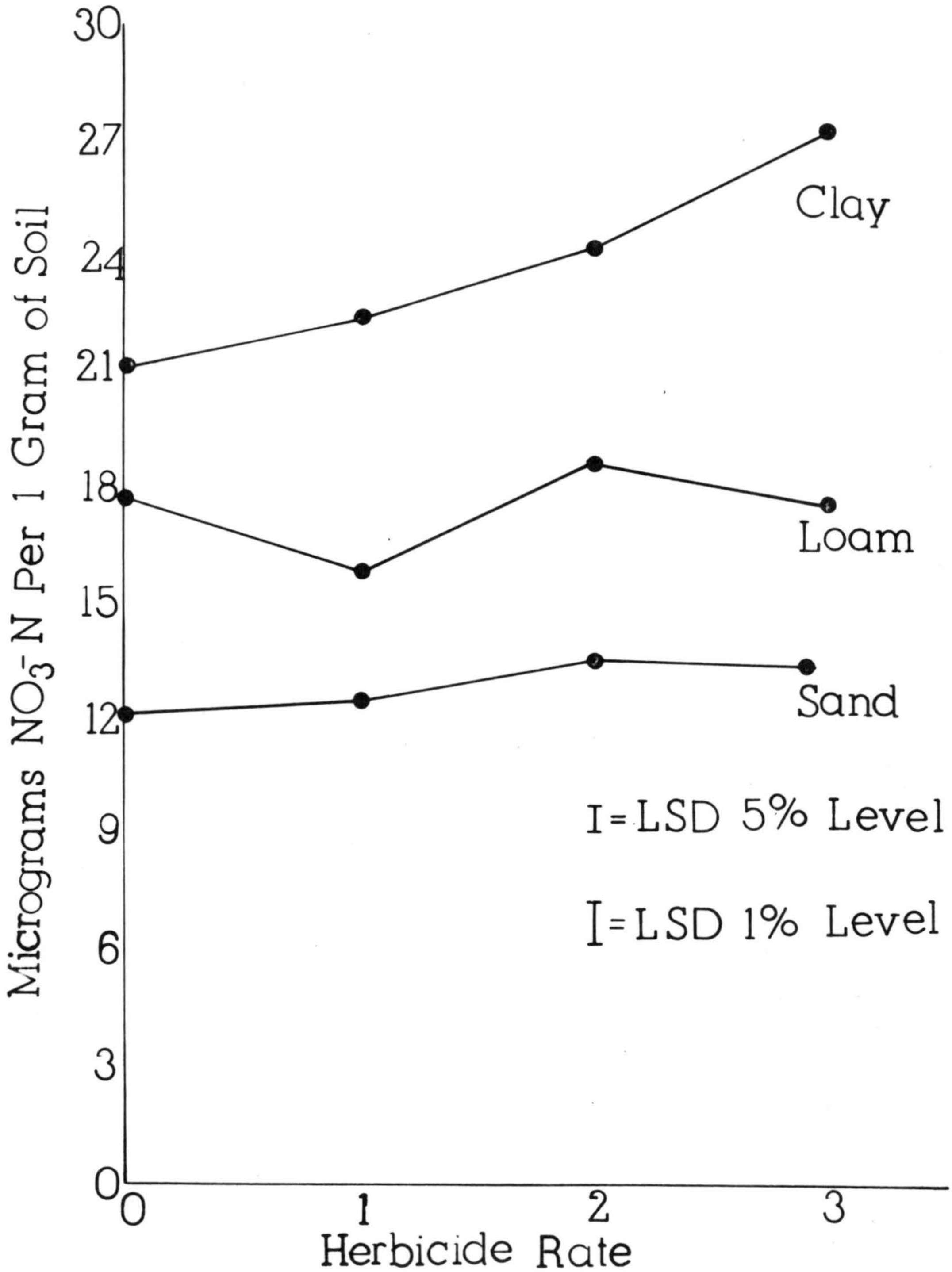


Fig. 2.--Soil type by herbicide rate interaction.

DISCUSSION OF RESULTS

Herbicides were applied to three types of soil (Gilcrest sand, Rocky Ford loam, and Las Animas clay) and the nitrate nitrogen produced by the soil over an incubation period of 30 days and at controlled temperatures measured. There was no reduction of nitrate over that in the control soil, in fact a slight increase was noted in all cases. It was not the intent of this study to investigate the mechanism which altered the nitrate nitrogen content of soils. However, where possible, explanation of the mechanism is made.

Soil samples which were treated with $CaCN_2$ were found to contain a much higher level of nitrate than those soils to which the other herbicides had been added. It is reasonable that this should be so since $CaCN_2$ contains 21.5 per cent nitrogen and is known to decompose and liberate nitrogen which eventually is changed to nitrate. A general breakdown of the decomposition of calcium cyanamide in the soil is given by Crowther and Richardson (7).

Calcium cyanamide which is present in the fertilizer in a crystalline form, dissolves with decomposition in water to give an acid salt and calcium hydroxide:

$$2CaCN_2 + 2H_2O \longrightarrow Ca(HCN_2)_2 + Ca(OH)_2$$

In concentrated solutions a basic salt ultimately separates out in needles and free cyanamide is formed:

$$2Ca(HCN_2)_2 + 2H_2O \longrightarrow (CaOH)_2\ CN_2 + 2H_2CN_2$$

Free cyanamide may be regarded either $H_2N.CN$ or as carbodiimide HN C N H, and both forms are probably present in solution. It behaves as a weak monobasic acid; dibasic salts do not exist in solution.

An aqueous solution of pure cyanamide is relatively stable, but in the presence of acid or alkali or certain other catalysts it undergoes fairly rapid changes. In moderately alkaline solutions, especially when heated, it polymerises almost quantitatively to dicyanodiamide

NH_2
C NH. The rate of reaction increases with the pH value
NH.CN

up to about 9.6, but in still more alkaline conditions (pH greater than 10) the rate falls off rapidly, while hydrolysis to urea commences and becomes almost quantitative about pH value of 12.

In acid solutions free cyanamide is hydrolysed to urea, and the reaction is catalysed by many organic compounds, especially salts or oxides of iron or manganese. This is the formal change undergone in the soil.

Calcium cyanamide when applied to the soil usually decomposes into a form readily available for plant utilization. In the process it passes through a stage which is toxic to germinating weed seeds. In dry soils having a relatively high pH above 8.0, calcium cyanamide tends to polymerize into diciandiamid $(H_2NCN_2)_2$. This compound has little value either as a fertilizer or herbicide because of its relative stability and insolubility.

For the other two herbicides, CIPC and 444E, the amount of nitrogen which may have been introduced by the application of the herbicides, was negligible.

There are a number of possible explanations for the increase in nitrate nitrogen over that in the control in those soils treated with CIPC and 444E. One explanation might be that partial sterilization of the system is brought about by the treatment. There are several theories to explain how partial sterilization increases soil fertility. The process may destroy the biological check which has maintained a given population at a certain level. The addition of a toxic material or other severe treatment serves to kill or severely restrict the activities of some members of the microbial population. It is known that the protozoa and some higher fungi are especially susceptible. The organisms which have been killed serve as a high carbon-nitrogen ratio food source for the remaining portion of the population. Since these organisms are high in nitrogen, ammonia is released is nitrified and nitrate, in excess of that in a control soil, is found upon analysis. This may very well be the explanation for the increase in nitrate nitrogen found in this experimental study.

The data show a general increase in nitrate as a function of both temperature and time. The temperatures used were well within the range normally found in the same soils in the field. Temperature increases normally would double the amount of nitrate produced for each 10 degree rise in temperature (degrees centigrade). The increases herein reported are somewhat less than this. The temperature range used is quite similar to that which would be encountered in the field from spring to late summer and the rate of nitrification coupled with the information available as to the effect of length of incubation gives a means of predicting, at least in the case of $CaCN_2$, the amount of nitrate which would be available at a given length of time after application.

Each soil produces a characteristic and different curve for nitrate accumulation as a function of the variables studied in this experiment. The curve for a given soil is a function of many variables, in addition to those studied here. The immediate pretreatment of the sample prior to the initiation of the experiment is particularly important and was kept constant for all soils used. Field history, often difficult to obtain, would also condition the results which are obtained. The more clay in a soil, in general, the more favorable would the soil environment be for microorganisms. In general organic matter (food), water, and mineral nutrients increase with clay content while aeration may become less desirable.

When the effect of each herbicide was isolated and compared with the untreated soil, it was found that soils treated with $CaCN_2$ had a significantly greater amount of nitrate nitrogen. Soils treated with CIPC and 444E were not statistically different from the control. However, in the following interactions: temperature by herbicide and soil type by herbicide, there was a significant increase in the amount of nitrate nitrogen when compared to untreated soil. It is probable that the interaction effect comes closer to measuring what actually takes place when herbicides are applied to the soil than isolating one factor and using it to represent the overall effect. Processes in nature seldom function as the result of the operation of a single variable, rather many variables are involved in a single measurement. In experimental research attempts are made to eliminate or hold constant all variables except the one under consideration. Whether or not such idealized experimental conditions are actually produced is a matter for conjecture.

All herbicidal applications were made prior to incubation with one exception. A split application of CIPC was used in which the equivalent of three pounds per acre was applied prior to incubation, and then the same rate was applied to the same soil samples after they had incubated for one week. There was no indication of a reduction in the production of nitrate nitrogen resulting from this treatment. This would tend to indicate that repeated additions of the same type of herbicide (at rates commonly used for weed control) do not greatly influence microbial activity as measured by the specialized process of nitrate production. The practical recommendation would be that these herbicides could be used for a considerable number of years with little effect on the production of nitrate nitrogen and probably with little effect on the soil in general.

In summary it may be concluded that for the herbicides considered, there is no deleterious effect on the soil microbial population, particularly those organisms which produce nitrate nitrogen. The increase in nitrate nitrogen production would enhance crop growth and there is little indication that there would be any residual effects from the frequent use of these materials. The study indicates that if conditions were favorable, calcium cyanamide could serve both as a herbicide and as a fertilizer.

APPENDIX I

Coded Data

Bainbridge et.al. (4), states that in analyzing the results of a factorial experiment it is sometimes desirable to calculate separately a complete set of means and mean squares each relating to one degree of fredom. This complete analysis is most valuable in complex experimental designs which include confounding, different error components, and possibilities of error varying with factor level or replication, or where it is desirable to examine and allow for the effect of some uncontrolled variable. For example in the present experiment, the sum of squares associated with the temperature by herbicide interaction (containing four degrees of freedom) was 142.22. Using the tabular analysis described by Bainbridge et.al. (4), the sum of squares associated with each degree of freedom of this interaction are: 59.63 (linear by linear effect), 1.46 (linear by quadratic effect), 30.25 (quadratic by linear effect), and 0.88 (quadratic by quadratic effect), giving a more detailed study of the interaction. It is evident that two of the sum of squares of the temperature by herbicide interaction are not significant. Thus the degree of freedom associated with each of these two sums of squares might very well be combined with the error term, which would tend to increase the precision of future experiments.

The generalized tabular method is illustrated in Table 9 for the factorial experiment used in this study. The coefficients used in each stage of the calculation are found in Tables 10 and 11. Referring now to Table 9, the raw data are given in the column headed NO_3-N values. Column 1 was formed by first dividing the column headed by NO_3-N values into groups of threes to represent the three levels of factors (herbicides, soils, temperatures). The sums of each group of three numbers were obtained, and those numbers became the first 144 numbers of column 1. Those numbers were obtained by using coefficient 0 in Table 10. The second 144 numbers of column 1 were obtained by subtracting the first number (in the first group of three numbers) from the third or last number. Coefficient 1 in Table 10 was used in that step. The last 144 numbers in column 1 were obtained by subtracting two times the second number from the first number of the group of three numbers, and adding the third. Coefficient 2 of Table 10 was used in this step. This process was repeated over again for each group of three numbers in columns 1, 2, and 3. There are 144 groups containing three numbers in each of these columns.

Columns 4 and 5 were computed by dividing the columns into groups with four numbers each, as these represent factors which have four levels. The first 108 numbers in column 4 were obtained by summing the first four numbers of column 3. This is indicated as coefficient 0 Table 11. The second 108 numbers of column 4 were obtained by using coefficient 1 of Table 11 on the first four numbers of column 3. The third group of 108 numbers of column 4 were obtained by using coefficient 2 of Table 11 on the first four numbers of column 3. The last 108 numbers of column 4 were obtained by applying coefficient 3 of Table 11 to the first four numbers of column 3. This process was repeated for all groups of four numbers in columns 3 and 4.

Table 10.--ORTHOGONAL POLYNOMIAL COEFFICIENTS AND DIVISORS FOR 3-LEVEL FACTORS.

Coefficient number	1	2	3	Divisor
0	1	1	1	3
1	-1	0	1	2
2	1	-2	1	6

Table 11.--ORTHOGONAL POLYNOMIAL COEFFICIENT AND DIVISORS FOR 4-LEVEL FACTORS.

Coefficient number	1	2	3	4	Divisor
0	1	1	1	1	4
1	-3	-1	1	3	20
2	1	-1	-1	1	4
3	-1	3	-3	1	20
Check	-2	2	-2	6	

The column headed divisor (Table 9) was calculated by using the divisors associated with the coefficients in Tables 10 and 11. Going back to the column headed RDHST (Table 9) and in the example below, it will be noted that the columns headed by R and D contain four factors. The divisors associated with the coefficients in Table 11 were used for the first two columns. The next three columns headed by the letters HST contain only three factors, thus the divisors associated with the coefficients from Table 10 were used on those three columns.

Type of treatment	R D H S T	Divisor of each column	Divisor
Number of factors in each treatment	4 4 3 3 3		
Numerical code	0 0 0 0 0	4 4 3 3 3	432
for each	1 1 2 2 2	20 20 6 6 6	86,400
treatment	1 0 2 2 2	20 4 6 6 6	17,280
	0 0 0 1 1	4 4 3 2 2	192

The divisor associated with 0 treatment (when the treatment contains four factors) was found by looking for the number 0 in Table 11 under the heading coefficient number, and then reading across the table until the number four was found under the heading divisor. The divisor for any treatment containing four factors can be found in exactly the same manner. When the treatment contained only three factors the same method was used except Table 10 was used instead of Table 11. When the divisor of each column was found the product of these five numbers was the final divisor.

Each column was checked in the following manner in order to correct for mistakes. Beginning with the column headed NO_3-N values, the sum was obtained. The same column was divided into groups containing three numbers as done before. The first number of all groups (there are 144 groups hence 144 numbers) were added together. All second numbers of each group and all third numbers of each group were summed in like manner. This gave three sums which were written at the end of this column and labeled subtotal. The sum of these three sums was obtained, as shown at the end of Table 9. In Table 10, in the row prefixed by the word "check", the numbers 1, -1, and 3 were multiplied by the subtotal sums of the column headed NO_3-N values in such a way that the first subtotal sum was multiplied by 1, the second by -1 and the third by 3. The following example was taken from Table 9. The first, second, and third subtotal sums were 1,209, 1,567, and 2,081 respectively. The multiplier values taken from Table 10 were 1, -1 and 3. (1209 x 1 plus 1567 x -1 plus 2081 x 3 equaled 5885). When the sum of the subtotal sums for column 1 was compared to the number 5,885, they were found to be the same. A mistake would be present if the two numbers were not identical. This process was the same for all of the columns except 4 and 5. For these columns the subtotal sums were multiplied by the numbers in the row prefixed by the word "check" in Table 11.

The sum of squares associated with each single degree of freedom was obtained by squaring each item in column 5 and dividing by the divisor associated with the particular treatment.

Compared with the more orthodox method of calculating the sums of squares from a number of two-way, three-way, four-way, and even five-way tables the tabular method presents much less opportunity for copying errors, and also possesses the advantage that it is completely self-checking. Main effects and interactions can also be obtained from column 5. In this study these were obtained from 2 and 3-way tables.

Table 9 .--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).

RDHST	Treatment	NO_3-N values	I	II	III	IV	V	Divisor	Sum of squares
00000	Mean	2	17	81	236	1146	4857	432	54,607.52
00001	T1	9	32	69	273	1140	872	288	2,640.22
00002	T2	6	32	86	308	1264	156	864	28.17
00010	S1	7	15	91	329	1307	969	288	3,260.28
00011	S1T1	13	28	95	223	178	342	192	609.19
00012	S1T2	12	26	87	273	194	150	576	39.06
00020	S2	10	19	101	301	198	141	864	23.01
00021	S2T1	10	31	101	343	302	278	576	134.17
00022	S2T2	12	36	106	273	12	30	1728	0.52
00100	H1	4	23	101	293	30	-295	288	302.17
00101	H1T1	5	33	114	340	64	-107	192	59.63
00102	H1T2	6	35	114	358	50	29	576	1.46
00110	H1S1	8	24	76	245	201	-154	192	123.52
00111	H1S1T1	12	32	77	325	223	- 80	128	50.00
00112	H1S1T2	8	39	70	345	234	- 58	384	8.76
00120	H1S2	4	21	91	392	311	-130	576	29.34
00121	H1S2T1	11	30	91	36	86	-116	384	35.04
00122	H1S2T2	11	36	91	28	74	- 58	1152	2.92
00200	H2	4	26	106	44	60	285	864	94.01
00201	H2T1	7	35	93	70	122	215	576	80.25
00202	H2T2	8	40	102	40	12	39	1728	00.88
00210	H2S1	8	25	120	32	64	192	576	64.00
00211	H2S1T1	10	35	113	35	60	36	384	3.38
00212	H2S1T2	13	41	110	87	14	-114	1152	11.28
00220	H2S2	9	26	107	36	- 45	60	1728	2.08
00221	H2S2T1	11	37	88	53	69	8	1152	0.06
00222	H2S2T2	16	43	78	52	10	30	3456	0.26
01000	D1	9	27	105	57	107	1465	2160	993.62
01001	D1T1	6	27	101	39	40	542	1440	204.00
01002	D1T2	8	47	87	80	74	130	4320	3.91
01010	D1S1	9	27	140	67	36	415	1440	119.60
01011	D1S1T1	10	37	102	116	128	292	960	88.82
01012	D1S1T2	14	50	98	- 28	54	- 32	2880	0.36
01020	D1S2	9	24	142	36	- 24	427	4320	42.21
01021	D1S2T1	12	40	103	- 4	- 56	368	2880	47.02
01022	D1S2T2	14	50	113	8	56	- 44	8640	0.22
01100	D1H1	12	19	87	- 14	19	-177	1440	21.76
01101	D1H1T1	4	25	79	12	- 20	- 73	960	5.55
01102	D1H1T2	8	32	79	7	-118	63	2880	1.38
01110	D1H1S1	10	18	142	25	-176	- 18	960	0.34
01111	D1H1S1T1	10	26	95	6	12	8	640	0.10
01112	D1H1S1T2	12	33	88	47	6	- 54	1920	1.52
01120	D1H1S2	9	20	151	- 8	3	-198	2880	13.61
01121	D1H1S2T1	12	20	90	19	-128	44	1920	1.01
01122	D1H1S2T2	18	30	104	11	16	-174	5760	5.26

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--Continued.

RDHST	Treatment	NO3-N values	I	II	III	IV	V	Divisor	Sum of squares
01200	D1H2	6	23	173	34	- 20	283	4320	18.54
01201	D1H2T1	6	27	113	- 9	- 7	65	2880	1.47
01202	D1H2T2	9	41	106	14	40	145	8640	2.43
01210	D1H2S1	9	20	11	43	14	112	2880	4.36
01211	D1H2S1T1	9	29	9	42	- 5	76	1920	3.01
01212	D1H2S1T2	12	42	16	47	- 35	-254	5760	11.20
01220	D1H2S2	10	24	9	69	-128	-296	8640	10.14
01221	D1H2S2T1	10	29	7	38	4	-136	5760	3.21
01222	D1H2S2T2	16	38	12	54	- 7	106	17280	0.65
02000	D2	8	29	15	52	- 12	- 59	432	8.06
02001	D2T1	8	32	14	79	- 65	90	288	28.13
02002	D2T2	10	45	15	51	- 10	- 74	864	6.34
02010	D2S1	9	25	19	56	- 47	43	288	6.42
02011	D2S1T1	14	27	28	49	- 26	18	192	1.69
02012	D2S1T2	12	41	23	78	25	166	576	47.84
02020	D2S2	9	24	13	50	- 14	67	864	5.20
02021	D2S2T1	12	34	8	85	- 5	18	576	0.56
02022	D2S2T2	19	44	19	78	- 7	- 2	1728	0.00
02100	D2H1	8	26	8	98	-104	33	288	3.78
02101	D2H1T1	9	39	11	6	6	25	192	3.26
02102	D2H1T2	8	55	13	22	- 21	9	576	0.14
02110	D2H1S1	9	28	11	26	- 18	6	192	0.19
02111	D2H1S1T1	12	34	8	32	- 83	20	128	3.13
02112	D2H1S1T2	14	51	16	5	- 8	- 90	384	21.09
02120	D2H1S2	10	24	36	14	- 5	18	576	0.56
02121	D2H1S2T1	12	35	25	19	32	- 20	384	1.04
02122	D2H1S2T2	19	51	26	36	- 77	- 6	1152	0.03
02200	D2H2	8	24	13	9	9	- 23	864	0.61
02201	D2H2T1	9	35	6	15	18	15	576	0.39
02202	D2H2T2	9	48	17	16	82	7	1728	0.03
02210	D2H2S1	10	23	22	20	176	4	576	0.03
02211	D2H2S1T1	13	29	19	23	4	0	384	0.00
02212	D2H2S1T2	14	36	12	25	38	46	1152	1.84
02220	D2H2S2	9	19	21	25	51	4	1728	0.01
02221	D2H2S2T1	15	26	13	49	122	- 48	1152	2.00
02222	D2H2S2T2	19	33	18	10	- 36	34	3456	0.33
03000	D3	7	22	17	- 12	24	55	2160	1.40
03001	D3T1	10	41	11	8	25	164	1440	18.68
03002	D3T2	10	42	29	6	26	520	4320	62.59
03010	D3S1	8	20	26	23	6	175	1440	21.27
03011	D3S1T1	9	42	9	0	- 5	64	960	4.27
03012	D3S1T2	10	39	4	19	45	-104	2880	3.76
03020	D3S2	9	20	48	22	146	- 41	4320	0.39
03021	D3S2T1	15	30	19	27	- 22	-124	2880	5.34
03022	D3S2T2	23	37	13	5	11	-188	8640	4.09

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--
Continued.

RDHST	Treatment	NO3-N values	I	II	III	IV	V	Divisor	Sum of squares
03100	D3H1	6	35	46	-2	-30	-19	1440	0.25
03101	D3H1T1	9	48	6	30	77	-51	960	2.71
03102	D3H1T2	12	57	15	29	24	-19	2880	0.13
03110	D3H1S1	10	29	65	-11	7	-86	960	7.70
03111	D3H1S1T1	10	33	26	-15	-48	-104	640	16.90
03112	D3H1S1T2	17	40	25	11	-97	-38	1920	0.75
03120	D3H1S2	10	24	-15	-37	6	-46	2880	0.73
03121	D3H1S2T1	15	34	-15	-12	-9	168	1920	14.70
03122	D3H1S2T2	25	40	2	-13	-11	62	5760	0.67
03200	D3H2	7	33	7	17	74	-299	4320	20.69
03201	D3H2T1	7	39	17	10	-8	-145	2880	7.30
03202	D3H2T2	10	70	12	18	-19	-185	8640	3.96
03210	D3H2S1	10	29	-1	22	-12	4	2880	0.01
03211	D3H2S1T1	15	25	2	19	47	52	1920	1.41
03212	D3H2S1T2	15	49	-5	3	6	202	5760	7.08
03220	D3H2S2	9	28	-1	-46	-39	208	8640	5.01
03221	D3H2S2T1	17	36	12	-5	-14	188	5760	6.14
03222	D3H2S2T2	24	49	-3	58	77	142	17280	1.17
10000	R1	3	17	-11	14	314	607	2160	170.58
10001	R1T1	10	24	2	31	388	376	1440	98.18
10002	R1T2	6	46	-5	42	302	148	4320	5.07
10010	R1S1	6	20	10	20	461	341	1440	80.75
10011	R1S1T1	9	28	1	6	118	94	960	9.20
10012	R1S1T2	10	31	1	-2	144	2	2880	0.00
10020	R1S2	8	22	13	8	62	397	4320	36.48
10021	R1S2T1	10	25	-6	28	218	226	2880	17.73
10022	R1S2T2	14	32	0	1	68	-26	8640	0.08
10100	R1H1	4	23	12	26	112	-683	1440	323.95
10101	R1H1T1	7	34	5	35	-16	-423	960	186.38
10102	R1H1T2	7	85	8	12	-34	85	2880	2.51
10110	R1H1S1	8	27	11	-3	83	-456	960	216.60
10111	R1H1S1T1	9	32	10	-13	121	-212	640	70.23
10112	R1H1S1T2	9	36	-15	10	74	126	1920	8.27
10120	R1H1S2	10	21	18	42	137	-272	2880	25.69
10121	R1H1S2T1	9	32	17	21	82	-264	1920	36.30
10122	R1H1S2T2	14	35	12	17	98	-170	5760	5.02
10200	R1H2	4	32	-13	49	34	565	4320	73.89
10201	R1H2T1	7	41	-3	41	78	367	2880	46.77
10202	R1H2T2	9	78	8	14	8	187	8640	4.05
10210	R1H2S1	2	25	13	12	16	470	2880	76.70
10211	R1H2S1T1	8	25	-11	26	2	256	1920	34.13
10212	R1H2S1T2	10	40	17	2	-58	-418	5760	30.33
10220	R1H2S2	7	26	6	7	161	202	8640	4.72
10221	R1H2S2T1	10	35	-5	0	31	172	5760	5.14
10222	R1H2S2T2	13	43	10	7	206	238	17280	3.28

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--
Continued.

RDHST	Treatment	NO_3-N values	I	II	III	IV	V	Divisor	Sum of squares
11000	R1D1	7	33	4	- 38	29	355	10800	11.67
11001	R1D1T1	6	52	17	- 21	76	218	7200	6.60
11002	R1D1T2	10	88	13	- 31	42	-434	21600	8.72
11010	R1D1S1	11	28	- 2	- 20	158	115	7200	1.84
11011	R1D1S1T1	9	37	- 12	16	92	- 76	4800	1.20
11012	R1D1S1T2	7	48	5	23	- 22	-212	14400	3.12
11020	R1D1S2	10	24	- 7	1	-128	-221	21600	2.26
11021	R1D1S2T1	12	35	8	21	122	164	14400	1.87
11022	R1D1S2T2	19	47	13	11	- 16	268	43200	1.66
11100	R1D1H1	6	4	15	5	33	-617	7200	52.87
11101	R1D1H1T1	7	5	11	- 4	- 16	- 53	4800	0.59
11102	R1D1H1T2	7	2	17	5	- 24	487	14400	16.47
11110	R1D1H1S1	8	2	12	13	-170	-128	4800	3.41
11111	R1D1H1S1T1	9	0	15	- 6	- 6	40	3200	0.50
11112	R1D1H1S1T2	12	7	15	0	- 48	166	9600	2.87
11120	R1D1H1S2	11	4	14	- 4	31	292	14400	5.92
11121	R1D1H1S2T1	14	5	16	- 10	- 50	124	9600	1.60
11122	R1D1H1S2T2	17	7	17	- 29	- 66	-458	28800	7.28
11200	R1D1H2	6	- 1	20	- 18	- 34	943	21600	41.17
11201	R1D1H2T1	8	5	23	- 42	117	569	14400	22.48
11202	R1D1H2T2	10	5	26	- 29	46	325	43200	2.45
11210	R1D1H2S1	9	- 4	13	- 8	12	166	14400	1.91
11211	R1D1H2S1T1	9	2	15	- 54	11	-292	9600	8.88
11212	R1D1H2S1T2	11	9	10	- 47	-21	-26	28800	0.02
11220	R1D1H2S2	9	3	18	- 67	- 20	-290	43200	1.95
11221	R1D1H2S2T1	13	3	22	5	- 8	-592	28800	12.17
11222	R1D1H2S2T2	16	6	14	3	5	-386	86400	1.72
12000	R1D2	8	2	16	0	6	- 45	2160	0.94
12001	R1D2T1	11	3	16	4	5	-150	1440	15.63
12002	R1D2T2	10	10	20	6	- 18	150	4320	5.21
12010	R1D2S1	12	0	29	5	- 31	-101	1440	7.08
12011	R1D2S1T1	9	5	23	5	- 48	86	960	7.70
12012	R1D2S1T2	11	9	27	- 10	43	166	2880	9.57
12020	R1D2S2	12	1	24	4	-108	- 9	4320	0.02
12021	R1D2S2T1	11	4	13	- 10	- 25	- 6	2880	0.01
12022	R1D2S2T2	22	10	14	- 3	- 69	186	8640	4.00
12100	R1D2H1	6	3	20	12	4	41	1440	1.17
12101	R1D2H1T1	9	2	19	- 22	- 42	37	960	1.43
12102	R1D2H1T2	10	14	17	- 35	51	- 79	2880	2.17
12110	R1D2H1S1	10	6	22	- 31	28	60	960	3.75
12111	R1D2H1S1T1	11	7	11	- 40	7	- 16	640	0.40
12112	R1D2H1S1T2	6	15	16	17	36	- 18	1920	0.17
12120	R1D2H1S2	10	3	37	5	- 25	152	2880	8.02
12121	R1D2H1S2T1	13	5	20	- 4	- 90	- 80	1920	3.33
12122	R1D2H1S2T2	18	15	21	- 2	- 95	-238	5760	9.83
12200	R1D2H2	7	3	29	6	-109	-171	4320	6.77

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--Continued.

RDHST	Treatment	NO3-N values	I	II	III	IV	V	Divisor	Sum of squares
12201	R1D2H2T1	8	4	11	-9	58	-9	2880	0.03
12202	R1D2H2T2	9	6	10	-13	164	51	8640	0.30
12210	R1D2H2S1	9	3	62	-4	170	-146	2880	7.40
12211	R1D2H2S1T1	11	1	9	-26	-74	-52	1920	1.41
12212	R1D2H2S1T2	14	4	14	-6	0	-50	5760	0.43
12220	R1D2H2S2	10	5	46	21	35	-90	8640	0.94
12221	R1D2H2S2T1	15	8	15	4	104	252	5760	11.03
12222	R1D2H2S2T2	19	6	17	4	-130	186	17280	2.00
13000	R1D3	5	3	55	9	106	205	10800	3.89
13001	R1D3T1	11	-4	20	7	233	376	7200	19.64
13002	R1D3T2	10	9	23	20	-64	52	21600	0.13
13010	R1D3S1	8	1	-2	2	-28	175	7200	4.25
13011	R1D3S1T1	10	4	5	3	67	28	4800	0.16
13012	R1D3S1T2	21	6	3	3	35	256	14400	4.55
13020	R1D3S2	11	4	6	6	38	-317	21600	4.65
13021	R1D3S2T1	15	2	13	-3	58	-212	14400	3.12
13022	R1D3S2T2	29	7	3	-4	11	16	43200	0.01
13100	R1D3H1	7	2	8	4	64	-119	7200	1.97
13101	R1D3H1T1	10	-1	9	-2	-57	-111	4800	2.57
13102	R1D3H1T2	11	10	9	-10	-148	-11	14400	0.01
13110	R1D3H1S1	9	4	11	-3	43	-196	4800	8.00
13111	R1D3H1S1T1	10	-4	9	-6	-10	-200	3200	12.50
13112	R1D3H1S1T2	15	8	12	-16	-139	-418	9600	18.20
13120	R1D3H1S2	10	2	3	-19	8	-116	14400	0.93
13121	R1D3H1S2T1	16	5	1	-48	-101	48	9600	0.24
13122	R1D3H1S2T2	25	9	1	-29	-121	-206	28800	1.47
13200	R1D3H2	6	5	6	-32	-82	61	21600	0.17
13201	R1D3H2T1	8	13	5	5	100	-137	14400	1.30
13202	R1D3H2T2	10	18	3	-3	-39	-245	43200	1.39
13210	R1D3H2S1	10	4	8	1	-130	322	14400	7.20
13211	R1D3H2S1T1	9	6	4	1	-67	436	9600	19.80
13212	R1D3H2S1T2	16	15	7	-2	158	358	28800	4.45
13220	R1D3H2S2	9	4	13	-3	-71	430	43200	4.28
13221	R1D3H2S2T1	17	6	11	-1	20	76	28800	0.20
13222	R1D3H2S2T2	25	16	12	-1	-1	178	86400	0.37
20000	R2	4	6	0	-1	-16	49	432	5.56
20001	R2T1	10	1	10	-6	-8	88	288	26.89
20002	R2T2	10	6	-1	-6	-2	-32	864	1.19
20010	R2S1	13	-3	7	1	-33	55	288	10.50
20011	R2S1T1	8	2	7	-13	34	74	192	28.52
20012	R2S1T2	14	7	1	-29	60	-98	576	16.67
20020	R2S2	14	4	8	-3	-12	-17	864	0.33
20021	R2S2T1	14	10	6	-20	8	58	576	5.84
20022	R2S2T2	20	3	2	-7	-52	190	1728	20.89
20100	R2H1	9	2	6	9	-8	-19	288	1.25

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--Continued.

RDHST	Treatment	NO_3-N values	I	II	III	IV	V	Divisor	Sum of squares
20101	R2H1T1	8	11	7	-3	-14	-125	192	81.38
20102	R2H1T2	6	9	7	-9	0	83	576	11.96
20110	R2H1S1	9	1	18	-12	23	-74	192	28.52
20111	R2H1S1T1	9	10	0	-1	11	-42	128	13.78
20112	R2H1S1T2	11	8	5	-17	24	88	384	20.17
20120	R2H1S2	10	5	29	-17	-15	-106	576	19.51
20121	R2H1S2T1	9	1	-4	-7	-10	-38	384	3.76
20122	R2H1S2T2	17	6	0	0	-8	-112	1152	10.89
20200	R2H2	3	5	10	6	-2	85	864	8.36
20201	R2H2T1	9	3	8	-25	22	37	576	2.38
20202	R2H2T2	7	13	7	-1	20	-59	1728	2.01
20210	R2H2S1	3	1	29	-3	26	112	576	21.78
20211	R2H2S1T1	10	5	11	25	54	74	384	14.26
20212	R2H2S1T2	13	7	9	4	66	-32	1152	0.89
20220	R2H2S2	9	5	12	8	5	100	1728	5.79
20221	R2H2S2T1	12	6	-7	5	-11	70	1152	4.25
20222	R2H2S2T2	12	7	5	-1	112	136	3456	5.35
21000	R2D1	7	4	-6	-26	-39	85	2160	3.34
21001	R2D1T1	6	3	-9	9	28	130	1440	11.74
21002	R2D1T2	9	10	3	-6	-48	-62	4320	0.89
21010	R2D1S1	10	5	2	-10	42	25	1440	0.43
21011	R2D1S1T1	10	-6	7	2	-4	28	960	0.82
21012	R2D1S1T2	21	12	-1	-2	-22	-68	2880	1.61
21020	R2D1S2	10	7	5	15	-38	-47	4320	0.51
21021	R2D1S2T1	13	8	5	0	46	-32	2880	0.36
21022	R2D1S2T2	19	14	-4	-20	12	-32	8640	0.12
21100	R2D1H1	6	4	13	-11	17	-97	1440	6.53
21101	R2D1H1T1	7	6	9	-48	-12	-39	960	1.58
21102	R2D1H1T2	7	22	1	-29	2	-103	2880	3.68
21110	R2D1H1S1	11	2	0	-16	26	2	960	0.00
21111	R2D1H1S1T1	10	5	1	5	6	-14	640	0.31
21112	R2D1H1S1T2	21	2	-1	9	-14	104	1920	5.63
21120	R2D1H1S2	10	-1	16	-3	29	-10	2880	0.03
21121	R2D1H1S2T1	11	1	4	-5	4	-114	1920	6.77
21122	R2D1H1S2T2	18	4	-1	-6	14	56	5760	0.54
21200	R2D1H2	5	4	17	-13	24	-161	4320	6.00
21201	R2D1H2T1	5	11	5	-13	-37	-5	2880	0.01
21202	R2D1H2T2	10	33	0	11	8	-533	8640	32.88
21210	R2D1H2S1	10	9	12	-23	2	-92	2880	2.94
21211	R2D1H2S1T1	9	5	10	20	-5	-74	1920	2.85
21212	R2D1H2S1T2	11	5	5	-12	-17	-320	5760	17.78
21220	R2D1H2S2	10	4	-1	-3	26	148	8640	2.54
21221	R2D1H2S2T1	11	5	7	-25	8	202	5760	7.08
21222	R2D1H2S2T2	16	4	-1	-17	1	208	17280	2.50
22000	R2D2	9	14	-8	-19	12	-39	432	3.52

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--Continued.

RDHST	Treatment	NO_3-N values	I	II	III	IV	V	Divisor	Sum of squares
22001	R2D2T1	12	8	8	-22	-1	-6	288	0.13
22002	R2D2T2	14	24	-2	-7	-22	-30	864	1.04
22010	R2D2S1	14	2	22	5	-11	-27	288	2.53
22011	R2D2S1T1	17	-6	11	-19	-38	6	192	0.19
22012	R2D2S1T2	17	10	-3	13	-19	6	576	0.06
22020	R2D2S2	11	2	8	12	-22	-135	864	21.09
22021	R2D2S2T1	22	4	14	-15	27	30	576	1.56
22022	R2D2S2T2	24	9	7	-1	-37	-18	1728	0.19
22100	R2D2H1	8	12	-1	-1	50	53	288	9.75
22101	R2D2H1T1	12	12	-6	19	-6	-5	192	0.13
22102	R2D2H1T2	9	41	-4	18	31	35	576	2.13
22110	R2D2H1S1	9	4	-26	0	-34	50	192	13.02
22111	R2D2H1S1T1	10	7	12	-5	-11	-6	128	0.28
22112	R2D2H1S1T2	14	15	-1	-17	20	8	384	0.13
22120	R2D2H1S2	10	5	-5	-3	27	38	576	2.51
22121	R2D2H1S2T1	13	6	17	-11	-4	-14	384	0.51
22122	R2D2H1S2T2	17	14	-1	-46	-49	-52	1152	2.35
22200	R2D2H2	6	-10	-15	29	23	-39	864	1.76
22201	R2D2H2T1	7	-7	-15	-12	-26	-87	576	13.14
22202	R2D2H2T2	11	2	-7	5	34	33	1728	0.63
22210	R2D2H2S1	9	0	-8	-13	-54	-48	576	4.00
22211	R2D2H2S1T1	10	-8	-1	-8	-14	30	384	2.34
22212	R2D2H2S1T2	15	-7	-3	0	18	-24	1152	0.50
22220	R2D2H2S2	10	-2	-4	22	33	72	1728	3.00
22221	R2D2H2S2T1	13	1	-4	4	-22	174	1152	26.28
22222	R2D2H2S2T2	17	3	-5	9	14	252	3456	18.38
23000	R2D3	8	5	20	-10	-44	95	2160	4.18
23001	R2D3T1	13	3	3	34	31	40	1440	1.11
23002	R2D3T2	12	-1	-6	49	6	56	4320	0.73
23010	R2D3S1	12	12	1	8	14	-15	1440	0.16
23011	R2D3S1T1	12	2	-1	40	11	16	960	0.27
23012	R2D3S1T2	15	3	10	75	15	-36	2880	0.45
23020	R2D3S2	21	3	10	53	-36	101	4320	2.36
23021	R2D3S2T1	18	3	4	9	14	-44	2880	0.67
23022	R2D3S2T2	31	6	4	7	-1	-64	8640	0.47
23100	R2D3H1	6	2	10	2	-14	-179	1440	22.25
23101	R2D3H1T1	12	-7	12	-14	1	7	960	0.05
23102	R2D3H1T2	11	4	0	16	20	79	2880	2.17
23110	R2D3H1S1	10	-2	3	-1	-1	-46	960	2.20
23111	R2D3H1S1T1	11	-1	11	11	36	-98	640	15.01
23112	R2D3H1S1T2	4	5	5	12	-9	-52	1920	1.41
23120	R2D3H1S2	11	-1	2	18	26	-110	2880	4.20
23121	R2D3H1S2T1	15	-2	1	-4	7	-98	1920	5.00
23122	R2D3H1S2T2	23	-2	0	13	-41	112	5760	2.18
23200	R2D3H2	7	-3	-18	24	12	-7	4320	0.01

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--Continued.

RDHST	Treatment	NO_3-N values	I	II	III	IV	V	Divisor	Sum of squares
23201	R2D3H2T1	7	0	-25	12	-20	25	2880	0.22
23202	R2D3H2T2	14	2	-3	23	-27	-271	8640	8.50
23210	R2D3H2S1	9	0	-4	49	-84	156	2880	8.45
23211	R2D3H2S1T1	10	7	3	38	83	82	1920	3.50
23212	R2D3H2S1T2	17	5	-4	17	26	180	5760	5.63
23220	R2D3H2S2	10	3	25	-15	-11	-64	8640	0.47
23221	R2D3H2S2T1	15	-5	28	-10	-98	-86	5760	1.28
23222	R2D3H2S2T2	24	-1	5	-28	117	-184	17280	1.96
30000	R3	4	-11	15	-20	-12	-211	2160	20.61
30001	R3T1	5	-2	-5	9	36	112	1440	8.71
30002	R3T2	8	2	4	25	-56	-64	4320	0.95
30010	R3S1	7	-3	40	10	87	77	1440	4.12
30011	R3S1T1	10	-1	-1	-24	-14	78	960	6.34
30012	R3S1T2	7	6	-8	-4	38	14	2880	0.07
30020	R3S2	6	-1	28	1	24	329	4320	25.06
30021	R3S2T1	12	-4	15	52	116	202	2880	14.17
30022	R3S2T2	28	0	-1	26	156	98	8640	1.11
30100	R3H1	4	5	17	-17	54	99	1440	6.81
30101	R3H1T1	10	0	2	27	178	-131	960	17.88
30102	R3H1T2	6	5	1	-10	132	-15	2880	0.08
30110	R3H1S1	7	-1	-4	10	11	-52	960	2.82
30111	R3H1S1T1	9	2	9	-3	47	-54	640	4.56
30112	R3H1S1T2	12	0	1	-1	48	-28	1920	0.41
30120	R3H1S2	10	0	-6	0	69	-84	2880	2.45
30121	R3H1S2T1	9	2	1	-7	14	-98	1920	5.00
30122	R3H1S2T2	12	-1	3	-12	16	-180	5760	5.63
30200	R3H2	8	-4	6	4	8	-25	4320	0.14
30201	R3H2T1	7	5	-1	10	26	79	2880	2.17
30202	R3H2T2	7	12	3	12	-64	59	8640	0.40
30210	R3H2S1	8	-2	13	-1	-58	-10	2880	0.03
30211	R3H2S1T1	8	-6	7	16	24	222	1920	25.67
30212	R3H2S1T2	9	2	8	18	-6	44	5760	0.34
30220	R3H2S2	10	0	1	17	57	74	8640	0.63
30221	R3H2S2T1	8	1	5	58	-3	34	5760	0.20
30222	R3H2S2T2	14	-1	-5	33	-68	-4	17280	0.00
31000	R3D1	6	-7	20	38	-27	405	10800	15.19
31001	R3D1T1	7	9	-1	-9	-8	346	7200	16.63
31002	R3D1T2	10	10	7	-17	-16	282	21600	3.68
31010	R3D1S1	6	-2	14	-1	-24	195	7200	5.28
31011	R3D1S1T1	11	4	20	5	-76	188	4800	7.36
31012	R3D1S1T2	17	3	1	2	-54	-24	14400	0.04
31020	R3D1S2	12	0	-3	-1	-66	-657	21600	19.98
31021	R3D1S2T1	28	8	7	7	4	-332	14400	7.65
31022	R3D1S2T2	45	0	8	3	-72	-744	43200	12.81

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--Continued.

RDHST	Treatment	NO_3-N values	I	II	III	IV	V	Divisor	Sum of squares
31100	R3D1H1	6	-6	10	-21	-19	-179	7200	4.45
31101	R3D1H1T1	6	11	0	-6	8	-281	4800	16.45
31102	R3D1H1T2	15	6	-13	-2	72	-341	14400	8.08
31110	R3D1H1S1	9	-1	-11	-1	-80	64	4800	0.85
31111	R3D1H1S1T1	9	2	-11	23	8	10	3200	0.03
31112	R3D1H1S1T2	14	9	9	37	-16	112	9600	1.31
31120	R3D1H1S2	10	-8	12	1	-13	244	14400	4.13
31121	R3D1H1S2T1	11	-4	-2	16	-30	118	9600	1.45
31122	R3D1H1S2T2	15	-3	0	31	8	64	28800	0.14
31200	R3D1H2	6	4	8	15	2	-39	21600	0.07
31201	R3D1H2T1	5	11	29	-13	-51	73	14400	0.37
31202	R3D1H2T2	10	3	5	-9	22	-315	43200	2.30
31210	R3D1H2S1	9	-1	26	-4	4	162	14400	1.82
31211	R3D1H2S1T1	9	12	-6	-3	-23	-274	9600	7.82
31212	R3D1H2S1T2	14	6	1	7	3	168	28800	0.98
31220	R3D1H2S2	10	5	15	7	-70	-30	43200	0.02
31221	R3D1H2S2T1	11	3	4	-3	-16	106	28800	0.39
31222	R3D1H2S2T2	14	4	-2	-16	-5	-432	86400	2.16
32000	R3D2	6	-1	22	-26	2	-35	2160	0.57
32001	R3D2T1	6	-3	24	-3	-85	190	1440	25.07
32002	$3D2T2	20	-9	3	-13	34	70	4320	1.13
32010	R3D2S1	9	-7	29	7	43	-77	1440	4.12
32011	R3D2S1T1	15	3	5	-51	-36	62	960	4.00
32012	R3D2S1T2	17	1	7	-40	-79	-38	2880	0.50
32020	R3D2S2	12	3	6	8	-16	-413	4320	39.48
32021	R3D2S2T1	30	4	9	-9	5	-302	2880	31.67
32022	R3D2S2T2	36	1	-1	-1	27	-218	8640	5.50
32100	R3D2H1	6	-6	-2	8	-62	-33	1440	0.76
32101	R3D2H1T1	11	3	11	13	26	-131	960	17.88
32102	R3D2H1T2	8	16	3	6	17	177	2880	10.88
32110	R3D2H1S1	10	-7	20	-14	116	60	960	3.75
32111	R3D2H1S1T1	11	-8	5	-14	9	-42	640	2.76
32112	R3D2H1S1T2	4	4	1	0	92	84	1920	3.68
32120	R3D2H1S2	9	7	-1	29	-55	264	2880	24.20
32121	R3D2H1S2T1	12	6	-9	-14	30	190	1920	18.80
32122	R3D2H1S2T2	19	4	12	-26	-5	24	5760	0.10
32200	R3D2H2	8	2	-5	29	-93	-257	4320	15.29
32201	R3D2H2T1	8	-6	5	34	-54	-53	2880	0.98
32202	R3D2H2T2	10	10	7	-3	-92	-233	8640	6.28
32210	R3D2H2S1	10	-10	10	14	-60	-62	2880	1.33
32211	R3D2H2S1T1	11	1	-5	-21	-8	26	1920	0.35
32212	R3D2H2S1T2	14	4	-5	-5	-40	-140	5760	3.40
32220	R3D2H2S2	10	1	-2	11	-45	130	8640	1.96
32221	R3D2H2S2T1	14	1	12	7	-52	274	5760	13.03
32222	R3D2H2S2T2	19	8	-3	-14	-60	352	17280	7.17

Table 9.--ANALYSIS OF VARIANCE USING ORTHOGONAL POLYNOMIALS (4).--Continued.

RDHST	Treatment	NO_3-N values	I	II	III	IV	V	Divisor	Sum of squares
33000	R3D3	6	2	-15	29	-18	375	10800	13.02
33001	R3D3T1	9	1	-7	-25	61	172	7200	4.11
33002	R3D3T2	18	1	-16	-9	-168	-396	21600	7.26
33010	R3D3S1	9	9	-22	-3	-16	55	7200	0.42
33011	R3D3S1T1	22	5	4	20	-31	36	4800	0.27
33012	R3D3S1T2	21	3	-3	16	-45	-188	14400	2.45
33020	R3D3S2	9	6	-15	-45	96	111	21600	0.57
33021	R3D3S2T1	29	5	-19	39	-34	-44	14400	0.13
33022	R3D3S2T2	50	2	3	5	-23	-228	43200	1.20
33100	R3D3H1	6	14	-4	-23	8	-253	7200	8.89
33101	R3D3H1T1	12	-4	-12	26	101	-47	4800	0.46
33102	R3D3H1T2	10	-12	-4	-13	44	173	14400	2.08
33110	R3D3H1S1	10	-8	4	-21	-19	-152	4800	4.81
33111	R3D3H1S1T1	10	-8	13	11	30	-90	3200	2.53
33112	R3D3H1S1T2	17	4	-1	29	147	124	9600	1.60
33120	R3D3H1S2	10	2	24	-8	-24	-112	14400	0.87
33121	$3D3H1S2T1	13	2	-8	15	33	-314	9600	10.27
33122	R3D3H1S2T2	25	1	7	-29	103	-352	28800	4.30
33200	R3D3H2	6	6	1	-17	96	147	21600	1.00
33201	R3D3H2T1	7	-14	2	-33	-20	-29	14400	0.06
33202	R3D3H2T2	11	1	-2	26	167	-345	43200	2.76
33210	R3D3H2S1	10	-8	10	16	-30	154	14400	1.65
33211	R3D3H2S1T1	9	7	12	-23	71	42	9600	0.18
33212	R3D3H2S1T2	16	9	-1	47	-54	-44	28800	0.07
33220	R3D3H2S2	9	3	35	-5	123	-90	43200	0.19
33221	R3D3H2S2T1	15	8	-13	-15	40	682	28800	16.15
33222	R3D3H2S2T2	23	2	-11	50	33	336	86400	1.31
Sub-totals		1209	1306	3208	1479	2340	4970		
		1567	1812	2348	1748	2680	-922		
		2081	2767	2239	1890	3288	4818		
					2460	3210	4498		
Sub-total sum		4857	5885	7795	7577	11518	13364		
Check total		5885	7795	7577	11518	13364			

APPENDIX II

Analysis of Variance taken
from Snedecor (26)

Coded Data

herbicide	1											
herbicide rate	0			1			2			3		
soil type	1	2	3	1	2	3	1	2	3	1	2	3
sampling date 1	6	12	12	6	10	14	10	14	20	8	7	28
sampling date 2	8	14	14	10	7	19	9	21	19	10	17	45
sampling date 3	10	12	19	10	11	22	14	17	24	20	17	36
sampling date 4	10	10	23	10	21	29	12	15	31	18	21	50
25												
sampling date 1	9	13	10	10	9	10	10	8	14	5	10	12
sampling date 2	6	10	12	6	9	12	6	10	13	7	11	29
sampling date 3	8	14	12	11	9	11	12	17	22	6	15	30
sampling date 4	10	9	15	11	10	15	13	12	18	9	22	29
35												
sampling date 1	2	7	10	3	6	8	4	13	14	4	7	6
sampling date 2	9	9	9	7	11	10	7	10	10	6	6	12
sampling date 3	8	9	9	8	12	12	9	14	11	6	9	12
sampling date 4	7	8	9	5	8	11	8	12	21	6	9	9

herbicide	2											
herbicide rate	0			1			2			3		
soil type	1	2	3	1	2	3	1	2	3	1	2	3
sampling date 1	6	8	11	7	9	14	6	11	17	6	12	12
sampling date 2	8	12	18	7	12	17	7	21	18	15	14	15
sampling date 3	8	14	19	10	6	18	9	14	17	8	4	19
sampling date 4	12	17	25	11	15	25	11	4	23	10	17	25
25												
sampling date 1	5	12	11	7	9	9	8	9	9	10	9	9
sampling date 2	4	10	12	7	9	14	7	10	11	6	9	11
sampling date 3	9	12	12	9	11	13	12	10	13	11	11	12
sampling date 4	9	10	15	10	10	16	12	11	15	12	10	13
35												
sampling date 1	4	8	4	4	8	10	9	9	10	4	7	10
sampling date 2	12	10	9	6	8	11	6	11	10	6	9	10
sampling date 3	8	9	10	6	10	10	8	9	10	6	10	9
sampling date 4	6	10	10	7	9	10	6	10	11	6	10	10

herbicide	3											
herbicide rate	0			1			2			3		
soil type	1	2	3	1	2	3	1	2	3	1	2	3
sampling date 1	8	13	16	9	10	13	7	13	12	7	9	14
sampling date 2	9	12	16	10	11	16	10	11	16	10	14	14
sampling date 3	9	14	19	9	14	19	11	15	17	10	14	19
sampling date 4	10	15	24	10	16	25	14	17	24	11	16	23
25												
sampling date 1	7	10	11	7	8	10	9	10	12	7	8	8
sampling date 2	6	9	10	8	9	13	5	9	11	5	9	11
sampling date 3	9	13	15	8	11	15	7	10	13	8	11	14
sampling date 4	7	15	17	8	9	17	7	10	15	7	9	15
35												
sampling date 1	4	8	9	4	2	7	3	3	9	8	8	10
sampling date 2	6	9	10	6	9	9	5	10	10	6	9	10
sampling date 3	8	10	9	7	9	10	6	9	10	9	10	10
sampling date 4	7	10	9	6	10	9	7	9	10	6	10	9

KEY

temperature

1 13°C
2 25°C
3 35°C

herbicide

1 $CaCN_2$
2 Chloro-IPC
3 444E

herbicide rate

herbicide	0	1	2	3
1	check	100	200	400
2	check	3	3+3	6
3	check	10	15	20

1 All herbicide rates are expressed as pounds of herbicide per acre.

soil type

1 Gilcrest sand
2 Rocky Ford loam
3 Las Animas clay

sampling date

1 5 days
2 10 days
3 20 days
4 30 days

5-way table

temperature								
13			25			35		
2	4	4	9	5	7	6	6	8
9	12	6	6	4	6	8	8	9
8	8	8	8	9	9	10	8	9
7	6	7	10	9	7	10	12	10
7	8	8	13	12	10	12	8	13
9	10	9	10	10	9	14	12	12
9	9	10	14	12	13	12	14	14
8	10	10	9	10	15	10	17	15
10	14	9	10	11	11	12	11	16
9	9	10	12	12	10	14	18	16
9	10	9	12	12	15	19	19	19
9	10	9	15	15	17	23	25	24
3	4	4	10	7	7	6	7	9
7	6	6	6	7	8	10	7	10
8	6	7	11	9	8	10	10	9
5	7	6	11	10	8	10	11	10
6	8	2	9	9	8	10	9	10
11	8	9	9	9	9	7	12	11
12	10	9	9	11	11	11	6	14
8	9	10	10	10	9	21	15	16
8	10	7	10	9	10	14	14	13
10	11	9	12	14	13	19	17	16
12	10	10	11	13	15	22	19	19
11	10	9	15	16	17	29	25	25
4	9	3	10	8	9	10	6	7
7	6	5	6	7	5	9	7	10
9	8	6	12	12	7	14	9	11
8	6	7	13	12	7	13	11	14
13	9	3	8	9	10	14	11	13
10	11	10	10	10	9	21	21	11
14	9	9	17	10	10	17	14	15
14	10	9	12	11	10	15	4	17
14	10	9	14	9	12	20	17	12
10	10	10	13	11	11	19	18	16
11	10	10	22	13	13	24	17	17
21	11	10	18	15	15	31	23	24
4	4	8	5	10	7	8	6	7
6	6	6	7	6	5	10	15	10
6	6	8	6	11	8	20	8	10
6	6	6	9	12	7	18	10	11
7	7	8	10	9	8	7	12	9
6	9	9	11	9	9	17	14	14
9	10	10	15	11	11	17	4	24
9	10	10	22	10	9	21	17	16
6	10	10	12	9	8	28	12	14
12	10	10	28	11	11	45	15	14
12	9	10	30	12	14	36	19	19
9	10	9	29	13	15	50	25	23
422	405	382	590	495	482	802	624	655

soil type								
1			2			3		
2	9	6	7	13	12	10	10	12
9	6	8	9	10	14	9	12	14
8	8	10	9	14	12	9	12	19
7	10	10	8	9	10	9	15	23
3	10	6	6	9	10	8	10	14
7	6	10	11	9	7	10	12	19
8	11	10	12	9	11	12	11	22
5	11	10	8	10	21	11	15	29
4	10	10	13	8	14	14	14	20
7	6	9	10	10	21	10	13	19
9	12	14	14	17	17	11	22	24
8	13	12	12	12	15	21	18	31
4	5	8	7	10	7	6	12	28
6	7	10	6	11	17	12	28	45
6	6	20	9	15	17	12	30	36
6	9	18	9	22	21	9	29	50
4	5	6	8	12	8	4	11	11
12	4	8	10	10	12	9	12	18
8	9	8	9	12	14	10	12	19
6	9	12	10	10	17	10	15	25
4	7	7	8	9	9	10	9	14
6	7	7	8	9	12	11	14	17
6	9	10	10	11	6	10	13	18
7	10	11	9	10	15	10	16	25
9	8	6	9	9	11	10	9	17
6	7	7	11	10	21	10	11	18
8	12	9	9	10	14	10	13	17
6	12	11	10	11	4	11	15	23
4	10	6	7	9	12	10	9	12
6	6	15	8	9	14	10	11	15
6	11	8	10	11	4	9	12	19
6	12	10	10	10	17	10	13	25
4	7	8	8	10	13	9	11	16
6	6	9	9	9	12	10	10	16
8	9	9	10	13	14	9	15	19
7	7	10	10	15	15	9	17	24
4	7	9	2	8	10	7	10	13
6	8	10	9	9	11	9	13	16
7	8	9	9	11	14	10	15	19
6	8	10	10	9	16	9	17	25
3	9	7	3	10	13	9	12	12
5	5	10	10	9	11	10	11	16
6	7	11	9	10	15	10	13	17
7	7	14	9	10	17	10	15	24
8	7	7	8	8	9	10	8	14
6	5	10	9	9	14	10	11	14
8	8	10	10	11	14	10	14	19
6	7	11	10	9	16	9	15	23
300	392	466	432	510	630	477	665	985

herbicide								
1			2			3		
2	9	6	4	5	6	4	7	8
9	6	8	12	4	8	6	6	9
8	9	10	8	9	8	8	9	9
7	10	10	6	9	12	7	7	10
7	13	12	8	12	8	8	10	13
9	10	14	10	10	12	9	9	12
9	14	12	9	12	14	10	13	14
8	9	10	10	10	17	10	15	15
10	10	12	4	11	11	9	11	16
9	12	14	9	12	18	10	10	16
9	12	19	10	12	19	9	15	19
9	15	23	10	15	25	9	17	24
3	10	6	4	7	7	4	7	9
7	6	10	6	7	7	6	8	10
8	11	10	6	9	10	7	8	9
5	11	10	7	10	11	6	8	10
6	9	10	8	9	9	2	8	10
11	9	7	8	9	12	9	9	11
12	9	11	10	11	6	9	11	14
8	10	21	9	10	15	10	9	16
8	10	14	10	9	14	7	10	13
10	12	19	11	14	17	9	13	16
12	11	22	10	13	18	10	15	19
11	15	29	10	16	25	9	17	25
4	10	10	9	8	6	3	9	7
7	6	9	6	7	7	5	5	10
9	12	14	8	12	9	6	7	11
8	13	12	6	12	11	7	7	14
13	8	14	9	9	11	3	10	13
10	10	21	11	10	21	10	9	11
14	17	17	9	10	14	9	10	15
12	12	15	10	11	4	9	10	17
14	14	20	10	9	17	9	12	12
10	13	19	10	11	18	10	11	16
11	22	24	10	13	17	10	13	17
21	18	31	11	15	23	10	15	24
4	5	8	4	10	6	8	7	7
6	7	10	6	6	15	6	5	10
6	6	20	6	11	8	8	8	10
6	9	18	6	12	10	6	7	11
7	10	7	7	9	12	8	8	9
6	11	17	9	9	14	9	9	14
9	15	17	10	11	4	10	11	14
9	22	21	10	10	17	10	9	16
6	12	28	10	9	12	10	8	14
12	28	45	10	11	15	10	11	14
12	30	36	9	12	19	10	14	19
9	29	50	10	13	25	9	15	23
422	590	802	405	495	624	382	482	655

8247731 ÷ 144 − C F

57275.91 − 54607.5 = 2668.41

2668.41

9336277 ÷ 144 − C.F

57890.81 − 54607.5 = 3283.31

3283.31

7920533 ÷ 144 − CF

55003.7 − 54607.5 = 396.2

396.2

Main effects of temperature, soil type, and herbicides.

herbicide rate

0			1			2			3		
2	9	6	3	10	6	4	10	10	4	5	8
9	6	8	7	6	10	7	6	9	6	7	10
8	8	10	8	11	10	9	12	14	6	6	20
7	10	10	5	11	10	8	13	12	6	9	18
7	13	12	6	9	10	13	8	14	7	10	7
9	10	14	11	9	7	10	10	21	6	11	17
9	14	12	12	9	11	14	17	17	9	15	17
8	9	10	8	10	21	12	12	15	9	22	21
10	10	12	8	10	14	14	14	20	6	12	28
9	12	14	10	12	19	10	13	19	12	28	45
9	12	19	12	11	22	11	22	24	12	30	36
9	15	23	11	15	29	21	18	31	9	29	50
4	5	6	4	7	7	9	8	6	4	10	6
12	4	8	6	7	7	6	7	7	6	6	15
8	9	8	6	9	10	8	12	9	6	11	8
6	9	12	7	10	11	6	12	11	6	12	10
8	12	8	8	9	9	9	9	11	7	9	12
10	10	12	8	9	12	11	10	21	9	9	14
9	12	14	10	11	6	9	10	14	10	11	4
10	10	17	9	10	15	10	11	4	10	10	17
4	11	11	10	9	14	10	9	17	10	9	12
9	12	18	11	14	17	10	11	18	10	11	15
10	12	19	10	13	18	10	13	17	9	12	19
10	15	25	10	16	25	11	15	23	10	13	25
4	7	8	4	7	9	3	9	7	8	7	7
6	6	9	6	8	10	5	5	10	6	5	10
8	9	9	7	8	9	6	7	11	8	8	10
7	7	10	6	8	10	7	7	14	6	7	11
8	10	13	2	8	10	3	10	13	8	8	9
9	9	12	9	9	11	10	9	11	9	9	14
10	13	14	9	11	14	9	10	15	10	11	14
10	15	15	10	9	16	9	10	17	10	9	16
9	11	16	7	10	13	9	12	12	10	8	14
10	10	16	9	13	16	10	11	16	10	11	14
9	15	19	10	15	19	10	13	17	10	14	19
9	17	24	9	17	25	10	15	24	9	15	23
295	378	473	288	370	482	333	400	531	293	419	595

sampling date

1			2			3			4		
2	9	6	9	6	8	8	8	10	7	10	10
7	13	12	9	10	14	9	14	12	8	9	10
10	10	12	9	12	14	9	12	19	9	15	23
3	10	6	7	6	10	8	11	10	5	11	10
6	9	10	11	9	7	12	9	11	8	10	21
8	10	14	10	12	19	12	11	22	11	15	29
4	10	10	7	6	9	9	12	14	8	13	12
13	8	14	10	10	21	14	17	17	12	12	15
14	14	20	10	13	19	11	22	24	21	18	31
4	5	8	6	7	10	6	6	20	6	9	18
7	10	7	6	11	17	9	15	17	9	22	21
6	12	29	12	28	45	12	30	36	9	29	50
4	5	6	12	4	8	8	9	8	6	9	12
8	12	8	10	10	12	9	12	14	10	10	17
4	11	11	9	12	18	10	12	19	10	15	25
4	7	7	6	7	7	6	9	10	7	10	11
8	9	9	8	9	12	10	11	6	9	10	15
10	9	14	11	14	17	10	13	18	10	16	25
9	8	6	6	7	7	8	12	9	6	12	11
9	9	11	11	10	21	9	10	14	10	11	4
10	9	17	10	11	18	10	13	17	11	15	23
4	10	6	6	6	15	6	11	8	6	12	10
7	9	12	9	9	14	10	11	4	10	10	17
10	9	12	10	11	15	9	12	19	10	13	25
4	7	8	6	6	9	8	9	9	7	7	10
8	10	13	9	9	12	10	13	14	10	15	15
9	11	16	10	10	16	9	15	19	9	17	24
4	7	9	6	8	10	7	8	9	6	8	10
2	8	10	9	9	11	9	11	14	10	9	16
7	10	13	9	13	16	10	15	19	9	17	25
3	9	7	5	5	10	6	7	11	7	7	14
3	10	13	10	9	11	9	10	15	9	10	17
9	12	12	10	11	16	10	13	17	10	15	24
8	7	7	6	5	10	8	8	10	6	7	11
8	8	9	9	9	14	10	11	14	10	9	16
10	8	14	10	11	14	10	14	19	9	15	23
246	334	397	313	345	506	330	436	528	320	452	650

correction factor $(4857)^2 \div 432 = 54607.5$

$5918861 \div 108 = 54804.27$

$54804.27 - 54607.5 = 196.77$

196.77

$6005945 \div 108 = 55610.60$

$55610.6 - 54607.5 = 1003.1$

1003.1

Main effects for herbicide rates and sampling dates.

temperature	13																																				
herbicide	1												2												3												
herbicide rate	0			1			2			3			0			1			2			3			0			1			2			3			
soil type	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
	26	33	37	23	37	41	28	49	56	22	31	39	30	37	33	23	35	41	29	39	41	22	36	39	25	37	37	23	30	35	21	31	39	28	37	39	1209
25	33	46	49	38	37	48	41	47	67	27	58	99	27	44	50	33	39	52	39	40	48	39	39	45	29	47	53	31	37	35	28	39	51	27	37	48	1567
35	34	47	68	36	49	84	45	67	94	56	62	159	34	51	73	35	42	74	33	50	78	39	47	71	36	54	75	38	51	73	42	56	69	38	53	70	2081
	93	127	154	97	123	173	114	163	217	105	161	297	91	132	156	91	116	167	101	129	164	100	122	155	90	138	165	92	118	163	91	126	159	93	127	157	4857

257249 ÷ 4 — CF

64312.25 − 54607.5 = 9704.75

9704.75 − 2668.41 − 396.2 − 196.77 − 3285.31 − 1422 − 140.96 − 782.93 − 414.39 − 218.93 − 157.23 − 357.99 − 111.71 − 120.64 − 405.25 = 30283

307.83

temperature	13												
herbicide	1				2				3				
herbicide rate	0	1	2	3	0	1	2	3	0	1	2	3	
sampling date 1	19	17	31	17	16	22	28	21	21	13	15	26	246
2	27	28	27	24	31	25	27	25	25	24	25	25	313
3	26	32	34	27	27	26	27	25	27	26	25	28	330
4	24	24	41	24	26	26	27	26	26	25	26	25	320
	96	101	133	92	100	99	109	97	99	88	91	104	1209
25													
sampling date 1	32	29	32	27	28	25	26	29	28	25	31	23	334
2	28	27	29	46	26	30	29	26	25	30	25	25	345
3	34	31	51	51	33	33	35	34	37	34	30	33	436
4	34	36	43	60	34	36	38	35	39	34	32	31	452
	128	123	155	184	121	124	127	123	129	123	118	112	1567
1	30	30	44	43	25	30	34	30	37	32	32	30	397
2	36	36	49	72	38	36	46	44	37	37	37	38	506
3	41	43	55	73	41	34	40	31	42	42	43	43	528
4	43	60	58	89	54	51	38	52	49	51	55	50	650
	150	169	206	277	158	151	158	157	165	162	167	161	2081

172691 ÷ 3 − CF

60897.00 − 54607.5 = 6289.5

6289.5 − 1003.1 − 396.2 − 196.77 − 2668.41 − 65.62 − 563 − 323.63 − 414.39 − 142.20 − 140.96 − 180.90 − 28.76 − 129.44 − 357.99 = 184.83

184.83

4-way tables

temperature	13												25												35												
herbicide rate	0			1			2			3			0			1			2			3			0			1			2			3			
soil type	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
sampling date 1	10	23	23	11	16	25	16	25	33	16	22	26	21	35	32	24	26	29	27	27	35	22	27	29	20	33	39	22	29	41	23	39	49	21	28	54	977
2	27	28	28	19	28	30	18	31	30	18	24	32	16	29	34	21	27	39	18	29	35	18	29	50	25	38	48	27	30	52	26	53	53	35	45	74	1164
3	24	28	28	21	31	32	23	32	31	20	29	31	26	39	39	28	31	39	31	37	48	25	37	56	27	40	57	29	31	59	34	46	58	38	35	74	1294
4	20	28	28	18	27	30	21	31	42	18	29	28	26	34	47	29	29	48	32	33	48	28	41	57	32	42	72	31	52	79	37	36	78	39	54	98	1422
	81	107	107	69	102	117	78	119	136	72	104	117	89	137	152	102	113	155	108	126	166	93	134	192	104	153	216	109	142	231	120	173	238	133	162	300	4857

192311 ÷ 3 − CF

64103.67 − 54607.5 = 9496.17

9496.17 − 2668.41 − 196.77 − 3283.31 − 1003.10 − 140.96 − 782.93 − 323.63 − 157.23 − 56.30 − 195.06 − 120.69 − 203.98 − 117.06 − 129.44 = 117.25

117.25

herbicide	1												2												3												
herbicide rate	0			1			2			3			0			1			2			3			0			1			2			3			
soil type	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
sampling date 1	17	32	32	19	25	32	24	35	48	17	24	46	15	28	26	18	26	33	23	29	36	20	28	31	19	31	36	20	20	30	19	26	33	22	25	32	977
2	23	33	35	23	27	41	22	41	42	23	34	85	24	32	39	20	29	42	20	42	39	27	32	36	21	30	36	24	29	38	20	30	37	21	32	35	1164
3	26	35	40	29	32	45	35	48	57	32	41	78	25	35	41	25	27	41	29	33	40	25	25	40	26	37	43	24	34	44	24	34	40	26	35	43	1294
4	27	27	47	26	39	55	33	39	70	33	52	88	27	37	50	28	34	51	29	25	49	28	37	48	24	40	50	24	35	51	28	36	49	24	35	47	1422
	93	127	154	97	123	173	114	163	217	105	151	297	91	132	156	91	116	167	101	129	164	100	122	155	90	138	165	92	118	163	91	126	159	93	127	157	4857

184449 ÷ 3 − CF

61483.0 − 54607.5 = 6875.5

6875.5 − 396.2 − 196.77 − 3283.31 − 1003.10 − 419.39 − 218.93 − 65.62 − 157.23 − 56.30 − 195.06 − 405.25 − 180.90 − 42.70 − 117.06 = 142.68

142.68

temperature	13									25									35									
herbicide	1			2			3			1			2			3			1			2			3			
soil type	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
sampling date 1	13	33	38	21	32	34	19	21	35	34	40	46	30	39	38	30	36	41	30	43	74	25	40	54	31	45	55	977
2	29	36	41	30	38	40	23	37	49	25	40	65	24	38	48	24	36	45	37	59	97	37	59	68	39	48	62	1164
3	31	44	44	28	38	39	29	38	39	37	55	75	41	44	50	32	45	57	54	57	101	35	38	73	39	57	74	1294
4	26	37	50	25	39	41	26	39	37	43	53	77	43	41	59	29	43	64	50	67	133	44	53	98	45	69	96	1422
	99	150	173	104	147	154	97	135	160	139	188	263	138	162	195	115	160	207	171	226	405	141	190	293	154	219	287	4857

256713 ÷ 4 − CF

64178.25 − 54607.5 = 9570.75

9570.75 − 396.2 − 2667.41 − 3283.31 − 1003.1 − 142.20 − 782.93 − 323.63 − 218.93 − 65.62 − 195.06 − 111.71 − 28.76

4-way tables.--continued

temperature	13				25				35				
herbicide rate	0	1	2	3	0	1	2	3	0	1	2	3	
sampling date 1	56	52	74	64	88	79	89	78	92	92	110	103	977
2	83	77	79	74	79	87	82	97	111	109	132	154	1164
3	80	84	86	80	104	98	116	118	124	119	138	147	1294
4	76	75	94	75	107	106	113	136	146	162	151	191	1422
	295	288	333	293	378	370	400	419	473	482	531	595	4857

532135 ÷ 9 − CF

59126.11 − 54607.5 = 4518.61

4518.61 − 2668.41 − 196.77 − 1003.10 − 323.63 − 56.30 − 140.96 = 129.44

129.44

temperature	13				25				35				
herbicide rate	0	1	2	3	0	1	2	3	0	1	2	3	
soil type 1	81	69	78	72	89	102	109	93	104	109	120	133	1158
2	107	102	119	104	137	113	126	134	153	142	173	162	1572
3	107	117	136	117	152	155	166	192	216	231	238	300	2127
	295	288	333	293	378	370	400	419	473	482	531	595	4857

743493 ÷ 12 − CF

61957.75 − 54607.5 = 7350.25

7350.25 − 2668.41 − 196.77 − 3283.31 − 782.93 − 140.96 − 157.23 = 120.64

120.64

herbicide	1			2			3			
soil type	1	2	3	1	2	3	1	2	3	
herbicide rate 0	93	127	154	91	132	156	90	138	165	1146
1	97	123	173	91	116	167	92	118	163	1140
2	114	163	217	101	129	164	91	126	159	1264
3	105	151	297	100	122	155	93	127	157	1307
	409	564	841	383	499	642	366	509	644	4857

716155 ÷ 12 − CF

59679.58 − 54607.50 = 5072.08

5072.08 − 396.20 − 3283.31 − 196.77 − 218.93 − 414.39 − 157.23 = 405.25

405.25

herbicide	1				2				3				
herbicide rate	0	1	2	3	0	1	2	3	0	1	2	3	
sampling date 1	81	76	107	87	69	77	88	79	86	70	78	79	977
2	91	91	105	142	95	91	101	95	87	91	87	88	1164
3	101	106	140	151	101	93	102	90	106	102	98	104	1294
4	101	120	142	173	114	113	103	113	114	110	113	106	1422
	374	393	494	553	379	374	394	377	393	373	376	371	4857

512287 ÷ 9 − CF

56920.78 − 54607.5 = 2313.28

2313.28 − 396.20 − 196.77 − 1003.10 − 414.39 − 65.62 − 56.30 = 180.90

180.90

soil type	1				2				3				
herbicide rate	0	1	2	3	0	1	2	3	0	1	2	3	
sampling date 1	51	52	66	59	91	71	90	77	94	95	117	109	977
2	68	67	62	71	95	85	113	98	110	121	118	156	1164
3	77	78	88	83	107	93	115	101	124	130	137	161	1294
4	78	78	90	85	104	108	100	124	147	157	168	183	1422
	274	280	306	298	397	357	418	400	475	503	540	609	4857

536547 ÷ 9 − CF

59616.33 − 54607.5 = 5008.83

5008.83 − 3283.31 − 196.77 − 1003.10 − 157.23 − 195.06 − 56.30 = 117.06

117.06

3-way tables

temperature	13			25			35			
soil type	1	2	3	1	2	3	1	2	3	
sampling date 1	53	86	107	94	115	125	86	128	183	977
2	82	111	120	73	114	158	113	166	227	1164
3	88	120	122	110	144	182	128	152	248	1294
4	77	115	128	115	137	200	139	184	327	1422
	300	432	477	392	510	665	466	630	985	4857

756815 ÷ 12 — CF

63067.92 — 54607.5 = 8460.42

8460.42 — 1003.10 — 3283.31 — 2668.41 — 782.93 — 323.63 — 195.06 = 203.98

203.98

temperature	13			25			35			
herbicide	1	2	3	1	2	3	1	2	3	
sampling date 1	84	87	75	120	107	107	147	119	131	977
2	106	109	99	130	110	105	193	164	149	1164
3	119	105	106	167	135	134	212	146	170	1294
4	113	105	102	173	143	136	250	195	205	1422
	422	405	382	590	495	482	802	624	655	4857

532135 ÷ 9 — CF

59126.11 — 54607.5 = 4518.61

4518.61 — 2668.41 — 196.77 — 1003.1 — 323.63 — 56.3 — 140.96 = 129.44

129.44

temperature	13			25			35			
herbicide	1	2	3	1	2	3	1	2	3	
soil type 1	99	104	97	139	138	115	171	141	154	1158
2	150	147	135	188	162	160	226	190	214	1572
3	173	154	150	263	195	207	405	293	287	2127
	422	405	382	590	495	482	802	624	655	4857

995379 ÷ 16 — CF

62211.19 — 54607.5 = 7603.69

7603.69 — 2668.41 — 396.2 — 3283.31 — 782.93 — 142.2 — 218.93 = 111.71

111.71

temperature	13			25			35			
herbicide	1	2	3	1	2	3	1	2	3	
herbicide rate 0	96	100	99	128	121	129	150	158	165	1146
1	101	99	88	123	124	123	169	151	162	1140
2	133	109	91	155	127	118	206	158	167	1264
3	92	97	104	184	123	112	277	157	161	1307
	422	405	382	590	495	482	802	624	655	4857

707093 ÷ 12 — CF

58924.42 — 54607.5 = 4316.92

4316.92 — 2668.41 — 396.2 — 196.77 — 142.2 — 140.96 — 414.39 = 357.99

357.99

herbicide	1			2			3			
soil type	1	2	3	1	2	3	1	2	3	
sampling date 1	77	116	158	76	111	126	80	102	131	977
2	97	135	203	91	135	156	86	121	146	1164
3	122	156	220	104	120	162	100	140	170	1294
4	119	157	260	112	133	198	100	146	197	1422
	409	564	841	383	499	642	366	509	644	4857

717749 ÷ 12 — CF

59812.42 — 54607.5 = 5204.92

5204.92 — 396.20 — 3283.31 — 1003.10 — 218.93 — 65.62 — 195.06 = 42.7

42.7

3-way tables.--continued

temperature	13	25	35	
sampling date 1	246	334	397	977
2	313	345	506	1164
3	330	436	528	1294
4	320	452	650	1422
	1209	1567	2081	4857

2109695 ÷ 36 − CF

58602.6 — 54607.5 = 3995.1

3995.1 − 2668.4 − 1003.1 =

323.6

temperature	13	25	35	
soil type 1	300	392	466	1158
2	432	510	630	1572
3	477	665	985	2127
	1209	1567	2081	4857

2944423 ÷ 48 − CF

61342.1 − 54607.5 = 6734.6

67346 − 2668.4 − 3283.3 =

782.9

temperature	13	25	35	
herbicide 1	422	590	802	1814
2	405	495	624	1524
3	382	482	655	1519
	1209	1567	2081	4857

2775087 ÷ 48 − CF

57814.3 − 54607.5 = 3206.8

3206.8 − 2668.4 − 396.2 =

142.2

temperature	13	25	35	
herbicide rate 0	295	378	473	1146
1	288	370	482	1140
2	333	400	531	1264
3	293	419	595	1307
	1209	1567	2081	4857

2074091 ÷ 36 − CF

57613.6 − 54607.5 = 3006.1

3006.1 − 2668.4 − 196.8 =

140.9

soil type	1	2	3	
sampling date 1	233	329	415	977
2	268	391	505	1164
3	326	416	552	1294
4	331	436	655	1422
	1158	1572	2127	4857

2127203 ÷ 36 − CF

59088.9 − 54607.5 = 4481.5

4481.5 − 3283.3 − 1003.1 =

195.1

herbicide	1	2	3	
sampling date 1	351	313	313	977
2	429	382	353	1164
3	498	386	410	1294
4	536	443	443	1422
	1814	1524	1519	4857

2018607 ÷ 36 − CF

56072.4 − 54607.5 = 1464.9

1464.9 − 396.2 − 1003.1 =

65.6

herbicide	1	2	3	
herbicide rate 0	374	379	393	1146
1	393	374	373	1140
2	494	394	376	1264
3	553	377	377	1307
	1814	1524	1519	4857

2002135 ÷ 36 − CF

55614.9 − 54607.5 = 1007.4

1007.4 − 396.2 − 196.8 =

414.4

herbicide	1	2	3	
soil type 1	409	383	366	1158
2	564	499	509	1572
3	841	642	644	2127
	1814	1524	1519	4857

2808285 ÷ 48 − CF

58505.9 − 54607.5 = 3898.4

3898.4 − 396.2 − 3283.3 =

218.9

soil type	1	2	3	
herbicide rate 0	274	397	475	1146
1	280	357	503	1140
2	306	418	540	1264
3	298	400	609	1307
	1158	1572	2127	4857

2096813 ÷ 36 − CF

58244.8 − 54607.5 = 3637.3

3637.3 − 3283.3 − 196.8 =

157.2

herbicide rate	0	1	2	3	
sampling date 1	236	223	273	245	977
2	273	273	293	325	1164
3	308	301	340	345	1294
4	329	343	358	392	1422
	1146	1140	1264	1307	4857

1508319 ÷ 27 − CF

55863.7 − 54607.5 = 1256.2

1256.2 − 196.8 − 1003.1 =

56.3

2-way tables

Table 12.--ANALYSIS OF VARIANCE.

	D/F	SS	M^2	"F"
Temp	2	2,668.41	1,334.21	251.74**
Dates	3	1,003.10	334.37	63.08**
Soils	2	3,283.31	1,641.65	309.75**
Herb	2	396.20	198.1	37.38**
Rates	3	196.77	65.59	12.37**
		7,547.79		
Temp x dates	6	323.63	53.94	10.18**
Temp x soils	4	782.93	195.73	36.93**
Temp x herbs	4	142.20	35.55	6.71**
Temp x rates	6	140.96	23.49	4.43**
Dates x soils	6	195.06	32.51	6.13**
Dates x herbs	6	65.62	10.94	2.06*
Dates x rates	9	56.30	6.25	1.18
Soils x herbs	4	218.93	54.73	10.34**
Soils x rates	6	157.23	26.20	4.94**
Herbs x rates	6	414.39	69.06	13.03**
		2,497.25		
Temp x dates x soils	12	203.98	16.99	3.21*
Temp x dates x herbs	12	28.76		
Temp x dates x rates	18	129.44	7.19	1.35
Temp x soils x herbs	8	111.71	13.96	2.63*
Temp x soils x rates	12	120.64	10.05	1.98*
Temp x herbs x rates	12	357.99	29.83	5.63**
Dates x soils x herbs	12	42.70	3.55	
Dates x soils x rates	18	117.06	6.50	1.22
Dates x herbs x rates	18	180.90	10.05	1.89*
Soil x herb x rates	12	405.25	33.77	6.37**
		1,698.43		
Temp x herb x rates x soils	24	307.83		
Temp x herb x soils x dates	24	104.21		
Temp x herb x rates x dates	36	184.83		
Temp x rate x soils x dates	36	117.25		
Herb x rates x soils x dates	36	142.68		
		856.80		
Temp x dates x soils x herb x rates	72	351.23		
ERROR	228	1,208.03		
Total	431	12,951.50		

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