HR-64

EROSION CONTROL ON HIGHWAY BACKSLOPES

PROGRESS REPORT 1959

by

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Erosion Control on Highway Backslopes

1959

During 1959, research was continued by the Agronomy Department in cooperation with the Iowa Highway Commission on vegetative establishment and erosion control on highway backslopes (Project 1010). The work was continued at previously established sites and also several new experiments were initiated during the year. The work will be discussed for each separate experiment and location in this report.

Topsoil Replacement Study

Chariton, Iowa

A project started in the fall of 1958 on the McNay Memorial Farm near Lucas was continued during 1959. The purpose of this study was to compare the value of replacing topsoil on freshly-cut backslopes for vegetative establishment, along with the comparison of various types of mulches.

In the fall of 1958 the area was half-covered with topsoil, seeded (alta fescue, alsike and ladino clover, alfalfa, bromegrass and rye), and covered with various mulches. Mulch treatments included: straw (3 T./A.), manure (8 T./A.), plastic film, asphalt emulsion, and a bare check plot. As reported in the 1958 report, soil temperatures (1"-4") were highest under the plastic film and coolest under straw mulch, soil moisture varied little, while plant numbers in the fall of 1958 were significantly higher under plastic film and lowest under straw.

The plastic film was left on, as were the other mulches, over winter. The temperatures under plastic remained slightly warmer and plant growth continued longer in the late fall under plastic than on the other plots.

In the spring of 1959, the plastic was removed at which time the plant growth was much farther advanced than on other plots due to warmer temperatures and earlier growth in the spring. In June, 1959, plant matter yields were taken on all plots by clipping a swath down the center of each plot with a power sickle-type mower. Both fresh and dry plant matter yields are shown in table 1.

It was found that manure gave significantly higher fresh matter yields than all other treatments during the spring of 1959, while asphalt, straw and plastic gave somewhat similar growth and check plots gave poorest yields. It can be seen than plastic gave much better results on areas with no topsoil applied than where topsoil was present. This may have some significance as to the value of plastic film on improving soil moisture relationships, etc, on poor soil areas. An analysis of variance showed no general significant in-

Table 1. Fresh and dry plant matter yields - June, 1959.

Treatment	Mulch Trt.	Fresh Matter (lbs.)	Dry Matter (lbs.)
No topsoil	Manure	10.56	4.63
	Plastic	5.14	2.86
	Asphalt	4.00	2.12
	Straw	3.15	1.82
	Check	1.87	0.85
Topsoil	Manure	9.70	5.08
	Asphalt	6.85	3.83
	Straw	6.70	3.35
	Check	4.40	2.38
	Plastic	4.35	2.41

crease in yield due to topsoil application. However, for individual treatments, slight increases could be seen in some cases, which might indicate some value of topsoil in some cases. This is especially noted in the case of the check plot with no mulch, where the yield on topsoiled plots is much higher. However, in the case of manure, a decrease was noted on the topsoiled area. This may indicate that the mulches may compensate somewhat for the lack of topsoil, especially in the case of manure where plant nutrients and organic matter are supplied.

The same relationships were shown in the dry-matter yield, in general, with manure again giving highest yields and asphalt, plastic and straw slightly less with check plots again being poorest.

Erosion control was very good with all treatments except the check plots, on which some rilling and washing was noticed. Erosion was not a serious problem on this site, however, due to the relatively moderate slope.

In late July, a visual comparison of the percentage of plant cover on the different treatments showed manure to have the best cover, with plastic second, straw and asphalt about equal, and check plots having the poorest percent cover. A plant count was made of the legumes and grasses on each treatment using a 1 square foot quadrat. The average number of legumes, grasses, and total plants per square foot on each of the various treatments is presented in table 2. These plant counts were made after the rye cover crop had been mowed off.

Both straw and manure had significantly larger numbers of grasses than the check or plastic treatments, with asphalt being intermediate. However, in legumes, manure had a significantly higher number than asphalt, straw or check treatments, with plastic having the second highest number. In total number of plants per square foot, manure and plastic were again highest, with manure being significantly higher than the straw, asphalt or check, and plastic being significantly higher than the check treatment. Thus, although

Table 2. Avg. no. grasses, legumes, and total plants per square-foot. July, 1959.

Treatment	Mulch Trt.	Grasses	Legumes	Total plants
No topsoil	Manure	16.8	28.5	45.3
	Straw	24.5	4.8	29.3
	Asphalt	19.7	10.0	29.6
	Plastic	12.3	18.3	30.6
	Check	12.7	4.2	16.8
Topsoiled	Manure	27.3	23.6	51.0
	Straw	23.5	4.5	28.2
	Asphalt	16.5	7.0	23.5
	Plastic	15.8	19.7	35.5
	Check	8.3	3.8	12.2

manure and plastic mulches gave lower numbers of grasses per square foot, they gave much larger numbers of legumes. Plastic was especially poor in grass stands, especially on the non-topsoiled area. It appears that straw mulch had a depressing effect on the growth of legumes, while grasses thrived under the straw. Plastic, on the other hand, seemed to favor the establishment of legumes over grasses. This phenomenon was commonly noticed by visual comparison throughout the season. The cause for this cannot be explained, although differences in soil temperature may be an important factor. Topsoiling apparently had no effect on the number of plants established.

In the fall of 1959, estimates were made of the percentage of total plant cover on each treatment by means of density list quadrats. The percentage of the total cover made up by legumes and by grasses was also estimated, as shown in table 3.

Table 3. Estimated percentage of total plant cover and percent of total due to grasses and legumes. October, 1959.

Treatment	Mulch Trt.	% Total Cover	% of Total Cover due to: Legumes	% of Total Cover due to: Grasses
No topsoil	Straw	19	66	34
	Check	12	82	18
	Manure	59	88	12
	Plastic	48	92	8
	Asphalt	35	95	5
Topsoiled	Straw	21	66	34
	Check	28	68	32
	Manure	78	74	26
	Plastic	33	75	25
	Asphalt	71	97	3

Manure gave much higher total plant cover than any of the other treatments, especially on the "no-topsoil" area. Asphalt and plastic gave fairly good cover on both areas, with asphalt being almost as high as the manure plots on the topsoiled. Both straw and check gave poor plant cover on both areas. It may be noted, that with the exception of the plastic, all other treatments gave better total plant cover on the topsoiled area than on the untopsoiled. Legumes accounted for the major portion of the total cover on all treatments. However, legumes accounted for a much greater percentage of the total cover on the plastic, asphalt and manure plots than they did on the straw plots. This again indicates that legumes were favored on the plastic and asphalt plots, while grasses seemed to thrive more on straw-mulched plots.

Plant matter yields were also taken by clipping the growth from each treatment after cover estimates were determined. At the time of this report, these samples are being separated into legumes, grasses, and weeds to determine the percentage of the total plant matter made up by each. Since this data is still incomplete, only fresh weights of the total plant-matter samples will be reported (table 4).

Table 4. Fresh plant-matter yields. October, 1959.

Treatment	Mulch Trt.	Fresh wt. (lbs./plot)
No topsoil	Manure	3.52
	Asphalt	2.04
	Plastic	1.11
	Check	1.09
	Straw	0.60
Topsoiled	Manure	4.34
	Asphalt	3.52
	Straw	2.77
	Plastic	1.54
	Check	1.36

The manure treatment gave the highest fresh-weight yield of plant material of all treatments, with asphalt giving the second-highest yields. However, plastic, straw, and check plot yields were about equal and somewhat lower. Visual observation indicated a larger number of weeds on the check plots that may have accounted for check plot yields comparing more favorably to straw and plastic treatments. This factor may be revealed by the plant separations now underway. It is interesting to note, however, that all treatments gave higher fresh matter yields on the topsoiled than on the non-topsoiled area.

Conclusions

In general, the topsoiling treatment had only slight effect in increasing vegetative establishment in this study. The use of various mulches seemed to be sufficient to make up for lack of topsoil. Manure was especially effective in establishing a good stand of grasses and legumes, and in promoting further growth-perhaps due to the added nutrients and organic matter. Asphalt and plastic film were of some value in increasing stand, although later growth was not as great as on the manure plots. Plastic film was especially effective in increasing germination and growth after seeding, and promoted earlier growth in the spring, although this advantage was lost later in the season. Straw mulch seemed to depress both stand and growth, especially during the earlier stages of growth. Except for manure, which continued to give high yields and growth, the other mulches tended to become more or less equal in yield of plant matter later in the season.

Legumes seemed to be more favored under asphalt and plastic, while grasses were favored under straw. Soil temperatures were highest under plastic and asphalt and lowest under straw - which may be a factor as to which species is favored.

Erosion control, though not a serious problem on this site, was very good with all the mulch treatments tried.

Mulch Experiment on Sandy Backslope

Granger, Iowa

In the spring of 1959, an experiment was established on a backslope on Highway 141 about 5 miles north of Granger, Iowa. The purpose of this study is to compare the effectiveness of various types of mulches on controlling erosion and establishing vegetation on very sandy backslope material. The site of the experiment is on an approximately 2½:1 slope made in the fall of 1957 and is located between Highway station marks 244 and 247 on the east side of the highway. The soil material concerned is predominantly loose fine sand. The experimental area measures about 200 by 50 feet (10,000 $ft.^2$ or about 0.23 acre).

The experimental design is randomized block with 3 replications of 6 treatments each, along with 3 supplementary plots not included in the design. Mulch and soil treatments being studied are as follows:

1. Check (no mulch)
2. Straw mulch (2 T./A.)
3. Straw + netting
4. Asphalt (0.2 $gal./yd.^2$)
5. Arquad (0.2% on dry soil wt. basis)
6. Starch (100 lbs./A.)

(Additional supplementary plots compared a close-weave "Erosionet" netting with a check plot).

The experimental area was first lightly tilled by means of a tractor and tiller implement in May, 1959, and fertilizer was applied broadcast over the entire area at the rate of 100 lbs./A. each of N, P and K. The following seeding mixture was then sown broadcast:

Alfalfa - 11 lbs./A.
Red clover - 10 lbs./A.
Bromegrass - 25 lbs./A.
Perennial ryegrass 5 lbs./A.
Alta fescue - 7 lbs./A.
Oats - $\frac{1}{4}$ bu./A.

The above mulches and soil-treatments were then applied; the asphalt and arquad solutions by power sprayer, the starch by hand in dry form, and the nettings were staked by hand with wire staples.

Plant Counts

On July 10, 1959, the number of grasses, legumes, and total plants per square foot were determined on each treatment by means of count-list quadrats. Three counts were made on each plot - one at the bottom, middle and top. The three quadrats were averaged to give the average number of plants per square foot on each treatment as presented in table 5.

Table 5. Avg. no. grasses, legumes and total plants per square foot. July, 1959.

	Avg. no. plants/sq. ft.		
Treatment	Grasses	Legumes	Total
Check	26.8	3.7	30.5
Straw	33.2	8.6	41.8
Straw + netting	24.1	5.2	29.3
Asphalt	36.1	11.6	47.7
Arquad	46.2	8.9	55.1
Starch	39.1	7.8	46.9
Avg.	34.2	7.6	41.8

Although an analysis of variance showed no significant differences among treatments, a definite trend towards higher numbers of grasses, legumes and total plants seems indicated on the asphalt treatment with arquad and starch giving next highest counts. Straw-mulched plots were lower in plant numbers than the other treatments (except check) and showed indication throughout the season of a depressing effect on plant germination and growth.

Plant counts were not made at this time on the supplementary plots comparing close-weaved netting and non-mulched plots because little difference between the two treatments were noticed by visual observation. Also, it was felt that damage to the seeding would result if the netting was removed in order to take the count at that time.

Erosion Control

Observations made on erosion control on the various treatments were also made at this time. The asphalt plots suffered very little rilling except where the asphalt film was broken in various places. Practically no erosion was noticed on the straw, or straw + netting plots. The netting seemed to be effective in holding the straw in place against blowing and slippage and gave slightly better mulch coverage to the plot. Moderate rilling was noticed on the starch, arquad, and check plots - the check plots being more severe. Rills numbering 3 - 4 per plot and averaging from 1 to 10 inches in depth were noted running three-fourths the length of these plots. Erosion in general was most severe on the southern part of the experimental area where the soil material contained higher amounts of silt and clay. Where the material was mainly sand, rilling was very slight.

Plant Cover

Plant cover observations were made on each treatment by visual comparison. Asphalt plots had good but uneven cover. In some spots it seemed as if the asphalt crust prevented seedling emergence. However, both straw and asphalt had the best plant cover, starch, straw plus netting and arquad were about equal and intermediate, and check plots had the poorest cover.

Fall Plant Matter Yields + Cover

Density - list quadrats were again made in the fall of 1959 to estimate percentage plant cover on the different treatments. The percentage of the total cover due to grass, legumes, and weeds was also estimated. Following this, plant matter was clipped and weighed in the field to determine fresh plant matter yields. These samples are presently being separated into species so that the percentage of plant matter yield due to each may be determined. Dry matter yields will then be determined for each treatment. Data presently available on fresh weights and plant cover are presented in table 6.

Table 6. Plant matter yield and estimated percentage plant cover. October, 1959.

		Estimated percentage plant cover			
Treatment	Fresh Matter (lbs.)	Total	Grass	Legumes	Weeds
Arquad	2.10	37	50	4	46
Starch	2.01	26	30	13	57
Check	1.77	29	33	10	57
Straw + netting	1.43	37	7	2	91
Asphalt	1.41	32	4	6	90
Straw	1.31	33	29	2	69
Supplemental Treatments:					
Erosion netting	0.92	25	--	--	--
Check	1.59	15	--	--	--

Fresh weights of plant matter were higher on the arquad and starch plots, with check plots being third highest in yield. Straw plus netting, asphalt and straw mulch were lowest and about equal in yield of fresh matter. Total percent plant cover was approximately equal on all plots, however, with arquad and straw plus netting having greatest percent cover and starch being lowest. The three treatments having the lowest fresh matter yield had the highest percentage of cover due to weeds. However, due to some annual weeds being mature and dry at the time of sampling, they didn't provide much cover, but added greatly to the weight of the clippings. This may cause some treatments to appear better than they actually are, in plant matter yield, but the species separation data will give a more accurate comparison.

Of the two supplementary treatments, the erosion-netting gave less fresh-matter yield, but gave somewhat better plant cover. Erosion was not serious on either treatment.

Conclusions

Early in the season, plant germination and growth was very fast and heaviest under the asphalt-treated plots, and slowest under the straw-mulched plots. In the middle of the season, asphalt, arquad and starch had the highest number of plants per square-foot - while the straw-mulched plots had the smaller number of both grasses and legumes per square-foot. However, the straw and straw-plus-netting along with the asphalt gave very good erosion control, while the starch, arquad and check plots suffered moderate to severe rilling.

At the end of the growing season, both arquad and starch had the largest yield of fresh-matter while asphalt dropped with the straw-mulched plots to the lowest yields. Straw-mulch again seemed to depress plant germination and growth, although giving good erosion control. Asphalt gave good germination and early growth, probably due to higher soil temperatures. However, the stand under asphalt was patchy due to the ashpalt crust preventing emergence in some places.

The erosion-netting shows some promise for erosion control but the plant stand was not improved greatly on this sandy area. Further conclusions can be made on all treatments after the data on species separations and dry-matter yields are completed.

Phosphate Rate Study on Calcareous Loess

Moville, Iowa

A study to determine the optimum rate of P_2O_5 fertilizer for stand establishment on calcareous loess was initiated near Moville on Highway 20 in early June, 1959. The experimental area was located on the south backslope between highway station numbers 116-119, and included an area of 300 by 40 feet on a 2:1 slope. The soil material was Ida silt loam. The area was previously prepared and seeded by the Iowa Highway Commission in the spring of 1959 with the following seeding mixture:

Bromegrass	-	7 lbs./A.
Western wheatgrass	-	5 "
Alfalfa	-	5 "
Red clover	-	3 "
Perennial ryegrass	-	5 "

Fertilizer at the rate of 200 lbs./A. of 21-34-0 was also applied at the time of seeding.

Following seeding and prior to seedling emergence, the following additional fertilizer treatments were top-dressed on the seeded area:

1. 80 lbs./A. N + 80# lbs./A. P_2O_5
2. 80 " N +160 " P_2O_5
3. 80 " N +240 " P_2O_5
4. 80 " N +320 " P_2O_5.

The experiment was arranged in a randomized block design of 3 replications. Thus, there were 12 plots, each 10 feet wide and oriented up-and-down slope.

Plant Matter Yields

Throughout the season, visual observation showed no large differences in density of growth, rate of growth, or amount of plant cover density among the treatments. In the fall of 1959, clippings were made on each plot to determine the amount of plant-matter produced on each treatment. The clippings were made from $\frac{1}{4}$ -milacre quadrats (1/4000 A.) to facilitate conversion of data to the tons-per-acre basis, as presented in table 7.

Table 7. Fresh-matter yields in Tons/Acre. October, 1959.

Treatment	Fresh matter yields (T./A.)
80# N + 80# P_2O_5	1.24
80# N +160# P_2O_5	1.50
80# N +240# P_2O_5	1.62
80# N +320# P_2O_5	1.50

The yield of fresh-matter was noticed to increase with rate of P_2O_5 applied up to the rate of 240 lbs./A. At the highest fertilizer rate, 320 lbs./A. of P_2O_5, the yield dropped slightly to the level obtained with 160 lbs./A. of P_2O_5.

The plant material samples are being separated into legumes, grasses and weeds for determination of the amounts of each species produced on each treatment. Also dry matter yields will be measured from these samples to enable more complete conclusions to be obtained from this study.

Fertilizer Rate Trials on Kansan Till

Seymour, Iowa

A fertilizer-rate trial was initiated in the fall of 1959 on a backslope on Highway 55, 5 miles north of Seymour, Iowa. The purpose of this study is to determine the optimum fertilizer rate and combination of N and P for establishment of vegetation on exposed Kansan till material.

The experimental area is 216 by 20 feet in size (120 $ft.^2$ or 0.003 A.) located on a west-facing 3:1 slope on exposed Kansan glacial till subsoil material under a Seymour surface soil. It is located 917 feet south of the Hwy. 55 and 2 intersection. This particular site was selected because of the evenness of the slope and due to the large amount of Kansan till material exposed along with various other strata. The backslope face is transected by several visible horizons of various soil materials. A topsoil layer of 0-2 feet of loess (Seymour silt loam) covers the top of the slope. Just under the loessial cap is located a 4-6 foot wide layer of a distinct reddishferreto zone. The bulk of the exposed area was oxidized and leached Kansan glacial till, however, towards the bottom of the slope, calcium carbonate concretions and depositions are noticeable, indicating the beginning of an oxidized and unleached strata. Prior to applying the treatments, soil samples were taken of each strata for analysis of nutrient content.

The area was then prepared for seeding by light tillage and harrowing. The experiment consisted of a randomized-block design of 9 treatments and 4 replications, giving a total of 36 plots. The following fertilizer treatments were applied by hand:

1. 0-0-80
2. 0-80-80
3. 0-160-80
4. 40-0-80
5. 40-80-80 (Same as Hwy. Comm. specifications)
6. 40-160-80
7. 80-0-80
8. 80-80-80
9. 80-160-80.

The fertilizer was lightly raked in by hand and the following seeding mixture applied broadcast:

Bromegrass	-	10 lbs./A.
Orchard grass	-	6 "
Timothy	-	4 "
Lespedeza	-	5 "
Alfalfa	-	5 "

The area was again lightly harrowed and a mulch of $1\frac{1}{2}$ tons/acre of straw applied by hand.

Observations will be made of early spring growth and it will be followed through the growing season to notice plant cover density, plant and species numbers, etc. Plant matter yields and cover density measurements will be made, along with erosion control observations, to determine the optimum rate of fertilizer application for vegetative establishment on this material.

HIGHWAY BACKSLOPE RESEARCH

Report on Agronomic Studies

1954 - 1956

Paul Peperzak and W. D. Shrader*

Introduction

This report is an attempt to cover all research done by the authors on the problem of highway backslope vegetative stabilization during the period January 1, 1954 to April 1, 1956. This research was done under Project No. 1010, sponsored jointly by the Agricultural Experiment Station, Iowa State College and the Iowa State Highway Commission.

Some of the data and results have been previously reported in:

a. Highway backslope vegetative stabilization, 1954 Progress Report in Agronomic Studies. Paul Peperzak and W. D. Shrader.

b. Correlation of selected soil indices with plant growth on highway backslopes, Ph. D. Thesis, Iowa State College, 1956. Paul Peperzak.

In the course of the present report frequent references will be made to the above papers.

Research done in the two year period, 1954-1956, included the following:

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1. Three field experiments were initiated and are still being continued. One of these experiments has furnished pertinent data already.
2. Four greenhouse experiments were initiated and harvested.
3. A survey of problem soils exposed on highway backslopes was made.
4. Plant and soil samples were collected on 55 sites within these problem materials.
5. A total of 254 soil samples thus taken were analyzed on both physical and chemical characteristics.
6. On the basis of these analyses, problem soils were described and characterized.
7. A statistical analysis was made to determine possible relationships between the selected soil indices and plant growth on highway backslopes.

A fairly well defined research plan was herewith completed and it is now felt that a summary of all data and results obtained in this study will prove both desirable and informative.

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received during the course of the research program.

Statement of Problem and Objectives of Research Program

The problem in highway backslope revegetation is one of excessive costs mainly. Costs involved in maintaining backslopes, (seeded or not seeded), which are easily eroded; and costs involved in high seeding rates and in weed control.

All of these costs might be reduced if a vegetative cover could be established rapidly so that erosion is prevented; reseeding is unnecessary and weed growth is limited.

Thus, the objective is the rapid establishment of a vegetative cover on backslopes cut in different materials.

A study of optimum seeding rates and most suitable mixtures for each of the major subsoil materials is a botanical one and has been handled by the Botany Department, I. S. C., under the same project.

It is our problem to investigate which is a favorable environment for plant growth on these materials. It is, therefore, necessary

1. to know the materials (see Introduction 3, 4, 5 and 6)
2. to study the correlation of existing plant growth with the soil materials on which it was found (Introduction 4, 5 and 7)
3. to try to improve plant growth on these soil materials by additives--fertilizers and/or soil conditioners--(Introduction 1 and 2)

It will be seen that the problem has indeed been approached from these three angles.

EXPERIMENTAL

Problem Areas, Occurrence and Extent

It was noticed, during a preliminary survey of highway backslopes, that those which were cut and seeded prior to 1948 usually had a dense vegetative cover. A 2 to 4-inch layer of topsoil has been formed on these older cuts, so that differences in plant growth between different soil materials are usually obliterated.

For the present study we examined especially those slopes which were cut and seeded rather recently, say in the last five years, and which showed a wide variation in subsoil materials.

A summary of this survey appears in Table 1.

From the listing it is obvious that problem areas especially occur in western and southern Iowa. The almost level topography of northern Iowa--with the exception of the steep slopes and cuts in calcareous rock material in the northeastern part of the State--excludes by its very nature the construction of backslopes of any significant size in the course of highway building.

Two distinct patterns of backslopes can be found within the problem areas. Each occurs in its own specific geographic region. The boundary between the two regions falls roughly along U. S. Highway 71. This boundary is approximately the same as the one which limits the deposit of deep loess (over 200 inches) in western Iowa.

Highway backslopes west of this boundary expose high cuts in deep, mostly calcareous, loess, overlaying calcareous till.

If insufficient vegetation has been established on these slopes, severe erosion may occur, especially in the deep loess material. Till exposures in this area seem to suffer severe erosion only when they are of pronounced sandy texture or when large sand pockets occur.

Backslopes in this category carried, in general, a fair to poor vegetation on the different weathering zones of loess and till. Good vegetation was mostly observed on the oxidized and calcareous zones in either loess or till. Of the two plant species, bromegrass and alfalfa, bromegrass seemed to prevail on leached loess. Both species occurred in almost even proportion on all other soil materials.

In the second region of the survey, approximately east of Highway 71, backslopes often give large exposures of till in many stages of weathering, covered by loess material to various depths. Erosion occurs especially in the more sandy materials and it may become serious on ordinary till if no satisfactory vegetation has been established within a few years after grading.

Vegetation usually makes a fairly satisfactory growth in this area except on these specific problem zones which may constitute a large percentage of a backslope surface. Plant growth may be virtually nil in such cases.

Slightly weathered till material supports, in general, a fair to good vegetation, but it appears that growing conditions must be made almost ideal by a strict following of standardized seeding procedures in order to insure a rapid establishment of plant growth on these soils. The results of field and greenhouse experiments have indicated that application of fertilizer, especially of a combination of nitrogen and phosphorus will greatly speed up this process.

The best growth is, in general, observed on the loess material overlaying the till. There is an indication that vegetation on loess in this region is more luxurious than that in the western part of the state. A higher degree of weathering, giving the materials properties which may make them more like mature soils, may account for this phenomenon.

Alfalfa and bromegrass occurred to equal extent on the loess weathered till material. Bromegrass appeared to be the dominant species on leached loess. In the case that any vegetation at all was present on ferretto zones and B horizons of surficial soils, bromegrass plants again outnumbered alfalfa.

A generalized profile sequence in this area includes the following zones and horizons: (1) surficial soil, (2) B-horizon of surficial soil, (3) oxidized and leached loess, (4) oxidized and calcareous loess, (5) fossil A_2 horizon, (6) ferretto zone (fossil B horizon), (7) oxidized and leached till, (8) oxidized and calcareous till, (9) un-oxidized and calcareous till.

An almost similar profile may include gumbotil instead of a ferretto zone.

One or two feet below the top of a backslope one may find fairly poor growth on the exposed B_2 horizon of the surficial soil. Not more than a scanty vegetation is usually supported by the three problem materials which can be found below the present

B_2 horizon. These materials are a distinct very light gray or white (when dry) fossil A_2 horizon, a contrasting reddish-brown ferretto zone and a gray gumbotil zone with plastic sticky clay when wet or hard and cracking when dry.

Un-oxidized till may occur in the lower part of a backslope. Vegetation on this material is in most places fair, but always far less satisfactory than it is on the oxidized material immediately above it. Extremely poor plant growth was observed in a few instances on un-oxidized till, but it is believed that other circumstances rather than unfavorable soil conditions are to be blamed for this condition.

Two other kinds of material have been surveyed and sampled which, however, do not strictly belong in the above-described pattern.

Some slopes expose both acid and non-acid shale material. Growth is extremely poor on the acid material and fair to poor on the non-acid shale. Exposures of shale on highway backslopes are not of common occurrence and have, therefore, been little studied in this connection.

Sandy materials have been an object of study, either in the form of aeolian sand near big rivers or in the form of colluvium at the foot of backslopes in drift material. Plant growth on these materials is irregular and ranges from very poor to excellent. This difference in growth appears to have been caused by a wide range in soil physical and chemical properties within this group of seemingly like material.

Characterization of Major Individual Zones in Backslopes

Of 241 samples taken, at 55 sites (see figure 1 and pp. 142-147, reference b.), from different backslope materials, 192 samples were selected as representative of specific zones.

Averages of analytical data* are given in Tables 2 to 4. Till and loess materials are here divided into their distinct zones of weathering. Data for oxidized and calcareous, oxidized and leached and de-oxidized and leached loess are, moreover, separated according to their geographic location.

Till material. As a group this material includes all till in which weathering has progressed but little. Ferretto, gumbotil and fossil A_2 horizons, originally developed from till, are not included in this group but will be described separately. Till materials are, in general, loamy and include sandy loams and clay loams. Color range from dark olive gray for un-oxidized zones to yellowish brown for oxidized stages.

Values for volume weight and aggregation for all till samples appear to be higher than the average of the backslope materials. Eighty percent of the samples fall in the lower category of total porosity which is mostly due to a general lower capillary porosity. Wilting percentage is on the low side while all but 10 percent of the samples fall in the two lower intervals for moisture equivalent. (M. E. 24.65%). Available water as measured by (M. E. - W. P.) is, consequently, lower than average. Initial nitrate and nitrifiable nitrogen are

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*Individual analytical data are presented in the Appendix of reference b: pp. 148-182.

slightly higher than average while available phosphorus shows a relatively even distribution, except for the fact that only 6 percent of the samples have more available phosphorus than 3 lbs./acre. Seventy-three percent of the till samples have a pH higher than 7.25. The large number of samples with low cation exchange capacity, low exchangeable hydrogen, low total exchangeable bases and high base saturation is apparent from frequency distributions of analytical values (see reference b: pp. 41-50).

Loess material. Texture of loess materials in the surveyed region ranges from silt loam to silty clay loam depending on location and degree of weathering. Colors vary from yellowish brown and light olive brown for the oxidized state, to light brown gray and light olive for the de-oxidized zones.

Eighty percent of this material has yields which fall in the upper two yield classes as was also observed in the case of till materials. A further comparison with till reveals that many of the attributes of loess are complementary to those of till. This is especially striking in the case of sand and silt content, volume weight, the various moisture percentages, aggregation, total porosity and available phosphorus. This might indicate that a high intercorrelation exists between these factors, the primary cause being located in textural differences. Thus, in the case of loess, one may expect that low sand and high silt contents can be related to low volume weight, a higher water availability (as measured by M. E. - W. P.), a lower percentage of water stable aggregates and a high total porosity. It is doubtful if the amount of available phosphate is directly related to the texture per se. It might be explained by the fact that the major phosphate carrying mineral, appatite, occurs in the silt fraction predominant in loess.

All other chemical characteristics follow a relatively even distribution except for the cation exchange capacity. With 50 percent of all loess samples having a clay content of 20-29%, a rough calculation gives an average cation exchange capacity for this clay fraction in the neighborhood of 80 me. Assuming that organic matter is practically absent, this indicates that clay minerals present in loess must be largely of the montmorillonite type.

Table 3 shows some obvious change in properties of oxidized loess material with the degree of weathering. This is recognizable not only by the degree of leaching but also by the geographical location of the loess materials. Previous authors have found that weathering in loess has progressed with the distance between source and location of deposit. The present findings indicate that leached loess has a lower sand and higher clay content than calcareous loess.

The most prominent differences between calcareous and leached loess are increased aggregation (from .019 mm. to .398 mm.), wilting point (from 8.9% to 13.9%), moisture equivalent (from 22.7% to 26.5%), and cation exchange capacity (from 15.1 me. to 20.2 me.).* All these increases may be correlated again with a simultaneous increase in clay content (from 15.5% to 28.3%)

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*Figures quoted here refer to loess material in the eastern part of the state, but similar differences are observed in the western part.

which in this case does not seem to have been affected by deposition but by increased weathering. A further increase in clay content and a relative decrease in aeration and capillary porosity is caused by difference in distance between source and location of loess deposits. A remarkable decrease in available potassium occurs also from west to east, both in leached and unleached loess.

B horizons. Materials included in this group may have developed under different conditions of plant growth (grass or trees) and may belong to quite different soil types. Heterogeneous though they may be, they are grouped here together because they may have several factors in common with respect to re-vegetation of backslopes. They are, in general, of silty clay loam texture and range in color from dark yellowish brown to light gray brown. All B horizons studied appeared to have been developed from loess. Consequently, they may be considered as loess zones in which weathering has progressed to a great extent.

Texturally, they contain an average of seven percent more clay than the oxidized leached loess in eastern Iowa. Due to their higher clay content they have a higher aggregation, lower aeration porosity, higher wilting point and moisture equivalent and higher cation exchange capacity than is average for loess materials.

Average values for B horizons (Table 4) as compared with those for oxidized or leached loess (Table 3), however, reveal that both groups of materials are very much alike in soil physical properties. In this respect it is interesting to note that even though the B horizons have a distinctly higher clay content, the total content of fine material, silt plus clay, is approximately the same in both cases. One might infer from this that physical conditions are as well determined by the total silt and clay content as by the clay content alone. The largest difference between B horizons and oxidized and leached loess occurs in the content of nitrifiable nitrogen which is only 5.8 lbs./acre in B horizons as compared to 21.0 to 38.4 lbs./acre in the latter group. The average phosphorus content of B horizons is remarkably high in comparison with that of all other backslope materials. Another high value occurs in the form of exchangeable hydrogen (5.3 me.) which is only second to that in acid shales (8.5 me.). Base saturation percentage and pH are, consequently, exceptionally low and follow the similar relationships.

Buried A_2 horizons. These buried soils have been formed in till either under grass or forest vegetation. This light-colored material (yellowish brown to pale olive and with occasional light gray fine mottling) has a wide range in texture from silt loam via loam to sandy clay loam. Similarities between A_2 horizons and till material, from which they may in part be derived, may be observed from the frequency distribution of the samples. Notable deviations occur in aggregation, moisture equivalent and available water (M. E. - W. P.). The nature of A_2 material warrants comparison with average values of leached till zones. Aggregation appears to be far less and volume weight is somewhat higher in the case of A_2 material. Wilting point and moisture equivalent are indeed lower but the difference between these two values yields an amount of available water which is almost equal to that in oxidized leached till. Porosity data are slightly lower too. Average data for nitrogen and potassium indicate the extremely leached and chemically poor character of these A_2 materials. Nitrifiable nitrogen content in A_2 horizons is 4.3 lbs./acre as compared to 29.6 lbs./acre in oxidized and leached till. Available potassium is likewise decreased from 257 lbs./acre to 119 lbs./acre. Compared with leached till, there is a larger difference in cation exchange capacities (from 17.2 me. for leached till to 12.0 me. for A_2 materials) than in exchangeable hydrogen (from 1.8 me. to 2.0 me. respectively) resulting in a lower percent base saturation for A_2 material.

Ferretto zones. Both ferretto zones and gumbotil are highly weathered zones of maximum clay accumulation comparable with B horizons in modern soil profiles. The difference between ferretto zones and gumbotil seems to be caused by prevailing drainage conditions and vegetation at the time of formation.

Ferretto zones included in this survey have materials of clay loam texture, which often times grade into the more sandy loam and loam classes. Their colors vary from brownish yellow and yellowish brown to strong brown, mostly variegated with red and yellow red. They are somewhat richer in clay than the till material from which they are derived. Consequently, they have a higher than average wilting point and moisture equivalent but are like till in total water availability (M. E. - W. P.). Most (75%) of the ferretto samples have an aeration porosity lower than 8.6 percent and a high capillary porosity. This again is in apparent correlation with their high clay content. Compared with ordinary oxidized and leached till (Table 2) ferretto materials appear to have a lower value for water stable aggregates (.380 mm. versus .633 mm. in leached till) which in this instance might be related to a higher degree of weathering. A similar relationship of decreased aggregation with degree of weathering was noted among the various weathering groups of till.

Average values for nitrogen and phosphorus are even lower than those for A_2 materials, and are, as a matter of fact, lower than in any other backslope material with the exception of shales.

Cation exchange capacity is approximately 25 percent higher than in oxidized and leached till, but is almost the same as in the deoxidized and leached till.

Gumbotil. Material belonging to this group is generally of distinct clayey texture. The color is light brownish gray or light olive, variegated in different degrees with yellow, yellowish brown, strong brown or yellow red. It may easily be distinguished from ferretto material by its color and texture. Its clay content is considerably higher than that of ordinary de-oxidized leached till, with which it may be compared and is, in fact, maximal in comparison with any other backslope material (with the exception of the two non-acid shale samples). Ninety percent of the sampled gumbotils had clay contents higher than 36.9 percent, while the average clay content was 48.2 percent.

Volume weight (1.37 gr./cc.) is about 10 percent less than that of any of the other till materials including ferretto. This may be attributed to its high capillary porosity. Aeration porosity is as low as that of ferretto material. Aggregation is between that for ferretto and de-oxidized and leached till. Wilting point, moisture equivalent and maximum water availability are higher than for any other material found on backslopes. The average value for wilting point is 21.2 percent and for moisture equivalent, 37.5 percent. As in all problem materials, nitrifiable nitrogen is low. Available potassium is very high for till-derived material and cation exchange capactiy (average of 25.8 me.) appears to be again a maximum value. Both high values may be explained by the high content of, presumably, highly weathered clay material.

Sand material. This group contains rather heterogeneous material (as has been noted before), but due to the distinct textural feature of very high sand, associated with low clay and silt contents, it is interesting to observe possible simultaneous changes in various soil properties. The following close correlation with texture may be observed: A high average volume weight of 1.60, a value which was found only in buried A_2 material; extremely low averages for wilting point (3.1%), moisture equivalent (7.2%), M. E. - W. P. (4.1%), capillary porosity (18.1%) and total porosity (35.7%); and a simultaneous maximum average value for aeration porosity (17.6%). None of these values is equalled by those in other soil materials except for total porosity which is minimal in the case of A_2 material (32.4%). The contents of initial and nitrifiable nitrogen are remarkably high--as a matter of fact, maximal--while available potassium is second lowest, with

139 lbs./acre, after that in A_2 material, with 119 lbs./acre. The cation exchange capacity is, according to expectations, quite low (6.3 me.).

The color of these sand materials is predominantly light olive brown indicating the presence of some organic matter, which, in its turn, accounts for the high figures for nitrogen.

Shale. A few of the prominent features of this material will be discussed here even though only two samples of each kind, acid and non-acid shale, were obtained.

The acid shale material is gray brown or yellowish brown and of clay loam texture. In physical characteristics it is much like till. The distinct feature is, of course, its acidity recognizable by low pH (4.6), high exchangeable hydrogen (8.5 me.) and low base saturation (36%). Vegetation is obviously limited due to this high acidity which may be toxic to the plants. The high phosphorus content (7.8 lbs./acre) is curious.

The two samples of the non-acid material were dark gray-brown and olive respectively. Both had a clay texture with an average maximal amount of clay of 55.8%. The usual properties of water percentages and porosity are again correlated with this high clay content.

From the above discussion on soil materials it is quite obvious that many of the measured soil properties are intercorrelated. It appears that many of these correlations are caused primarily by association with specific textural features. These again appear to be largely determined by the way in which deposition of the material occurred (in the case of loess materials) or by the degree of weathering to which the material has been subjected.

Greenhouse Experiments

HG 01. The effect of addition of fertilizers and soil conditioners to four different backslope soil materials on plant growth thereon. The four soil materials used in this experiment were: gumbotil, oxidized Kansan till, calcareous loess and aeolian sand. Plant growth was measured with sudangrass as indicator crop. Details and final results of this experiment appeared in the first progress report (reference a: pp. 9-19).

A statistical analysis of the results is given in Tables 5 to 8. Fertilizer and conditioner treatments, singly and in combination, resulted in highly significant increases in plant growth on all soils, except on Kansan till. On this material conditioner treatments failed to improve plant growth, probably because of the coarse and loose pseudo-aggregated structure of this soil material even without treatment with soil conditioners.

On gumbotil all fertilizer treatments including nitrogen appear to increase plant growth significantly; and if in combination with phosphate, yields of plant tops are roughly four times as high as those of the nitrogen treatment alone.

Similar results are obtained on aeolian sand: nitrogen and phosphate in combination give yields which are double of those of the nitrogen treatment alone.

Plant growth on Kansan till is especially helped by the addition of nitrogen and phosphate in combination. Nitrogen alone fails to give an appreciable increase here.

Yields on calcareous loess are doubled by an addition of phosphate alone, but are again tremendously increased by an application of nitrogen and phosphate together. Nitrogen alone has apparently no effect.

Except in the case of gumbotil, which already has a high K-content, addition of potash to the N + P fertilizer appears to increase somewhat the effect on plant growth.

All conditioner treatments increased yields on gumbotil, but the increase was significant only in the case of the F2 conditioner (a latex preparation).

Resin powder, used as soil conditioner, gave marked increases in plant growth on both the loose textured materials, loess and sand.

All other conditioners improved growth on sand, but none of the conditioners had any appreciably effect on Kansan till.

Interaction between fertilizers and soil conditioners were significantly present on all soils except on Kansan till again. Individual data (see reference a: pp. 14-17) show that combination of fertilizers and conditioners are especially successful where the right fertilizer mixture has been used (see above discussion on fertilizer effects).

Root growth (see reference a: pp. 10, 14-18) showed in most cases relative increases due to fertilizer and/ or soil conditioner treatments in a similar fashion as top growth. Percentage wise, however, increments in root growth were half as large as those in top growth.

HG 02. The effect of fertilizer--NP and NPK--additions to gumbotil and oxidized Kansan till on plant growth thereon. Details and results of this experiment have previously been reported in reference a: pp. 19-22. Two indicator plants were used: sudangrass and rice.*

Both wet and dry weights of plant tops were recorded. Wet weights seem to give a better measure of plant growth, as it includes the water taken up by the plant under actual growing conditions.

An analysis of variance plus summary of averages of plant weights (sudangrass) on gumbotil is presented in Table 9.

The analysis shows that nitrogen alone has a definite effect on plant growth, which appears to be increased when phosphate is added to the nitrogen. Phosphate additions alone increase vegetative growth too; the effect is, however, not significant.**

In general, it may be concluded that increasing phosphate applications did not improve plant growth at a low nitrogen level (N_1). At higher nitrogen levels (N_2 & N_3, 200 and 300 lbs. N/A resp.),

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*In view of the anomalous behavior of rice in this experiment, we will exclude the results obtained with this indicator plant from the discussion.

**In this series of experiments variation between individual pots was so large that, together with the small number of repetitions (2), it was virtually impossible to obtain differences which were statistically significant.

however, increased phosphate applications result in successive increments in growth. The highest level of combined nitrogen and phosphate (N_3P_3 = 300 lbs. N/A + 300 lbs. P_2O_5/A) more than doubled plant growth in comparison with the N_1P_1 treatment.

A second part of the same experiment involved oxidized Kansan till. An analysis of a part of these data is given in Tables 10a and 10b.

Even though the analysis indicates significant effects, there are few significant differences between individual treatments or levels, due to the relatively large variance and standard deviation.

An increase in nitrogen levels alone decreases plant yields instead of increasing them. Increased phosphate applications, however, result in large increments in plant growth.

Interaction between nitrogen and phosphate is such that, in combination with higher phosphate applications, increased nitrogen levels eventually have a positive effect on plant growth. From this it would appear that the right balanced combination of nitrogen and phosphate is of the utmost importance in the case of Kansan till.

Similar conclusions may be drawn from Table 10b where successive increases of the NP level result in yield increments from 21% to 134%. A relatively low application of potash (K_1 = 100 lbs. K_2O/A) improved plant growth slightly to moderately at each of the different NP levels.

HG 03. The effect of fertilizers and soil conditioner on the growth of sudangrass on four subsoils and one topsoil. The four backslope materials in this experiment were: 1) unoxidized till, 2) gumbotil, 3) ferretto and 4) buried A_2. Plant growth on these (poor) subsoils was compared with that on a relatively fertile Tama topsoil.

Treatments were chosen on the basis of the results of the two previous greenhouse experiments: HG 01 and HG 02, and on the chemical analysis of each soil material separately.

Chemical Analysis of Soil Materials
Used in Experiment HG 03 & HG 04

Soil material	pH	exch. H me/100 gr.	C.E.C. me/100 gr.	init N (lbs/A)	avail P (lbs/A)	avail K (lbs/A)	moist equiv. (%)
Unoxidized Till	7.4	0.00	2.1	3	<1	208	13.0
Gumbotil	7.3	3.30	26.2	6	<1	296	31.5
Ferretto	5.85	2.72	15.7	<1	<1	124	18.4
Buried A_2	5.3	3.58	8.0	3	<1	86	15.6
Tama topsoil	5.95	7.22	-	-	-	714	-

The fertilizer treatments included combinations of N_3 (300 lbs N/A), 4 levels of phosphate (100 to 400 lbs. P_2O_5/A), K (different amounts of added potash, depending on available K in soil material; maximum total amount = 300 lbs available K_2O/A) and minor nutrients (B, Mn, Zn, Cu, Mo and Fe). The conditioner employed in this experiment was powdered resin, the same as used in HG 01 (B). From a preliminary laboratory experiment, it was determined that addition of resin at the rate of 0.2% of total soil weight at moisture equivalent gave near optimum aggregation and aggregate stability.

A summary and analyses of variance of the results of this experiment are given in Tables 11-17.

A glance at Table 11 shows that the proper combination of fertilizers may boost yields on subsoils as high as 22 times those of the check treatments. Off hand, it seems that the addition of soil conditioner does not greatly improve yields, except where the fertility status is at an optimum. In that case, conditioner may sizably increase the already relatively high growth response.

It also appears that with optimum fertilizer additions, plant growth on these subsoil materials may be almost as good as on the fairly fertile, but non-fertilized, topsoil. This point especially is of importance since it proves that--apart from the disadvantage due to slope--these subsoils have the capacity to support a decent vegetation, provided that their fertility is raised to a sufficient level.

Tables 12-16 indicate the effects (and their significance) of the different fertilizers and conditioner singly or in combination on the plant growth on each of the various soil materials.

The resin effect, taken over all fertilizer treatments including nitrogen and the control treatment, is significant only in the case of buried A_2 soil material. The lack of natural aggregation of this closely-packed fine silt material explains, of course, the beneficial effect of a soil conditioner in providing a better aeration for plant growth. The average effect of resin over all combinations with N_3P_3 (N_3P_3, N_3P_3K and N_3P_3KM) is also significant on the same soil material; so are the interactions of the conditioner with several fertilizer combinations.

The only other soil material which shows some response, though non-significant, with resin is the unoxidized till. In this case, however, the effects are negative, instead of positive. The release of toxic substances from the till material may be the cause of this adverse effect.

Nitrogen alone gives no significant increase in plant growth except in the case of the topsoil. Phosphorus alone, however, has on all soils a highly significant effect, which is even increased by nitrogen on the ferretto material and topsoil. The phosphorus effect is the highest of all effects on unoxidized till and gumbotil.

Table 17 gives an estimate of the linear response of plant growth on all soil materials to five successive levels of P (each level represents an increase of 100 lbs P_2O_5/A, starting with zero).

Unoxidized till and gumbotil experience a significant linear effect, but on all soils, including these two, P has a highly significant residual or curvilinear effect. The topsoil forms a notable exception; the linear effect of P is highly significant but small (.0380), and the residual, curvilinear effect is non-significant.

The effect of potassium, averaged over the N P level, is significant but negative in the case of unoxidized till. On the other low-K soil materials, its effect is positive but not significant.

Minor elements, averaged over the $N_3P_3(K)$ level, are inconsistent in their effects on plant growth. The effect is negative on unoxidized till, ferretto and topsoil, and positive on gumbotil and buried A_2. The effect is significant in the latter case only.

The combination of nitrogen and phosphorus has already been mentioned. The combined effect is highly significant on all soil materials and is usually of the same order as, or higher than, the effect of phosphorus alone (averaged over the same N level).

The addition of potash to the NP combination gives an increased effect both on ferretto and buried A_2.

Addition of minor elements to the NP level gives a higher effect on ferretto, but this effect is lower than that of the NPK combination. Something similar happens in the case of gumbotil, where the NPM effect is higher than the NP effect, but lower than the effect of P alone. Buried A_2 is the only soil material which gives an increased response to the addition of minor elements: the NPKM combination has the highest effect of all combinations on this subsoil.

Summarizing these results, it appears that plant growth on all subsoils shows a highly significant response to the addition of a combined N and P fertilizer. The combination of 300 lbs N/A + 300 lbs P_2O_5/A seems to be very suitable. The level of phosphorus may even be raised another 100 lbs/A in the case of unoxidized till and gumbotil, in view of the linear response on these subsoils.

Addition of potash and minor elements may give an extra response on ferretto and buried A_2 material. Soil conditioner may improve the structure of buried A_2 material considerably at the higher fertility levels. This last point may be important in case an old backslope has a satisfactory vegetation, except for that zone. Simultaneous addition of conditioner and fertilizers may eliminate this "bare zone."

HG 04. The effect of fertilizers and soil conditioner on the growth of alfalfa and bromegrass on four subsoils and one topsoil. Soil materials, fertilizers and conditioner were the same in this experiment as in Experiment HG 03, with the exception that lime was added to three soils with pH lower than 6.0. A factorial design was used as much as possible, but several treatments, such as phosphorus levels and minor elements, were added in non-factorial combinations.

Tables 18-22 give the results in dry weights of plant roots and tops. Again, it may be seen that many combinations of fertilizers have a tremendous positive effect on plant growth, increasing both top and root growth. It is also evident that the ratio of alfalfa and brome vegetation can be changed or controlled by different combinations of fertilizers. The same is true for the ratio of roots to tops.

The combination of nitrogen and phosphorus gives large increases in plant growth, both alfalfa and brome, on all soil materials. Total plant growth is increased by addition of soil conditioner and other fertilizers, besides N and P, only in the case of ferretto and buried A_2. Growth of bromegrass alone is notably improved by the RN_2P_3KM treatment on unoxidized till. Addition of lime and potash to the N_2P_3 combination on buried A_2 boosts top growth of bromegrass from 8 to 24%.

The ratio of alfalfa to brome is roughly 70:30 on all soil materials, except on gumbotil where it is 45:55. Phosphorus alone, or in combination with lime or potash, increases especially alfalfa growth so that the ratio approaches 90:10. Nitrogen combinations tend to shift the ratio somewhat in favor of bromegrass. Rarely, however, is the weight of brome tops larger than that of alfalfa tops, at least with the particular seeding ratio used in this experiment.

Root growth follows top growth closely and is increased by the same favorable fertilizer combinations. Soil conditioner has a special large effect on root growth on unoxidized till and ferretto. Addition of lime, potash and minor elements to NP combinations increase root growth another 30 to 100%.

Total weight of roots is, in most cases, 60 to 70% that of tops, except on buried A_2 and Tama topsoil where root growth exceeds top growth by 20 to 30%. The ratio of roots to tops is almost doubled on unoxidized till by the addition of soil conditioner to the N_2P_3KM treatment. This effect is not seen on any of the other soil materials.

Tables 23-27 present the analyses of variance of the factorial treatments, including N and P treatments, and--some--also K and/or L treatments. Nitrogen alone has, in no case, a significant effect on alfalfa top growth as is to be expected. The effect on brome tops (and roots to a lesser extent), however, is highly significant in all cases. Phosphorus alone has a high positive effect on alfalfa and brome top and root growth on all soils. The effect on alfalfa tops is highest on unoxidized till (5.0275), on brome tops and on roots in the case of gumbotil (2.1517 and 4.7633, respectively).

The only significant effect of potash alone is on root growth in the case of ferretto, while the effect on roots on buried A_2 is even higher but non-significant (.8554 versus .7621).

Lime alone gives significant effects on buried A_2 (alfalfa tops: .7596) and Tama topsoil (alfalfa tops: -1.3525; brome tops: 1.7517; roots: -3.3958). It should be noted that the effect of liming on the topsoil is largely negative.

Of the fertilizer combinations, it is again the N_2P_3 interaction which yields the highest results on all subsoil materials, especially on brome tops and total root growth.

The only other combinations which merit attention are: N_2LK on alfalfa tops (.5692); P_3K and N_2P_3K (.7429 and .4846, respectively) on ferretto; LP_3 and P_3K on alfalfa tops on buried A_2 (.7321 and .5662, respectively); and N_2L on brome tops on the topsoil (1.1233).

The analysis of variance of phosphorus levels is given in Table 28. As in the previous experiment, unoxidized till and gumbotil are the only two subsoils which show a linear response of plant growth to successive levels of phosphorus. The effect is largest in the case of gumbotil. Curvilinear effect of P-levels is highly significant for all plant growth on ferretto and for brome on buried A_2.

The effects of minor elements and soil conditioner alone, taken over a full nutrient level, are presented in Tables 29-32. Table 33 gives the same, including the effect of and interaction with lime on topsoil. Soil conditioner fails to exert a significant effect on gumbotil but increases brome tops (and roots) apparently on all other subsoils. Only in the case of buried A_2 can one find a significant effect of minor elements on plant growth; but the effect is positive in the case of alfalfa and negative on brome, resulting in a non-significant effect on root growth.

The effects of liming the topsoil on plant growth are largely negative, except on bromegrass where both lime and soil conditioner, but not their interactions, show a high positive effect.

The results of this experiment lead, in general, to the same conclusions as in Experiment HG 03. The advantage of the present experiment is that the same plant species were used as are actually employed in backslope seeding so that these results are directly applicable to the establishment of a vegetative cover on highway backslopes.

We arrive to the following conclusions:

1. A basic fertilizer mixture of 200 lbs N/A + 300 lbs P_2O_5/A is ideal for a rapid and dense establishment of a mixed alfalfa-brome vegetation on the major subsoil materials as exposed on highway backslopes.

An additional 100 lbs P_2O_5/A may give a more luxurious plant growth; but since we are aiming at a <u>sufficient</u> vegetative cover and not at a maximum yield, the N_2P_3 combination is at least as good as the N_2P_4 combination and more economical.

2. Addition of 200 lbs K_2O/A to the basic N_2P_3 combination will increase especially root growth on ferretto and buried A_2 zones. These two zones are usually located side by side, which makes a special treatment more convenient. The heavy gully-erosion usually occurring on these materials emphasizes the importance of extra root growth.

3. Further addition of lime, minor elements and soil conditioner may give additional increases in plant growth. This seems, however, unnecessary from a practical as well as from an economic standpoint, since the vegetative cover obtained before the addition of these "extras" appears to be fully adequate.

Table 1. Occurrence and extent of highway backslopes of problematic nature

Highway Number	From:	To:	County	Classification*
1 (State)	Kalona	Washington	Washington	BC1
1 (State)	Washington	Brighton	Washington	C4
1 (State)	Fairfield	#16 (State)	Jefferson/ Van Buren	C4
2 (State)	Sidney	Shenandoah	Fremont	C4
6 (US)	Colfax	Newton	Jasper	CD4/6
6 (US)	Newton	Grinnell	Jasper	C4
14 (State)	Monroe	Red Rock	Marion	B2
14 (State)	Red Rock	Knoxville	Marion	C4
14 (State)	Knoxville	Chariton	Marion/Lucas	BCD4
14 (State)	Chariton	Corydon	Lucas/Wayne	BCD4/6
15 (State)	Eddyville	Ottumwa	Wapello	BC4/6
16 (State)	#218 (US)	Denmark	Lee	BC4
21 (State)	Deep River	What Cheer	Poweshiek/ Keokuk	BC4

*	Classification
A	level country, no cuts
B	low cuts ($<15'$)
C	medium high cuts (15' - 30')
D	high cuts ($>30'$)
E	vertical cuts
1	graded, no vegetation
2	just seeded
3	new vegetation, poor take, bare zones
4	old vegetation, poor take, bare zones
5	new vegetation, fair
6	old vegetation, fair
7	new vegetation, good
8	old vegetation, good

Table 1. (Continued). Occurrence and extent of highway backslopes of problematic nature

Highway Number	From:	To:	County	Classification*
25 (State)	#6 (US)	Greenfield	Adair	CD4
25 (State)	Greenfield	Creston	Adair/Union	CD4/6
31 (State)	Quimby	Washta	Cherokee	D1
34 (US)	10 mi. W. of Albia	Albia	Monroe	D4
34 (US)	Ottumwa	Batavia	Wapello	CD2
34 (US)	Lockridge	Mt. Pleasant	Henry	C4
34 (US)	Mt. Pleasant	Danville	Henry/ Des Moines	s C4/6
37 (State)	Soldier	Dunlap	Monona/ Crawford	CD1/2
59 (US)	Cherokee	Holstein	Cherokee/Ida	C4
61 (US)	Wapello	Mediapolis	Louisa/ Des Moines	CD4/8
65 (US)	Lucas	#306 (State)	Lucas	CD2
69 (US)	Leon	Lamoni	Decatur	CD3
78 (State)	Brighton	Olds	Washington/ Henry	C2/6
78 (State)	Winfield	Morning Sun	Henry/Louisa	C2
89 (State)	Madrid	Woodward	Boone	CD4
90 (State)	Dexter	W. Des Moines	Dallas/Polk	CD1/2
92 (State)	Council Bluffs	12 mi. E. of Council Bluffs	Pottawattamie	E4
92 (State)	#189 (State)	Greenfield	Adair	CD4/6
92 (State)	Oskaloosa	#21 (State)	Mahaska/ Keokuk	CD4/8
137 (State)	Oskaloosa	Eddyville	Mahaska	C4
141 (State)	Sioux City	Mapleton	Woodbury	E4
141 (State)	Coon Rapids	#25 (State)	Carroll/ Greene	CD4/6
141 (State)	Bagley	Perry	Guthrie/ Dallas	B4/6
148 (State)	#95 (State)	Corning	Adams	C4
148 (State)	Bedford	Missouri State	Taylor	C4/6
169 (US)	#141 (State)	Adel	Dallas	C4/6
169 (US)	#90 (State)	Winterset	Madison	CD4/6
169 (US)	Winterset	Lorimor	Madison	B4/6/8
169 (US)	Mt. Ayr	Missouri State	Ringgold	CD1/3
183 (State)	Ute	Soldier	Monona	D1
212 (State)	#21 (State)	Marengo	Iowa	C3
268 (State)	#59 (US)	Irwin	Shelby	CD4
273 (State)	Drakesville	#63 (US)	Davis	C4

Table 2. Average values of plant yields and 20 soil factors in four weathering zones in till material

	U.U.T.[a] (17)[b]	O.U.T. (20)	O.L.T. (17)	D.L.T. (5)
Yield (gm./plot)	1(4)- 92(13)	43.0	38.3	36.6
Sand (%)	38.3	43.0	38.3	36.6
Silt (%)	32.4	28.8	31.8	28.2
Clay (%)	29.2	28.2	29.9	35.2
Mean aggr. diam. (mm.)	.817	.927	.633	.486
Vol. wt. (gm./cc.)	1.50	1.56	1.51	1.53
Wilting point (%)	11.0	10.1	12.7	14.4
Moist. equiv. (%)	20.7	20.5	22.7	21.1
M. E. - W. P. [c](%)	9.7	10.4	10.0	6.7
Total porosity (%)	39.6	39.0	38.2	41.6
Aeration porosity (%)	8.9	10.0	8.5	4.5
Capillary porosity (%)	30.7	29.0	29.7	37.1
pH	7.9	8.0	7.1	6.8
Initial N (lbs./A.)	3.4	4.5	4.2	3.0
Nitrif. N (lbs./A.)	22.4	28.2	29.6	24.0
Avail. P (lbs./A.)	0.9	0.7	1.5	0.6
Avail. K (lbs./A.)	299	243	257	246
Cation exch. cap. (me.)	12.1	13.6	17.2	20.0
Exchangeable H (me.)	0.0	0.0	1.8	2.4
Total exch. bases (me.)	12.1	13.6	15.4	17.6
Base saturation (%)	100	100	89	88

[a] U.U.T. = unoxidized and unleached till
O.U.T. = oxidized and unleached till
O.L.T. = oxidized and leached till
D.L.T. = deoxidized and leached till

[b] Figures in parentheses refer to number of samples of which average values were obtained.

[c] Available water measured as difference of moisture equivalent and wilting point.

Table 3. Average values of plant yields and 20 soil factors for two weathering zones in loess material in different regions of deposition

	Oxidized and unleached loess		Oxidized and leached loess		
	W[a]	E	W	C	E
	(6)[b]	(7)	(4)	(5)	(14)
Yields (gm./plot)	104	165	39	158	121
Sand (%)	18.7	16.3	12.9	15.2	12.4
Silt (%)	69.9	68.2	63.2	61.9	59.3
Clay (%)	11.4	15.5	23.9	22.9	28.3
Mean aggr. diam. (mm.)	.036	.019	.367	.444	.398
Vol. wt. (gm./cc.)	1.27	1.34	1.28	1.31	1.34
Wilt. point (%)	9.0	8.9	16.2	12.0	13.9
Moist. equiv. (%)	21.0	22.7	25.8	27.9	26.5
M. E. - W. P.[c] (%)	12.0	13.8	9.6	15.9	12.6
Total porosity (%)	51.3	50.1	53.8	50.5	44.4
Aeration porosity (%)	10.8	11.6	13.6	11.7	9.5
Capillary porosity (%)	40.5	38.5	40.2	38.8	34.9
pH	8.2	8.2	6.8	7.0	6.7
Initial N (lbs./A.)	3.5	2.6	3.8	5.4	3.8
Nitrif. N (lbs./A.)	24.0	14.0	21.0	21.0	24.9
Avail. P (lbs./A.)	1.2	3.1	3.8	6.4	5.5
Avail. K (lbs./A.)	338	188	327	298	241
Cation exch. cap.(me.)	16.6	15.1	21.5	18.6	20.2
Exchangeable H (me.)	0.0	0.0	3.1	2.7	2.7
Total exch. bases(me.)	16.6	15.1	18.4	15.9	17.5
Base saturation (%)	100	100	86	85	87

[a] W = region west of Highway 71.
C = region including backslope numbers 10, 14, 15, 16, 17 and 18.
E = region including all backslopes east of Highway 69.

[b] Figures in parentheses refer to number of samples of which average values were obtained.

[c] Available water measured as difference of moisture equivalent and wilting point.

Table 4. Average values of plant yields and 20 soil factors for six backslope materials

	B hor.	Buried	Ferretto	Gumbo-	Sand	Shale	
		A_2 hor.	zone	til	material	acid	alk.
	(10)[a]	(10)	(14)	(16)	(7)	(2)	(2)
Yields (gm./plot)	17	12	8	9	52	4	37
Sand (%)	11.0	35.9	42.2	20.6	77.1	35.4	9.0
Silt (%)	53.2	40.8	22.5	31.2	17.0	32.7	35.2
Clay (%)	35.8	23.3	35.3	48.2	5.9	31.9	55.8
Mean aggr. diam. (mm.)	.349	.201	.380	.426	.211	.318	.216
Vol. wt. (gm./cc.)	1.32	1.60	1.51	1.37	1.60	1.52	1.39
Wilt. point (%)	16.3	7.7	15.9	21.2	3.1	11.5	15.5
Moist. equiv. (%)	29.6	19.3	27.2	37.5	7.2	21.4	25.9
M. E. - W. P.[b] (%)	13.3	11.6	11.3	16.3	4.1	9.9	10.4
Total porosity (%)	50.9	32.4	42.8	55.4	35.7	40.2	49.9
Aeration porosity (%)	10.6	7.0	5.7	5.8	17.6	9.0	8.3
Capillary porosity (%)	40.3	25.4	37.1	49.6	18.1	31.2	41.6
pH	6.0	6.8	7.1	7.1	8.14	4.6	8.1
Initial N (lbs./A.)	2.8	3.0	2.6	2.9	5.6	1.8	0.5
Nitrif. N (lbs./A.)	5.8	4.3	2.7	3.2	39.0	1.8	6.0
Avail. P (lbs./A.)	9.8	0.6	0.5	0.5	2.1	7.8	0.5
Avail. K (lbs./A.)	280	119	209	296	139	240	172
Cation exch. cap. (me.)	23.0	12.0	21.3	25.8	6.3	13.4	16.0
Exchangeable H (me.)	5.3	2.0	1.9	2.6	0.2	8.5	0.0
Total exch. bases (me.)	17.7	10.0	19.4	23.2	6.1	4.9	16.0
Base saturation (%)	77	83	91	90	97	36	100

[a] Figures in parentheses refer to number of samples of which average values were obtained.

[b] Available water measured as difference of moisture equivalent and wilting point.

Table 5. Analysis of Variance of Plant Weights (tops only) in Fertilizer-Soil Conditioner Experiment on Gumbotil

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	d.f.	m.s.	Significance
Fertilizer treatments	7	665.4934	**
Conditioner treatments	4	2.3239	**
F x C interaction	28	2.1471	**
Replicates	1	.0088	
Error	39	.3538	
Total	79		

	P = .05	P = .01
LSD fertilizer treatments	1.076	1.441
LSD conditioner treatments	.854	1.143
LSD F x C treatments	2.407	3.222

Fertilizer treatments

		NP	NPK	N	NK	P	C	PK	K
NP	(19.22)	-							
NPK	(18.95)	-	-						
N	(4.00)	**	**	-					
NK	(3.72)	**	**	-	-				
P	(.69)	**	**	**	**	-			
C	(.66)	**	**	**	**	-	-		
PK	(.65)	**	**	**	**	-	-	-	
K	(.63)	**	**	**	**	-	-	-	-

Conditioner treatments

		F2	R	Fl	Kr	C
F2	(6.55)	-				
R	(6.16)	-	-			
Fl	(6.13)	-	-	-		
Kr	(5.98)	-	-	-	-	
C	(5.50)	*	-	-	-	-

Table 6. Analysis of Variance of Plant Weights (tops only) in Fertilizer-Soil Conditioner Experiment on Kansan Till

	d.f.	m.s.	significance
Fertilizer treatments	7	107.9141	**
Conditioner treatments	4	.4199	NS
F x C interaction	28	.3724	NS
Replicates	1	2.8350	
Error	39	.8249	
Total	79		

	P = .05	P = .01
LSD fertilizer treatments	1.643	2.199

Fertilizer treatments

		NPK	NP	N	NK	P	PK	C	K
NPK	(8.54)	-							
NP	(6.70)	*	-						
N	(.80)	**	**	-					
NK	(.73)	**	**	-	-				
P	(.59)	**	**	-	-	-			
PK	(.52)	**	**	-	-	-	-		
C	(.52)	**	**	-	-	-	-	-	
K	(.48)	**	**	-	-	-	-	-	-

Conditioner treatments

Kr	(2.50)	)	
R	(2.50)	)	
F1	(2.42)	)	no significant differences
F2	(2.25)	)	
C	(2.14)	)	

Table 7. Analysis of Variance of Plant Weights (tops only) in Fertilizer-Soil Conditioner Experiment on Calcareous Loess

	d.f.	m.s.	significance
Fertilizer treatments	7	215.9796	**
Conditioner treatments	4	2.8314	**
F x C interaction	28	1.8575	**
Replicates	1	.0103	
Error	39	.2166	
Total	79		

	P = .05	P = .01
LSD fertilizer treatments	.842	1.126
LSD conditioner treatments	.665	.890
LSD F x C treatments	1.883	2.520

Fertilizer treatments

		NPK	NP	P	PK	C	K	NK	N
NPK	(11.47)	-							
NP	(10.75)	-	-						
P	(1.79)	**	**	-					
PK	(1.61)	**	**	-	-				
C	(.96)	**	**	(*)	-	-			
K	(.87)	**	**	*	-	-	-		
NK	(.75)	**	**	*	*	-	-	-	
N	(.73)	**	**	*	*	-	-	-	-

Conditioner treatments

		R	Kr	C	F1	F2
R	(4.23)	-				
Kr	(3.88)	-	-			
C	(3.35)	*	-	-		
F1	(3.32)	**	-	-	-	
F2	(3.30)	**	-	-	-	-

Table 8. Analysis of Variance of Plant Weights (tops only) in Fertilizer-Soil Conditioner Experiment on Aeolian Sand

	d.f.	m.s.	significance
Fertilizer treatments	7	266.8380	**
Conditioner treatments	4	11.1763	**
F x C interaction	28	2.7327	**
Replicates	1	.6408	
Error	39	.2030	
Total	79		

	P = .05	P = .01
LSD fertilizer treatments	.815	1.091
LSD conditioner treatments	.644	.862
LSD F x C treatments	1.823	2.440

Fertilizer treatments

		NPK	NP	NK	N	K	PK	P	C
NPK	(13.49)	-							
NP	(11.10)	**	-						
NK	(7.37)	**	**	-					
N	(6.55)	**	**	*	-				
K	(.84)	**	**	**	**	-			
PK	(.83)	**	**	**	**	-	-		
P	(.81)	**	**	**	**	-	-	-	
C	(.80)	**	**	**	**	-	-	-	-

Conditioner treatments

		R	Kr	F2	F1	C
R	(6.19)	-				
Kr	(5.87)	-	-			
F2	(5.17)	**	*	-		
F1	(4.78)	**	**	-	-	
C	(4.11)	**	**	**	*	-

Table 9. Analysis of Variance of Average Weights of Plant Tops on Gumbotil

	d.f.	m.s.	significance
Treatments	5	109.9028	NS
N levels	1	409.5008	*
P levels	2	44.8108	NS
NP levels	2	25.1958	NS
Error	6	66.0491	
Total	11		

	P = .05	P = .01
LSD N levels	22.961	34.784

Treatments		
N_3P_3	(55.95)[a]	no significant differences
N_2P_3	(44.75)	
N_2P_2	(38.10)	
N_2P_1	(33.05)	
N_1P_3	(27.80)	
N_1P_2	(26.90)	
N_1P_1	(26.15)	

ave N_2 levels	(38.63)	no significant differences
ave N_1 levels	(26.95)	

ave P_3 levels	(36.28)	no significant differences
ave P_2 levels	(32.50)	
ave P_1 levels	(29.60)	

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[a] not included in A. O. V.

Table 10a. Analysis of Variance of Average Weights of Plant Tops on Kansan Till-- NP Treatments

	d.f.	m.s.	significance
Treatments	8	100.1206	**
N levels	2	56.7372	*
P levels	2	236.8822	**
NP interaction	4	53.4314	*
Error	9	10.3361	
Total	17		

	P = .05	P = .01
LSD individual treatments	14.544	20.897
LSD N or P treatments	8.396	12.063

Treatments	N_2P_3	N_1P_3	N_1P_2	N_3P_2	N_3P_3	N_1P_1	N_2P_2	N_2P_1	N_3P_1
N_2P_3 (25.85)[a]	-								
N_4P_4 (22.60)									
N_1P_3 (22.05)	-	-							
N_1P_2 (17.70)	-	-	-						
N_3P_2 (16.65)	-	-	-	-					
N_3P_3 (13.85)	-	-	-	-	-				
N_1P_1 (12.35)	-	-	-	-	-	-			
N_2P_2 (8.75)	*	-	-	-	-	-	-		
N_2P_1 (8.40)	*	-	-	-	-	-	-	-	
N_3P_1 (3.30)	**	*	(*)	-	-	-	-	-	-

ave N_1 levels (17.37))
ave N_2 levels (14.33)) no significant differences
ave N_3 levels (11.22))

	P_3	P_2	P_1
ave P_3 levels (20.58)	-		
ave P_2 levels (14.32)	-	-	
ave P_1 levels (8.02)	**	-	-

---

[a] not included in A. O. V.

Table 10b. Analysis of Variance of Average Weights of Plant Tops on Kansan Till-- NP vs. NPK Treatments

	d.f.	m.s.	significance
Treatments	7	91.3120	*
(NP) levels	3	172.4440	*
K levels	1	34.5156	NS
(NP)K interaction	3	29.1123	NS
Error	8	24.4269	
Total	15		

	P = .05	P = .01
LSD individual treatments	22.794	33.163
LSD (NP) levels	16.118	23.450

Treatments		
$N_4P_4K_1$	(28.45)	no significant differences
$N_4P_4K_0$	(22.60)	
$N_2P_2K_1$	(17.65)	
$N_3P_3K_0$	(13.85)	
$N_3P_3K_1$	(13.75)	
$N_1P_1K_0$	(12.35)	
$N_1P_1K_1$	(9.45)	
$N_2P_2K_0$	(8.75)	

ave N_4P_4 level	(25.52)	no significant differences
ave N_3P_3 level	(13.80)	
ave N_2P_2 level	(13.20)	
ave N_1P_1 level	(10.90)	
ave K_0 level	(14.39)	no significant differences
ave K_1 level	(17.35)	

Table 11. Average Plant Weights (tops) of Sudangrass Grown on Four Subsoils and One Topsoil, as Affected by Fertilizer and Soil-conditioner Treatments

Treatment	Unoxidized Till	Gumbo	Ferretto	Buried A_2	Topsoil
0[a]	0.62[b]	0.55	0.46	0.61	11.77
N3	0.49	0.40	0.46	0.63	16.23
N3P1	2.30	2.69	5.46	6.07	17.33
N3P2	3.18	6.45	5.91	7.42	18.10
N3P3	6.10	8.39	9.47	7.37	21.94
N3P4	6.58	10.51	8.27	6.34	21.61
N3P3K	4.38	-	10.26	9.48	-
N3P3(K)M	3.27	8.07	9.17	10.34	20.44
R	0.39	0.42	0.40	0.62	10.69
RN3	0.39	0.42	0.48	0.55	14.77
RN3P3	5.72	9.79	9.82	11.99	27.76
RN3P3K	4.08	-	12.80	12.83	-
RN3P3(K)M	4.97	10.90	11.86	16.29	24.68

[a] 0 = check

N_3 = 300 lbs N/A

P_a = a x 100 lbs P_2O_5/A

K = x lbs K_2O/A, so that x + available K_2O = 300 lbs K_2O/A

M = minor nutrient solution

R = soil conditioner (resin)

[b] grams dry weight/3 pots, multiply with 500 to obtain readings in lbs/A, or divide by 4 to convert to tons/A

Table 12. Analysis of Variance of Plant Weights on Unoxidized Till

	source	d.f.	m.s.	F[a]	effect[b]
	Treatments	12	.669741	47.534**	
	Replicates	2			
	Error	22	.014089		
	Total	36			
R-effect	Fertilizer (0,N_3,N_3P_3,N_3P_3K,N_3P_3KM)	4	1.820911	129.238**	
	Resin (+,-)	1	.008343		-.033352
	F x R	4	.030858	2.190	
N-effect	Fertilizer (0,N_3)	1	.009134		-.055180
	Resin (+,-)	1	.061596	4.371*	-.143290
	F x R	1	.011362		.061543
P-effect	Fertilizer (N_3,N_3P_3)	1	3.879842	275.380**	1.137225
	Resin (+,-)	1	.008927		-.054552
	F x R	1	.002218		.027195
K-effect	Fertilizer (N_3P_3,N_3P_3K)	1	.081442	5.780*	-.164765
	Resin (+,-)	1	.003814		-.035658
	F x R	1	.000206		-.008302

Table 12. (continued). Analysis of Variance of Plant Weights on Unoxidized Till

	source	d.f.	m.s.	F[a]	effect[b]
M-effect	Fertilizer (N_3P_3K,N_3P_3KM)	1	.000172		-.007573
	Resin (+,-)	1	.016244	1.152	.073586
	F x R	1	.041451	2.942	.117546
NP-effect	Fertilizer (0,N_3P_3)	1	3.512464	249.305**	1.082045
	Resin (+,-)	1	.040434	2.869	-.116095
	F x R	1	.023623	1.676	.088738
N_3P_3K-effect	Fertilizer (0,N_3P_3K)	1	2.524207	179.161**	.917280
	Resin (+,-)	1	.046423	3.294	-.124397
	F x R	1	.019410	1.377	.080437
N_3P_3KM-effect	Fertilizer (0,N_3P_3KM)	1	2.482700	176.215**	.909707
	Resin (+,-)	1	.000140		-.006850
	F x R	1	.117591	8.346**	.197983

[a] $F_{\frac{1}{22}}$ = 4.30 (P.05), 7.94 (P.01)

[b] Effect is expressed in figures after transformation ($x_{ij} = 1 + \log y_{ij}$)

Table 13. Analysis of Variance of Plant Weights on Gumbotil

	source	d.f.	m.s.	F^{a}	effect^{b}
	Treatments	10	1.215463	103.374**	
	Replicates	2			
	Error	20	.011757		
	Total	32			
R-effect	Fertilizer (O,N_3,N_3P_3,N_3P_3M)	3	3.427516	291.508**	
	Resin (+,-)	1	.002518		.020486
	F x R	3	.016532	1.406	
N-effect	Fertilizer (O,N_3)	1	.019615	1.668	-.080860
	Resin (+,-)	1	.008849		-.054313
	F x R	1	.009544		.056403
P-effect	Fertilizer (N_3,N_3P_3)	1	5.327324	453.119**	1.332582
	Resin (+,-)	1	.001942		.025445
	F x R	1	.001636		.023355
M-effect	Fertilizer (N_3P_3,N_3P_3M)	1	.002776		.030417
	Resin (+,-)	1	.027238	2.316	.095285
	F x R	1	.006482		.046485

Table 13. (Continued). Analysis of Variance of Plant Weights on Gumbotil

	source	d.f.	m.s.	F[a]	effect[b]
NP-effect	Fertilizer (0,N_3P_3)	1	4.700424	399.797**	1.251722
	Resin (+,-)	1	.002875		-.030958
	F x R	1	.019084	1.623	.079758
NPM-effect	Fertilizer (0, N_3P_3M)	1	4.936443	419.872**	1.282763
	Resin (+,-)	1	.000723		.015527
	F x R	1	.047812	4.066	.126243

[a] $F_{\frac{1}{20}}$ = 4.35 (P.05), 8.10 (P.01)

[b] Effect is expressed in figures after transformation ($x_{ij} = 1 + \log y_{ij}$)

Table 14. Analysis of Variance of Plant Weights on Ferretto

	source	d.f.	m.s.	F[a]	effect[b]
	Treatments	12	1.175391	103.475**	
	Replicates	2			
	Error	24	.011359		
	Total	38			
R-effect	Fertilizer (O,N3,N_3P_3,N_3P_3K,N_3P_3KM)	4	3.349499	294.872**	
	Resin (+,-)	1	.007388		.032431
	F x R	4	.006774		
N-effect	Fertilizer (O,N3)	1	.004814		.040060
	Resin (+,-)	1	.001461		-.022073
	F x R	1	.005350		.042233
P-effect	Fertilizer (N3,N3P3)	1	5.120050	450.748**	.651515
	Resin (+,-)	1	.000844		.016788
	F x R	1	.000034		-.003372
K-effect	Fertilizer (N_3P_3,N_3P_3K)	1	.018523	1.630	.078577
	Resin (+,-)	1	.009094		.055057
	F x R	1	.005202		.041640

Table 14. (Continued). Analysis of Variance of Plant Weights on Ferretto

	source	d.f.	m.s.	F[a]	effect[b]
M-effect	Fertilizer (N_3P_3K, N_3P_3KM)	1	.006822		-.047686
	Resin (+,-)	1	.027904	2.456	.096443
	F x R	1	.0000002		-.000253
NP-effect	Fertilizer $(0, N_3P_3)$	1	5.438880	478.816**	1.346462
	Resin (+,-)	1	.001942		-.025445
	F x R	1	.004530		.038862
NPK-effect	Fertilizer $(0, N_3P_3K)$	1	6.092200	536.332**	1.425038
	Resin (+,-)	1	.000787		.016195
	F x R	1	.019442	1.711	.080502
NPKM-effect	Fertilizer $(0, N_3P_3KM)$	1	5.691296	501.038**	1.377352
	Resin (+,-)	1	.000762		.015942
	F x R	1	.019319	1.700	.080248

[a] $F \frac{1}{24} = 4.26$ (P.05), 7.82 (P.01)

[b] Effect is expressed in figures after transformation $(x_{ij} = 1 + \log y_{ij})$

Table 15. Analysis of Variance of Plant Weights on Buried A_2

	source	d.f.	m.s.	F^a	$effect^b$
	Treatments	12	1.017229	258.339**	
	Replicates	2			
	Error	24	.003937		
	Total	38			
	Fertilizer ($0, N_3, N_3P_3, N_3P_3K, N_3P_3KM$)	4	2.875112	730.174**	
R-effect	Resin (+,-)	1	.066476	16.882**	.094146
	F x R	4	.020960	5.323*	
	Fertilizer ($0, N_3$)	1	.001386		-.021495
N-effect	Resin (+,-)	1	.002266		-.027485
	F x R	1	.003141		-.032358
	Fertilizer (N_3, N_3P_3)	1	4.337925	1101.835**	1.202487
P-effect	Resin (+,-)	1	.016375	4.159	.073880
	F x R	1	.053645	13.625**	.133723
	Fertilizer (N_3P_3, N_3P_3K)	1	.012109	3.075	.063532
K-effect	Resin (+,-)	1	.080922	20.554**	.164238
	F x R	1	.005642	1.433	-.043365

Table 15. (Continued). Analysis of Variance of Plant Weights on Buried A_2

	source	d.f.	m.s.	F[a]	effect[b]
M-effect	Fertilizer (N_3P_3K,N_3P_3KM)	1	.018683	4.745*	.078915
	Resin (+,-)	1	.075889	19.275**	.159048
	F x R	1	.004372	1.110	.038175
NP-effect	Fertilizer (0,N_3P_3)	1	4.184226	1062.795**	1.180992
	Resin (+,-)	1	.033859	8.600**	.106238
	F x R	1	.030824	7.829*	.101365
NPK-effect	Fertilizer (0,N_3P_3K)	1	4.646512	1180.216**	1.244523
	Resin (+,-)	1	.011859	3.012	.062873
	F x R	1	.009408	2.389	.056000
NPKM-effect	Fertilizer (0,N_3P_3KM)	1	5.254464	1334.636**	1.323438
	Resin (+,-)	1	.030632	7.780*	.101048
	F x R	1	.027749	7.048*	.096175

[a] $F_{\frac{1}{20}}$ = 4.35 (P.05), 8.10 (P.01)

[b] Effect is expressed in figures after transformation ($x_{ij} = 1 + \log y_{ij}$)

Table 16. Analysis of Variance of Plant Weights on Tama Topsoil

	Source	d.f.	m.s.	F[a]	effect[b]
	Treatments	10	.050082	6.108**	
	Replicates	2			
	Error	20	.008198		
	Total	32			
R-effect	Fertilizer (O,N_3,N_3P_3,N_3P_3M)	3	.149726	18.262**	
	Resin (+,-)	1	.002329		.019704
	F x R	3	.008488	1.035	
N-effect	Fertilizer (O,N_3)	1	.058483	7.133*	.139622
	Resin (+,-)	1	.005926		-.044445
	F x R	1	.000093		.005562
P-effect	Fertilizer (N_3,N_3P_3)	1	.128400	15.662**	.206882
	Resin (+,-)	1	.002701		.030005
	F x R	1	.014238	1.736	.068892
M-effect	Fertilizer (N_3P_3,N_3P_3M)	1	.006757		-.047460
	Resin (+,-)	1	.021096	2.573	.083857
	F x R	1	.000678		-.015040

Table 16. (Continued). Analysis of Variance of Plant Weights on Tama Topsoil

	source	d.f.	m.s.	F[a]	effect[b]
NP-effect	Fertilizer $(0, N_3P_3)$	1	.360193	43.936**	.346503
	Resin (+,-)	1	.001792		.024443
	F x R	1	.016630	2.028	.074453
NPM-effect	Fertilizer $(0, N_3P_3M)$	1	.268281	32.725**	.299043
	Resin (+,-)	1	.000265		.009403
	F x R	1	.010590	1.291	.059413

[a] $F \frac{1}{20} = 4.35$ (P.05), 8.10 (P.01)

[b] Effect is expressed in figures after transformation $(x_{ij} = 1 + \log y_{ij})$

Table 17. Analysis of Variance of Plant Weights as Affected by Levels of P

soil material	source	d.f.	m.s.	F	b[a]
Unoxidized Till	Linear	1	2.179182	18.558*	.2695
	Residual	3	.117423	8.334**	
	Total	4	-		
	(Error)	(22)	(.014089)		
Gumbotil	Linear	1	3.236185	13.850*	.3284
	Residual	3	.233658	19.872**	
	Total	4	-		
	(Error)	(20)	(.011758)		
Ferretto	Linear	1	2.056203	4.749	.2618
	Residual	3	.432999	38.119**	
	Total	4	-		
	(Error)	(24)	(.011359)		
Buried A	Linear	1	1.307343	3.118	.2087
	Residual	3	.419318	106.480**	
	Total	4	-		
	(Error)	(24)	(.003938)		
Tama Topsoil	Linear	1	.043369	46.236**	.0380
	Residual	3	.000938	.114	
	Total	4	-		
	(Error)	(20)	(.008198)		

[a] b is the slope of the linear response of plant growth to 5 successive levels of P

Table 18. Plant Weights (Tops and Roots) of Alfalfa and Bromegrass Grown on Unoxidized Till as Affected by Fertilizer and Soil-conditioner Treatments

	Tops				Roots	Roots/Tops
Treatment	Alfalfa	Brome	Total	Alf:Brome	Total	Ratio
0[a]	2.65[b]	1.18	3.83	69:31	2.06	.54
N2	3.03	1.21	4.24	71:29	1.76	.42
P3	11.80	1.01	12.81	92:8	7.55	.59
N2P1	13.72	3.93	17.65	78:22	13.26	.75
N2P2	17.17	4.87	22.04	78:22	15.83	.72
N2P3	22.17	8.14	30.31	73:27	20.13	.66
N2P4	19.58	6.74	26.32	74:26	17.15	.65
K	3.33	1.30	4.63	72:28	2.39	.52
N_2K	3.05	1.03	4.08	75:25	1.69	.41
P_3K	17.96	1.06	19.02	94:6	6.60	.35
N_2P_3K	20.46	8.68	29.14	70:30	20.15	.69
N_2P_3KM	20.81	6.14	26.95	77:23	20.44	.76
RN_2P_3KM	15.86	10.93	26.79	59:41	35.04	1.31

[a] 0 = check

N_2 = 200 lbs N/A

Pa = a x 100 lbs P_2O_5/A

K = x lbs K_2O/A, so that x + available K_2O = 300 lbs K_2O/A

M = minor element solution

R = soil conditioner (resin)

[b] grams dry weight/3 pots, multiply with 500 to obtain readings in lbs/A, or divide by 4 to convert to tons/A

Table 19. Plant Weights (Tops and Roots) of Alfalfa and Bromegrass Grown on Gumbotil as Affected by Fertilizer and Soil-conditioner Treatments

	Tops				Roots	Roots/Tops
Treatment	Alfalfa	Brome	Total	Alf:Brome	Total	Ratio
0[a]	.75[b]	.90	1.65	45:55	1.58	.96
N2	.88	.75	1.63	54:46	.93	.57
P3	13.71	1.09	14.80	93:7	9.91	.67
N2P1	4.52	11.15	15.67	29:71	10.90	.70
N2P2	13.56	11.24	24.80	55:45	14.53	.59
N2P3	15.47	13.47	28.94	53:47	21.18	.73
N2P4	19.61	15.80	35.41	55:45	25.90	.73
N2P3M	16.66	12.94	29.60	56:44	23.79	.80
RN2P3M	18.46	12.09	30.55	60:40	23.00	.75

[a] 0 = check

N_2 = 200 lbs N/A

Pa = a x 100 lbs P_2O_5/A

M = minor element solution

R = soil conditioner (resin)

[b] grams dry weight/3 pots, multiply with 500 to obtain readings in lbs/A, or divide by 4 to convert to tons/A

Table 20. Plant Weights (Tops and Roots) of Alfalfa and Brome grass Grown on Ferretto as Affected by Fertilizer and Soil-conditioner Treatments

	Tops				Roots	Roots/Tops
Treatment	Alfalfa	Brome	Total	Alf:Brome	Total	Ratio
0 [a]	1.11 [b]	.57	1.68	66:34	1.52	.90
L	1.48	.87	2.35	63:37	1.47	.62
N_2	1.42	1.14	2.56	55:45	1.48	.58
LN_2	1.67	.90	2.57	65:35	.76	.30
P_3	6.50	.88	7.38	88:12	2.83	.38
LP_3	11.58	1.32	12.90	90:10	3.36	.26
N_2P_1	11.68	11.00	22.68	51:49	12.51	.55
N_2P_2	13.45	10.61	24.06	56:44	16.54	.69
N_2P_3	14.38	10.48	24.86	58:42	10.34	.42
N_2P_4	12.83	14.67	27.50	47:53	15.87	.58
LN_2P_3	9.55	13.10	22.65	42:58	15.61	.69
K	4.22	.96	5.18	81:19	1.80	.35
LK	1.57	1.12	2.69	58:42	1.36	.50
N_2K	1.00	.95	1.95	51:49	1.28	.66
LN_2K	1.27	.96	2.23	57:43	1.02	.46
P_3K	11.70	.96	12.66	92:8	4.93	.39
LP_3K	7.73	.98	8.71	89:11	4.53	.52
N_2P_3K	16.64	14.15	30.79	54:46	20.19	.66
LN_2P_3K	13.38	12.46	25.84	52:48	20.55	.80
LN_2P_3KM	11.93	9.73	21.66	55:45	21.31	.98
RLN_2P_3KM	17.65	14.51	32.16	55:45	27.73	.86

[a] 0 = check
L = lime, adjusted to Ca-requirement level
N_2 = 200 lbs N/A

Pa = a x 100 lbs P_2O_5/A

K = x lbs K_2O/A, so that x + available K_2O = 300 lbs K_2O/A

M = minor element solution

R = soil conditioner (resin)

[b] grams dry weight/3 pots, multiply with 500 to obtain readings in lbs/A, or divide by 4 to convert to tons/A.

Table 21. Plant Weights (Tops and Roots) of alfalfa and Bromegrass Grown on Buried A_2 as Affected by Fertilizer and Soil-conditioner Treatments

Treatment	Tops				Roots	Roots/Tops
	Alfalfa	Brome	Total	Alf:brome	Total	Ratio
0[a]	1.51[b]	.54	2.05	74:26	1.57	.77
L	1.72	.88	2.60	66:34	1.83	.70
N_2	2.05	.51	2.56	80:20	2.08	.81
LN_2	1.30	.70	2.00	65:35	1.97	.98
P_3	5.49	1.85	7.34	75:25	7.48	1.02
LP_3	11.88	2.36	14.24	83:17	7.92	.56
N_2P_1	6.28	7.09	13.37	47:53	6.20	.46
N_2P_2	6.40	9.20	15.60	41:59	10.93	.70
N_2P_3	6.08	9.79	15.87	38:62	22.49	1.42
N_2P_4	8.92	9.96	18.88	47:53	17.90	.95
LN_2P_3	8.96	10.64	19.60	46:54	15.63	.80
K	.79	.73	1.52	52:48	3.01	1.98
LK	1.75	.80	2.55	69:31	2.95	1.16
N_2K	1.21	.89	2.10	58:42	2.56	1.22
LN_2K	1.12	.80	1.92	58:42	1.99	1.04
P_3K	7.69	1.77	9.46	81:19	7.87	.83
LP_3K	13.96	2.18	16.14	86:14	8.52	.53
N_2P_3K	10.14	10.92	21.06	48:52	25.01	1.19
LN_2P_3K	12.50	11.84	24.34	51:49	29.59	1.22
LN_2P_3KM	16.97	6.67	23.64	72:28	22.24	.94
RLN_2P_3KM	14.30	12.16	26.46	54:46	27.54	1.04

[a] 0 = check
L = lime, adjusted to Ca-requirement level
N_2 = 200 lbs N/A
Pa = a x 100 lbs P_2O_5/A
K = x lbs K_2O/A, so that x + available K_2O = 300 lbs K_2O/A
M = minor element solution
R = soil conditioner (resin)

[b] grams dry weight/3 pots, multiply with 500 to obtain readings in lbs/A, or divide by 4 to convert to tons/A

Table 22. Plant Weights (Tops and Roots) of Alfalfa and Bromegrass Grown on Tama Topsoil as Affected by Fertilizer and Soil-conditioner Treatments

	Tops				Roots	Roots/Tops
Treatment	Alfalfa	Brome	Total	Alf:Brome	Total	Ratio
O[a]	18.60[b]	8.44	27.04	69:31	36.76	1.36
L	15.61	6.87	22.48	69:31	20.85	.93
N2	20.65	9.88	30.53	68:32	39.64	1.30
LN2	17.38	18.30	35.68	49:51	36.15	1.01
P3	26.32	8.24	34.56	76:24	44.13	1.28
LP3	21.80	13.58	35.38	62:38	37.71	1.07
N2P1	23.22	13.31	36.53	64:36	49.15	1.34
N2P2	24.17	12.11	36.28	67:33	52.38	1.44
N2P3	26.37	15.32	41.69	63:37	53.64	1.29
N2P4	29.82	15.47	45.29	66:34	43.07	.95
LN2P3	20.92	24.15	45.07	46:54	38.71	.86
N2P3M	29.38	12.44	41.82	70:30	55.76	1.33
LN2P3M	19.14	20.67	39.81	48:52	32.66	.82
RN2P3M	22.78	23.20	45.98	49:51	66.79	1.45
RLN2P3M	19.26	25.07	44.33	43:57	39.50	.89

[a] O = check
L = lime, adjusted to Ca-requirement level
N_2 = 200 lbs N/A
Pa = a x 100 lbs P_2O_5/A
M = minor element solution
R = soil conditioner (resin)

[b] grams dry weight/3 pots, multiply with 500 to obtain readings in lbs/A, or divide by 4 to convert to tons/A

Table 23. Analysis of Variance of Plant Weights on Unoxidized Till as Affected by N_2, P_3 and K Factorial Treatments.

	source	d.f.	m.s.	F^a	effect
Alfalfa Tops	N_2	1	7.0092	3.279	1.0808
	P_3	1	151.6545	70.966**	5.0275
	K	1	1.1051	.517	.4292
	N_2P_3	1	6.7947	3.179	1.0642
	N_2K	1	3.0317	1.418	-.7108
	P_3K	1	.5859	.274	.3125
	N_2P_3K	1	2.1660	1.013	-.6008
	Error	24	2.1370		
Brome Tops	N_2	1	8.7725	20.901**	1.2092
	P_3	1	8.3662	19.933**	1.1808
	K	1	.0117	.027	.0442
	N_2P_3	1	9.3625	22.307**	1.2492
	N_2K	1	.0015	.003	.0158
	P_3K	1	.0176	.041	.0542
	N_2P_3K	1	.0260	.061	.0658
	Error	24	.4197		
Roots	N_2	1	26.3132	7.268*	2.0942
	P_3	1	90.2100	24.919**	3.8775
	K	1	.0187	.005	-.0558
	N_2P_3	1	30.6678	8.471**	2.2608
	N_2K	1	.0135	.003	.0475
	P_3K	1	.0590	.016	-.0992
	N_2P_3K	1	.0782	.021	.1141
	Error	24	3.6200		

$^{a}F\frac{1}{24}$ = 4.26 (P.05), 7.82 (P.01)

Table 24. Analysis of Variance of Plant Weights on Gumbotil as Affected by N_2, P_3 Factorial Treatments

	source	d.f.	m.s.	F[a]	effect
Alfalfa Tops	N_2	1	.2977	.243	.3150
	P_3	1	63.2507	51.704**	4.5917
	N_2P_3	1	.2214	.180	.2716
	Error	16	1.2233		
Brome Tops	N_2	1	12.4642	19.907**	2.0383
	P_3	1	13.8892	22.183**	2.1517
	N_2P_3	1	13.0832	20.896**	2.0883
	Error	16	.6261		
Roots	N_2	1	9.3987	5.619*	1.7700
	P_3	1	68.0676	40.698**	4.7633
	N_2P_3	1	11.8407	7.079*	1.9867
	Error	16	1.6725		

[a] $F\frac{1}{16}$ = 4.49 (P.05), 8.53 (P.01)

Table 25. Analysis of Variance of Plant Weights on Ferretto as Affected by N_2, L, P_3 and K Factorial Treatments

	source	d.f.	m.s.	F^a	effect
Alfalfa Tops	N_2	1	3.7520	4.072	.5592
	L	1	1.5914	1.727	-.3642
	P_3	1	125.8416	136.576**	3.2383
	K	1	2.0090	2.180	.4092
	N_2L	1	.8533	.926	-.2667
	N_2P_3	1	7.8894	8.562**	.8108
	N_2K	1	.0108	.012	.0300
	LP_3	1	.5677	.616	-.2175
	LK	1	2.2881	2.483	-.4367
	P_3K	1	.5334	.579	.2108
	N_2LP_3	1	3.0000	3.256	-.5000
	N_2LK	1	3.8874	4.219*	.5692
	N_2P_3K	1	1.5987	1.735	.3650
	LP_3K	1	.4181	.454	-.1867
	N_2LP_3K	1	1.1970	1.299	.3158
	Error	40	.9214		
Brome Tops	N_2	1	45.0081	110.803**	1.9367
	L	1	.0547	.135	.0675
	P_3	1	45.7471	112.622**	1.9525
	K	1	.2241	.552	.1367
	N_2L	1	.0010	.002	-.0092
	N_2P_3	1	43.3579	106.740**	1.9008
	N_2K	1	.1323	.326	.1050
	LP_3	1	.0280	.069	.0483
	LK	1	.4447	1.095	-.1925
	P_3K	1	.1064	.262	.0942
	N_2LP_3	1	.0280	.069	.0483
	N_2LK	1	.2552	.628	-.1458
	N_2P_3K	1	.3434	.845	.1692
	LP_3K	1	.4880	1.201	-.2017
	N_2LP_3K	1	.3816	.939	-.1783
	Error	40	.4062		

Table 25. (Continued). Analysis of Variance of Plant Weights on Ferretto as Affected by N_2, L, P_3 and K Factorial Treatments

	source	d.f.	m.s.	F[a]	effect
Roots	N_2	1	50.9075	96.106**	2.0596
	L	1	.3834	.724	.1788
	P_3	1	106.9526	201.912**	2.9854
	K	1	6.9692	13.157**	.7621
	N_2L	1	.5234	.988	.2088
	N_2P_3	1	57.7505	109.025**	2.1938
	N_2K	1	2.7123	5.120*	.4754
	LP_3	1	1.0890	2.056	.3012
	LK	1	.6936	1.309	-.2404
	P_3K	1	6.6231	12.503**	.7429
	N_2LP_3	1	.7475	1.412	.2496
	N_2LK	1	.2041	.385	-.1304
	N_2P_3K	1	2.8179	5.320*	.4846
	LP_3K	1	.7277	1.374	-.2462
	N_2LP_3K	1	.4860	.918	-.2012
	Error	40	.5297		

[a] F^{1}_{40} = 4.08 (P.05), 7.31 (P.01)

Table 26. Analysis of Variance of Plant Weights on Buried A_2 as Affected by N_2, L, P_3 and K Factorial Treatments

	source	d.f.	m.s.	F^a	effect
Alfalfa Tops	N_2	1	.0426	.056	-.0596
	L	1	6.9236	9.137**	.7596
	P_3	1	88.6991	117.064**	2.7187
	K	1	2.1548	2.844	.4237
	N_2L	1	1.8526	2.445	-.3929
	N_2P_3	1	.0326	.043	-.0521
	N_2K	1	.1863	.246	.1246
	LP_3	1	6.4313	8.488**	.7321
	LK	1	.0124	.016	.0321
	P_3K	1	3.8477	5.078*	.5662
	N_2LP_3	1	.6098	.805	-.2254
	N_2LK	1	.0032	.004	-.0162
	N_2P_3K	1	.2776	.366	.1521
	LP_3K	1	.0876	.116	-.0854
	N_2LP_3K	1	.0020	.003	-.0129
	Error	40	.7577		
Brome Tops	N_2	1	25.4916	73.484**	1.4575
	L	1	.2133	.615	.1333
	P_3	1	43.1302	124.330**	1.8958
	K	1	.1474	.425	.1108
	N_2L	1	.0061	.018	.0225
	N_2P_3	1	25.6377	73.905**	1.4617
	N_2K	1	.1825	.526	.1233
	LP_3	1	.0990	.285	.0908
	LK	1	.0070	.020	-.0242
	P_3K	1	.0456	.131	.0617
	N_2LP_3	1	.0280	.081	.0483
	N_2LK	1	.0005	.001	.0067
	N_2P_3K	1	.1027	.296	.0925
	LP_3K	1	.0056	.016	.0217
	N_2LP_3K	1	.0007	.002	.0075
	Error	40	.3469		

Table 26. (Continued). Analysis of Variance of Plant Weights on Buried A_2 as Affected by N_2, L, P_3 and K Factorial Treatments

	source	d.f.	m.s.	F[a]	effect
Roots	N_2	1	75.3634	30.432**	2.5071
	L	1	.0581	.023	-.0696
	P_3	1	236.6067	95.544**	4.4404
	K	1	8.7807	3.546	.8554
	N_2L	1	.3763	.152	-.1771
	N_2P_3	1	79.2840	32.015**	2.5704
	N_2K	1	3.7577	1.517	.5596
	LP_3	1	.0105	.004	-.0296
	LK	1	2.4615	.994	.4529
	P_3K	1	4.3259	1.747	.6004
	N_2LP_3	1	.1292	.052	-.1038
	N_2LK	1	2.5623	1.035	.4621
	N_2P_3K	1	6.4171	2.591	.7312
	LP_3K	1	3.2187	1.300	.5179
	N_2LP_3K	1	2.6936	1.088	.4738
	Error	40	2.4764		

[a] F^{1}_{40} = 4.08 (P.05), 7.31 (P.01)

Table 27. Analysis of Variance of Plant Weights on Tama Topsoil as Affected by N_2, L and P_3 Factorial Treatments.

	source	d.f.	m.s.	F[a]	effect
Alfalfa Tops	N_2	1	.3726	.155	.2492
	L	1	10.9755	4.574*	-1.3525
	P_3	1	22.3683	9.323**	1.9308
	N_2L	1	.0590	.024	-.0992
	N_2P_3	1	.9009	.375	-.3875
	LP_3	1	.5736	.239	-.3092
	N_2LP_3	1	.0176	.007	-.0542
	Error	28	2.3992		
Brome Tops	N_2	1	38.8108	25.303**	2.5433
	L	1	18.4104	12.003**	1.7517
	P_3	1	13.2014	8.606**	1.4833
	N_2L	1	7.5710	4.936*	1.1233
	N_2P_3	1	.9519	.620	.3983
	LP_3	1	2.2326	1.455	.6100
	N_2LP_3	1	1.7605	1.147	-.5417
	Error	28	1.5338		
Roots	N_2	1	34.2960	2.406	2.3908
	L	1	69.1894	4.855*	-3.3958
	P_3	1	69.3266	4.864*	3.3992
	N_2L	1	.6394	.044	.3258
	N_2P_3	1	2.4513	.172	-.6392
	LP_3	1	.1584	.011	-.1625
	N_2LP_3	1	18.2531	1.280	-1.7442
	Error	28	14.2505		

[a] F^{1}_{28} = 4.20 (P.05), 7.64 (P.01)

Table 28. Analysis of Variance of Alfalfa and Bromegrass Plant Weights as Affected by Levels of P

soil material	plant part	source	d.f.	m.s.	F	b[a]
Unoxidized Till	Alfalfa Tops	Linear	1	57.5468	10.509*	1.3850
		Residual	3	5.4759	2.562	
		(Error)	(24)	(2.1370)		
	Brome Tops	Linear	1	7.7724	13.734*	.5090
		Residual	3	.5659	1.348	
		(Error)	(24)	(.4197)		
	Roots	Linear	1	47.2508	7.236	1.2550
		Residual	3	6.5291	1.803	
		(Error)	(24)	(3.6200)		
Gumbotil	Alfalfa Tops	Linear	1	78.1176	66.738**	1.6137
		Residual	3	1.1705	.956	
		(Error)	(16)	(1.2233)		
	Brome Tops	Linear	1	35.0352	11.327*	1.0807
		Residual	3	3.0929	4.939*	
		(Error)	(16)	(.6261)		
	Roots	Linear	1	120.8816	122.697	2.0073
		Residual	3	.9852	.589	
		(Error)	(16)	(1.6725)		
Ferretto	Alfalfa Tops	Linear	1	21.7090	4.106	.8507
		Residual	3	5.2866	5.737**	
		(Error)	(40)	(.9214)		
	Brome Tops	Linear	1	23.4790	6.907	.8847
		Residual	3	3.3991	8.368**	
		(Error)	(40)	(.4062)		
	Roots	Linear	1	23.6031	2.782	.8870
		Residual	3	8.4822	16.013**	
		(Error)	(40)	(.5297)		

Table 28. (Continued). Analysis of Variance of Alfalfa and Bromegrass Plant Weights as Affected by Levels of P

soil material	plant part	source	d.f.	m.s.	F	b[a]
Buried A_2	Alfalfa Tops	Linear	1	6.1111	9.127	.4513
		Residual	3	.6695	.883	
		(Error)	(40)	(.7577)		
	Brome Tops	Linear	1	15.5520	8.546	.7020
		Residual	3	1.8197	5.245**	
		(Error)	(40)	(.3469)		
	Roots	Linear	1	76.5762	14.274	1.2643
		Residual	3	5.3645	2.166	
		(Error)	(40)	(2.4764)		
Tama Topsoil	Alfalfa Tops	Linear	1	15.3940	87.218**	.7163
		Residual	3	.1765	.073	
		(Error)	(28)	(2.3992)		
	Brome Tops	Linear	1	5.7992	11.673*	.4397
		Residual	3	.4968	.323	
		(Error)	(28)	(1.5338)		
	Roots	Linear	1	4.2941	.291	.3783
		Residual	3	14.7478	1.034	
		(Error)	(28)	(14.2505)		

[a] b is the slope of the linear response of plant growth to 5 successive levels of P.

Table 29. Analysis of Variance of Plant Weights on Unoxidized Till as Affected by Soil Conditioner (R) and Minor Elements (M)

	source	d.f.	m.s.	F[a]	effect
Alfalfa Tops	R	1	4.0837	1.910	-1.6500
	M	1	.0204	.009	.1167
	Error	24	2.1370		
Brome Tops	R	1	3.8240	9.111**	1.5967
	M	1	1.0753	2.562	-.8467
	Error	24	.4197		
Roots	R	1	35.5270	9.814**	4.8667
	M	1	.0140	.003	.0967
	Error	24	3.6200		

[a] F^{1}_{24} = 4.26 (P.05), 7.82 (P.01)

Table 30. Analysis of Variance of Plant Weights on Gumbotil as Affected by Soil Conditioner (R) and Minor Elements (M)

	source	d.f.	m.s.	F [a]	effect
Alfalfa Tops	R	1	.5400	.441	.6000
	M	1	.2360	.193	.3967
	Error	16	1.2233		
Brome Tops	R	1	.1204	.192	-.2833
	M	1	.0468	.075	-.1767
	Error	16	.6261		
Roots	R	1	.1040	.062	-.2633
	M	1	1.1354	.679	.8700
	Error	16	1.6725		

[a] F^{1}_{16} = 4.49 (P.05), 8.53 (P.01)

Table 31. Analysis of Variance of Plant Weights on Ferretto as Affected by Soil Conditioner (R) and Minor Elements (M)

	source	d.f.	m.s.	F [a]	effect
Alfalfa Tops	R	1	5.4532	5.918*	1.9067
	M	1	.3504	.380	-.4833
	Error	40	.9214		
Brome Tops	R	1	3.8081	9.375**	1.5933
	M	1	1.2421	3.058	-.9100
	Error	40	.4062		
Roots	R	1	6.8694	12.968**	2.1400
	M	1	.0962	.182	.2533
	Error	40	.5297		

[a] $F^{1}_{40} = 4.08$ (P.05), 7.31 (P.01)

Table 32. Analysis of Variance of Plant Weights on Buried A_2 as Affected by Soil Conditioner (R) and Minor Elements (M)

	source	d.f.	m.s.	F [a]	effect
Alfalfa Tops	R	1	1.1881	1.568	-.8900
	M	1	3.3300	4.394*	1.4900
	Error	40	.7577		
Brome Tops	R	1	5.0233	14.480**	1.8300
	M	1	4.4548	12.841**	-1.7233
	Error	40	.3469		
Roots	R	1	4.6816	1.890	1.7667
	M	1	9.0037	3.635	-2.4500
	Error	40	2.4764		

[a] F^{1}_{40} = 4.08 (P.05), 7.31 (P.01)

Table 33. Analysis of Variance of Plant Weights on Tama Topsoil as Affected by Lime (L), Soil Conditioner (R) and Minor Elements (M)

	source	d.f.	m.s.	F[a]	effect
Alfalfa Tops	L	1	24.9830	10.413**	-1.6661
	R	1	3.4992	1.458	-1.0800
	L	1	15.7781	6.576*	-2.2933
	RL	1	3.7632	1.568	1.1200
	M	1	.1261	.052	.2050
	L	1	20.5147	8.550**	-2.6150
	ML	1	1.9120	.797	-.7983
	Error	28	2.3992		
Brome Tops	L	1	26.9015	17.539**	1.7288
	R	1	19.1521	12.486**	2.5266
	L	1	8.5008	5.542*	1.6833
	RL	1	3.3708	2.197	-1.0600
	M	1	3.3708	2.197	-1.0600
	L	1	24.2536	15.812**	2.8433
	ML	1	.0300	.019	-.1000
	Error	28	1.5338		
Roots	L	1	230.7361	16.191**	-5.0633
	R	1	26.6114	1.867	2.9783
	L	1	211.5960	14.848**	-8.3983
	RL	1	1.4630	.102	-.6983
	M	1	1.2870	.090	-.6550
	L	1	120.5234	8.457**	-6.3383
	ML	1	5.5624	.390	-1.3617
	Error	28	14.2505		

[a] F^{1}_{28} = 4.20 (P.05), 7.64 (P.01)