THE EFFECT OF FERTILIZER, GYPSUM, AND HERBICIDE ON ESTABLISHMENT AND MAINTENANCE OF A VEGETATIVE GROUND COVER FOR EROSION CONTROL ON OKLAHOMA HIGHWAYS

By

LARRY DEAN MADDUX

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Thesis Approved:

Lester W. Reed
Thesis Adviser

Wayne W. Huffine

N. N. Durham
Dean of the Graduate School

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CHAPTER I

INTRODUCTION

Oklahoma contains over 15,000 miles of state and federal highways with more than 826,000 acres of roadside area. The advent of the interstate highway system and multiple lane highways will add many more acres of roadside to this figure. With this huge expanse of roadside area has come the realization of the need to protect these exposed surfaces from erosion. The critical problem which confronts the highway engineer and agronomist alike is that of establishing and maintaining a dense permanent vegetative cover on the highway right-of-way as quickly and as economically as possible.

By maintaining a dense vegetative cover, the erosion of highway backslopes, fills, and drainageways will be minimized and thereby eliminate much costly repair and maintenance work. At the present time, the Oklahoma State Highway Department spends in excess of 20 million dollars a year for maintenance.

The successful establishment and maintenance of roadside vegetation in Oklahoma is complicated by the great variation of elevation and climate within the state. The elevation ranges from approximately 5,000 feet in the Panhandle to below 400 feet in the Coastal Plains 600 miles to the southeast. Rainfall varies from less than 15 to more than 50 inches annually from the northwest to the southeast.

Temperature ranges from lows below zero in the winter to highs above 100 in the summer.

The main objective of this study was to evaluate the effect of fertilizer, gypsum, and herbicide treatments for the establishment and maintenance of a vegetative ground cover for the effective and economical control of erosion of highway slopes. The nitrogen fertilizer used was ammonium nitrate (33% N) and the phosphorus fertilizer used was treble super phosphate (45% P). Ben Franklin[1] grade gypsum was used for the gypsum treatment. Banvel D, a trade name of dicamba, (2 methoxy - 3, 6 - dichlorobenzoic acid), was the herbicide employed. Soil analyses were made on each plot to determine levels of pH, phosphorus, potassium, sodium, calcium and magnesium.

[1]U. S. Gypsum Trade Name

CHAPTER II

LITERATURE REVIEW

Fertilization

Proper fertilizers are an important factor in the establishment and maintenance of a dense, permanent, adapted vegetative cover on roadside areas. Highway engineering requirements of intensive drainage, soil compaction, and cutting and grading operations which expose or mix in less fertile subsoils frequently are not suitable or desirable for the successful establishment and maintenance of vegetation for erosion control.

Diseker et al. (9)[1] indicated the importance of roadside stabilization in Georgia by measuring runoff and erosion as affected by roadbank slopes and slope orientation. The results of three years of study showed that 3:1 slopes averaged 100 tons of annual soil loss per acre while 1:1 slopes lost 195 tons per acre. They also found that the soil loss per unit area on bare road cuts was 15 to 20 times greater than on steep cultivated fields in the same area.

Coffman and Edwards (7) in Ohio reported on the availability of plant nutrients in three situations along roadsides: deep cut, fill, and level sections. The deep cuts consisted of subsoil and parent material low in phosphorus and organic matter with satisfactory pH and

[1]Figures in parentheses refer to literature cited.

potassium levels. The fill sections were similar to the deep cut situations in regard to nutrients and pH, but the types of soil varied. The level sections approximated natural farming conditions with satisfactory levels of nitrogen, phosphorus, potassium and pH.

Friday (10) has reported that any soil area which has been disturbed by grading or moving requires twice the amount of fertilization for good vegetative cover as the same soil prior to grading operations. Beers (1) has stated that subsoils exposed when roadsides are cut or filled are nearly always low in nitrogen and vary widely in phosphate and potash content. Soils high in phosphate in surface layers may have almost no phosphate a foot or more in depth into the soil. There are some soils that have a medium to high test for potash in the surface layer, but a low to very low test in the subsoil.

Research conducted by Diseker and Richardson (8) in Georgia indicated that roadbank subsoils were almost devoid of plant nutrients when first exposed. Soils tested showed only traces of potassium and phosphorus, and no nitrogen. A study revealed heavy loss of applied plant nutrients from roadside banks in proportion to length and steepness of slope, with the greatest loss occurring on the steepest, longest slopes. Treatments prior to planting included 4-12-12 fertilizer at one ton per acre and lime at two tons per acre. Annual spring maintenance applications consisted of one-half ton of 4-12-12 per acre plus an additional 50 pounds of nitrogen per acre.

Further work conducted in Georgia by Richardson et al. (23) indicated that the yields of crownvetch and Abruzzi rye increased as fertilizer rates were increased up to 1,500 pounds of 12-6-6 per acre.

However, the crownvetch plant posulation decreased slightly as rates of fertilizer were increased.

Brown (5) conducted an experiment in Ohio using 25 combinations of nitrogen and phosphorus on highway backslopes with existing turf. A fertilizer mixture of 50 pounds of nitrogen and 75 pounds of P_2O_5 per acre was most effective in increasing the percent cover growth and color response. In the majority of cases, the rate of growth and increased cover was higher with a higher application, but the increase was not proportional to the amount of fertilizer added.

Blaser (2, 3) reported on recommendations for successful vegetative establishment of backslopes in Virginia. Since soil materials in the humid east are invariably low in organic matter and fertility, particularly nitrogen and phosphorus, 1,000 pounds of a 10-20-10 fertilizer and two tons of lime per acre were recommended.

Research work by Musser (20) favors initial applications of 1,200 pounds of 5-10-10 and two tons of lime per acre in work with Kentucky 31 tall fescue, crownvetch, bermudagrass, and lespedeza in Pennsylvania. Grasses require a minimum of 50 pounds of nitrogen, and 50 to 100 pounds of actual phosphorus and potassium per acre per year for maintenance.

On all new road construction areas in Missouri, Griffin (12) recommends fertilization based on representative soil sample analyses. Although the fertilizer requirements vary widely, the average for the state is 120 pounds of nitrogen, 180 pounds of available P_2O_5, and 140 pounds of K_2O per acre. The average for effective calcium is 900 pounds per acre. Liquid materials of a 3-2-1 ratio at 120 to 160 pounds of fertilizer per acre are used for maintenance applications on new turf and turfs in highly urbanized areas.

In bermudagrass seedings on highway slopes in Texas, McCully, et al. (16) indicate 400 pounds of 16-20-0 per acre appears to be the most favorable rate for successful stand establishment.

Mouldenhauer, et al. (19) recommended that subsoils exposed by roadbuilding and engineering operations should preferably be treated with 25 pounds of nitrogen, 180 pounds of P_2O_5, and 120 pounds of K_2O for the establishment of a grass-legume mixture, or with 70 pounds of nitrogen and 100 pounds of P_2O_5 followed by 50 pounds of nitrogen per acre annually for grass alone in southern Iowa and northern Missouri.

Millar (17) believes three applications of 5-10-5 at 1,000 pounds per acre would do more good than one application of 3,000 pounds. He suggests that one application be applied at seeding time and the other two during the following spring and fall.

New grassy sods often deteriorate soon after establishment because fertilizers are not applied for maintenance. Blaser, et al. (4) found that maintenance top dressings of fertilizer are necessary to hold the initial stand in the critical first three years after establishment. They found that a seeding of Kentucky 31 fescue and redtop produced a sod cover of 54 per cent three months after establishment. This cover degenerated to 18 per cent during the third year without maintenance fertilizer as compared with 60 per cent cover when treated with an annual fall application of 500 pounds of a 10-20-10 fertilizer.

From a three year experiment in Mississippi, Palmertree, et al. (22) concluded that established bermudagrass sods on roadsides require nitrogen refertilization to prevent degeneration. However, bermudagrass has not shown a visible response to maintenance applications of phosphorus and potassium on roadside slopes. Their recommendation was to apply 50 to 75 pounds of nitrogen per acre with one-half to three-fourths of the nitrogen as ammonium nitrate or urea and the remainder as ureaformaldehyde.

Gypsum

Because of engineering operations, highway roadside areas generally are not very permeable to water. Therefore, any treatment which would result in an improvement in soil structure could possibly aid in establishing a better cover crop for erosion control.

Blaser (3) stated that on soils with a high silt-clay fraction, the addition of gypsum can help keep the soil surface from puddling and help keep the soil more open to root and water movement. To be fully effective, gypsum must be worked into the top few inches of soil as it is not a good surface additive.

Gypsum ($CaSO_4 \cdot 2H_2O$) has been used as an amendment on soils with a high sodium content. The calcium replaces sodium on the exchange complex and the sodium sulfate is carried out in the drainage water. This replacement serves to floculate the soil and make it more permeable to water (26, 27). Results obtained by Padhi, et al. (21) indicate that soil disturbance plus appropriate treatment with gypsum will increase water percolation and sodium removal from solonetzic soils in Illinois. Greene (11) found that gypsum treatment increased the permeability of an impermeable Gezirah clay subsoil. Sodium constituted 10 per cent of the exchangeable ions in this soil.

The application of gypsum or other neutral calcium salts to an acid soil will almost invariably result in an increased outgo of potassium in percolating waters while lime applications will result in a conservation of potassium (26).

The effect of gypsum on non-sodic soils has not been sufficiently studied. Martin, et al. (15) tested the effect of gypsum on an unproductive serpentine soil high in magnesium but deficient in calcium. A substantial build-up in replaceable calcium took place in the surface six inches when eight tons of gypsum per acre was applied, but the second- and third-foot layers were unaffected. The surface foot of soil increased in calcium, but only the top six inches had a sufficiently improved calcium status to bring about really satisfactory plant growth.

Herbicide

The use of chemicals for weed control in combination with an effective fertilization program could possibly enhance soil stabilization for erosion control while substantially reducing highway mowing maintenance costs. The objective would be to establish a dense stand of grass which could effectively compete with subsequent weed growth.

Banvel D (or dicamba) is a postemergence herbicide for broadleaf weeds. Miller and Hogan (18) of Georgia found that dicamba at 0.5 to one pound per acre would control clover, plaintains, dandelion, and other broadleaf weeds. Control of buckhorn plaintain, wild garlic, broadleaf plaintain, ground ivy, dandelion, and henbit in Kentucky was obtained by application of 0.75 pound dicamba per acre by Herron et al. (13).

In the Northeast part of the United States, Callahan and Engel (6) controlled clover in bentgrass with Banvel D at 0.5 pound per acre. Dandelion control was not good, however. There was no discernible foliage burn at this rate. Jagschitz and Skogley (14) found dicamba to be one of the most effective and consistent herbicides for clover, chickweed and stitchwort control. Turf injury was generally less than from other herbicides used. Dry formulations at low rates are not as effective as liquid formulations.

Sinkler (24) found dicamba to be one of the most effective herbicides for the selective control of broadleaf plants and weedy grasses along Oklahoma highways.

CHAPTER III

METHODS AND MATERIALS

The purpose of this study was to evaluate nitrogen and phosphorus fertilizers, gypsum, and herbicide relative to their separate and combined effectiveness in promoting a vegetative cover for erosion control on highway slope areas. The investigations in this study were located in the interchange area of U. S. 69 and Business 69 northwest of Eufaula, hereafter referred to as the Eufaula experiment; the interchange area of U. S. 177 and I-40 northwest of Shawnee (the Shawnee experiment) and opposing cut and fill slopes on S. H. 34 northeast of Buffalo (the Buffalo cut slope experiment and the Buffalo fill slope experiment, respectively). Ammonium nitrate and treble super phosphate fertilizers were used for the nitrogen and phosphorus treatments. Ben Franklin grade gypsum as a soil additive was evaluated. Banvel D was the only herbicide evaluated for its effect on roadside vegetation maintenance. Soil analyses were made on each plot of each experiment except the Buffalo fill slope experiment where only check plots were analyzed, to determine levels of pH, phosphorus, potassium, sodium, calcium, and magnesium.

The Eufaula experiment was located in an excavation area of raw shale and sand with a slope of 5 per cent. The area was originally seeded and fertilized on May 14 to 16, 1965. It was fertilized with 200 pounds 12-12-12 per acre and then top dressed with 100 pounds ammonium nitrate per acre about September 1, 1965. The seeding mixture, in pounds of pure live seed per acre, consisted of: bermuda grass (Cynodon dactylon) - 8, buffalograss (Buchloe dactyloides) - 8, and little hop clover (Trifolium dubium) - 2.5. A few small ditches in the area were mulched with lovegrass hay at two tons per acre. The vegetation present at the time of treatment application consisted of bermudagrass, weeping lovegrass (Eragostis curvula) and buffalograss. The grasses were chlorotic and sparse.

The main plots of this experiment were 18 feet x 144 feet in size. A split-split plot design was used where main plots consisted of three levels of Ben Franklin gypsum: (1) check; (2) one ton per acre; and (3) two tons per acre. The subplots consisted of two levels of herbicide (Banvel D): (1) check; and (2) one pound ai (active ingredient) per acre. The sub-subplots consisted of four levels of fertilizer expressed in pounds actual per acre: (1) check; (2) 0-34-0; (3) 100-0-0; and (4) 100-34-0. The main plots were laid out as a randomized block design with four replications. The gypsum was applied with a Gandy[1] spreader and disked in April 16, 1966. Fertilizer was applied with a Gandy spreader on May 27, 1966. The herbicide was applied with a surfactant in 30 gallons of water per acre with a truck mounted spray boom on June 6, 1966.

The Shawnee experiment was located on a level sandy loam topsoil with a sandy clay loam subsoil. The area was originally treated in June, 1961. It was fertilized with 200 pounds 13-13-13 per acre and

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[1]Manufactured by the Gandy Company in Owatonna, Minnesota.

sprigged with bermudagrass. The bermudagrass was very sparse and clorotic at the time of treatment.

The main plots of this experiment were 20 feet x 144 feet in size. A split plot design was used where main plots consisted of two levels of herbicide (Banvel D): (1) check; and (2) one pound ai per acre. The subplots consisted of four levels of fertilizer expressed in pounds actual per acre: (1) check; (2) 0-34-0; (3) 100-0-0; and (4) 100-34-0. The main plots were laid out as a randomized block design with three replications. The fertilizer was applied with a Gandy spreader on June 28, 1966. The herbicide was applied with a surfactant in 30 gallons of water per acre with a truck mounted spray boom on August 5, 1966.

The Buffalo cut slope experiment was located on a sandy loam soil, on east-west facing cut slopes, each with a 33 per cent grade. The area was originally treated in the summer of 1964 when it was fertilized with 200 pounds 13-13-13 per acre, seeded to weeping lovegrass, and hay mulched. The weeping lovegrass and native sideoats grama (<u>Bouteloua curtipendula</u>) present at the time of treatment application were chlorotic and very sparse.

The design consisted of two slope exposures: (1) East exposure of 75 feet x 480 feet; and (2) West exposure of 60 feet x 480 feet. Each exposure consisted of four levels of fertilizer expressed in pounds actual per acre: (1) check; (2) 0-34-0; (3) 100-0-0; and (4) 100-34-0. Each exposure was laid out as a randomized block design with three replications. The fertilizer was applied with cyclone[2] seeders on July 14, 1966.

The Buffalo fill slope experiment was located on a sandy loam soil on east-west facing fill slopes, each with a 35 per cent grade. This area was originally treated in the summer of 1964, when it was fertilized with 200 pounds of 13-13-13 per acre and sprigged to bermugrass. The bermudagrass was thin and chlorotic and small ditches were beginning to form at the time of treatment.

The design consisted of two slope exposures: (1) East exposure of 75 feet x 240 feet and (2) West exposure of 45 feet x 240 feet. Each exposure consisted of four levels of fertilizer expressed in pounds actual per acre: (1) check; (2) 0-34-0; (3) 100-0-0; and (4) 100-34-0. Each exposure was laid out as a randomized block design with three replications. The fertilizer was applied with cyclone seeders on July 14, 1966.

Plant population counts, reported as mean basal density in percent, or mean ground cover in percent on the Buffalo fill slope experiment, were taken initially when the experiments were started with the final readings being taken during the fall of 1966. Counts were taken, using an inclined point transect on all tests, with the exception of the Buffalo fill slope experiment. Care was taken to avoid sampling immediately adjacent to plot borders. Ten random settings of the inclined plane transect were made in each plot at each reading date at the Eufaula experiment, while 40 random settings were made at the Shawnee and the Buffalo cut slope experiments. A square foot

[2]Manufactured by the Cyclone Seeder Company, Inc., in Urbana, Indiana.

quadrat was used to determine mean bermudagrass ground cover in percent in the Buffalo fill slope experiment with 25 random samples being taken in each plot at each reading date. Readings from each test location were taken from the same predetermined sampling areas for each date.

The method for statistical analysis of data was taken from Steel and Torrie (25). The analyses of variance were calculated on percent basal density, with the exception of the Buffalo fill slope experiment in which percent ground cover was used.

Soil samples were taken from each plot of each experiment to determine levels of pH, phosphorus, potassium, sodium, calcium, and magnesium. Prior to laboratory analyses all samples were air dried, finely ground and screened. Determinations on pH were run both as H_2O pH and 1:1 KCL pH. Phosphorus determination was by the Bray #1 procedure. Potassium, sodium, calcium, and magnesium determination were run on a flame spectrophotometer on a 1 N ammonium acetate extract solution.

CHAPTER IV

RESULTS AND DISCUSSION

The difference of the initial and final readings on grasses from each of the four highway research experiments was analyzed statistically. The effects of nitrogen and phosphorus fertilizer, gypsum, herbicide, and slope exposure on percent mean basal density or percent mean ground cover were evaluated.

Statistical analyses of data taken from the Eufaula experiment indicates nitrogen fertilization to be highly significant in promoting the mean basal density of the total grasses as shown in Figure 1. The response of the grasses to gypsum was inconsistent and not significant. Nitrogen fertilization is highly significant in increasing the basal density of bermudagrass, but not that of weeping lovegrass or buffalograss. There was a significant response by buffalograss to nitrogen x phosphorus interaction even though the buffalograss decreased in the plots during the growing season. Weeping lovegrass showed a significant response to gypsum x herbicide interaction. There was no significant response to phosphorus fertilization by any grass. Also, there was no significant response to herbicide treatment although a small response at the lower fertility levels is shown in Figure 2. There was a difference in weed infestation between the herbicide treated and the check plots, but no actual weed counts were made.

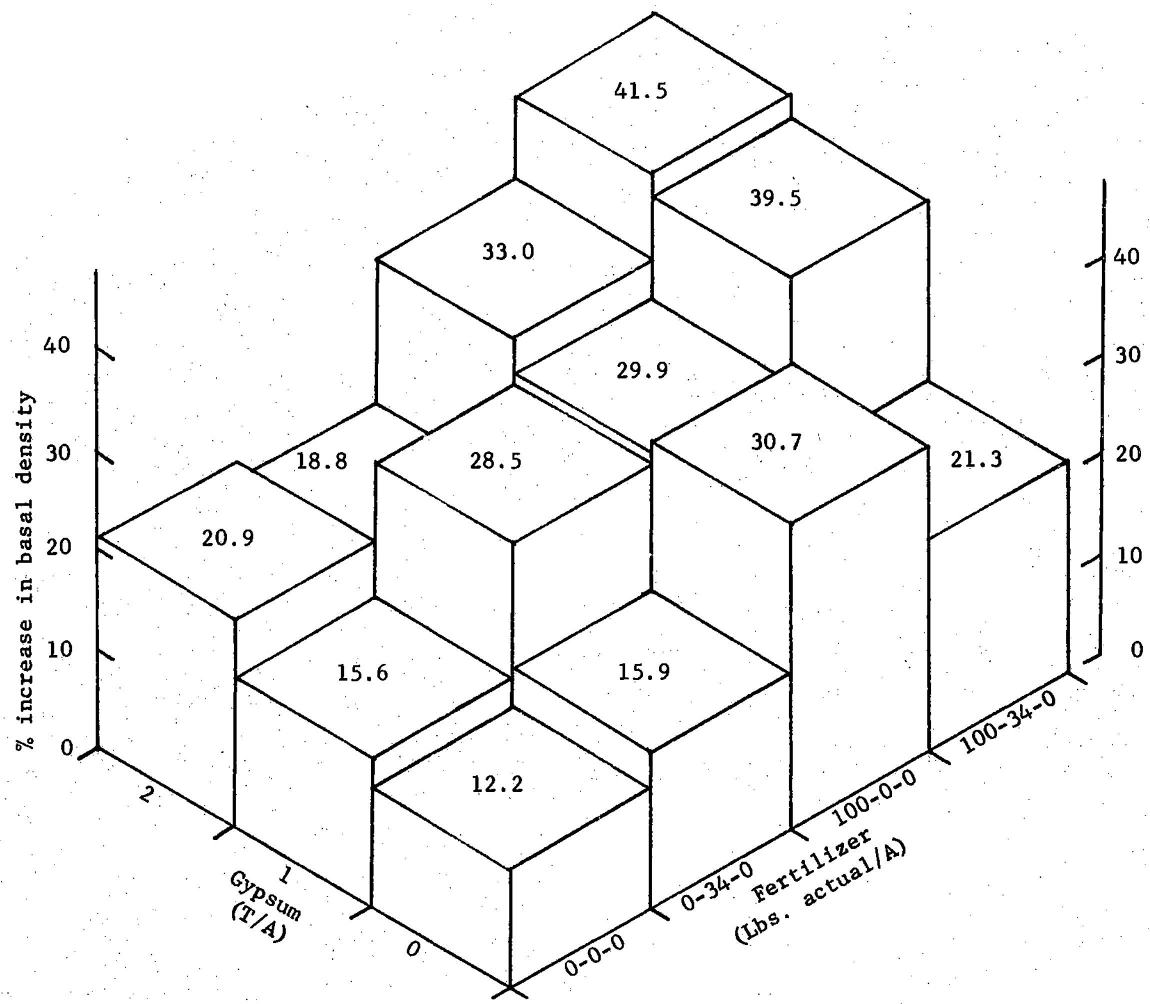

Figure 1. The Effect of Fertilizer and Gypsum on Percent Basal Density of Grasses on the Eufaula Experiment (Averaged over Two Levels of Herbicide).

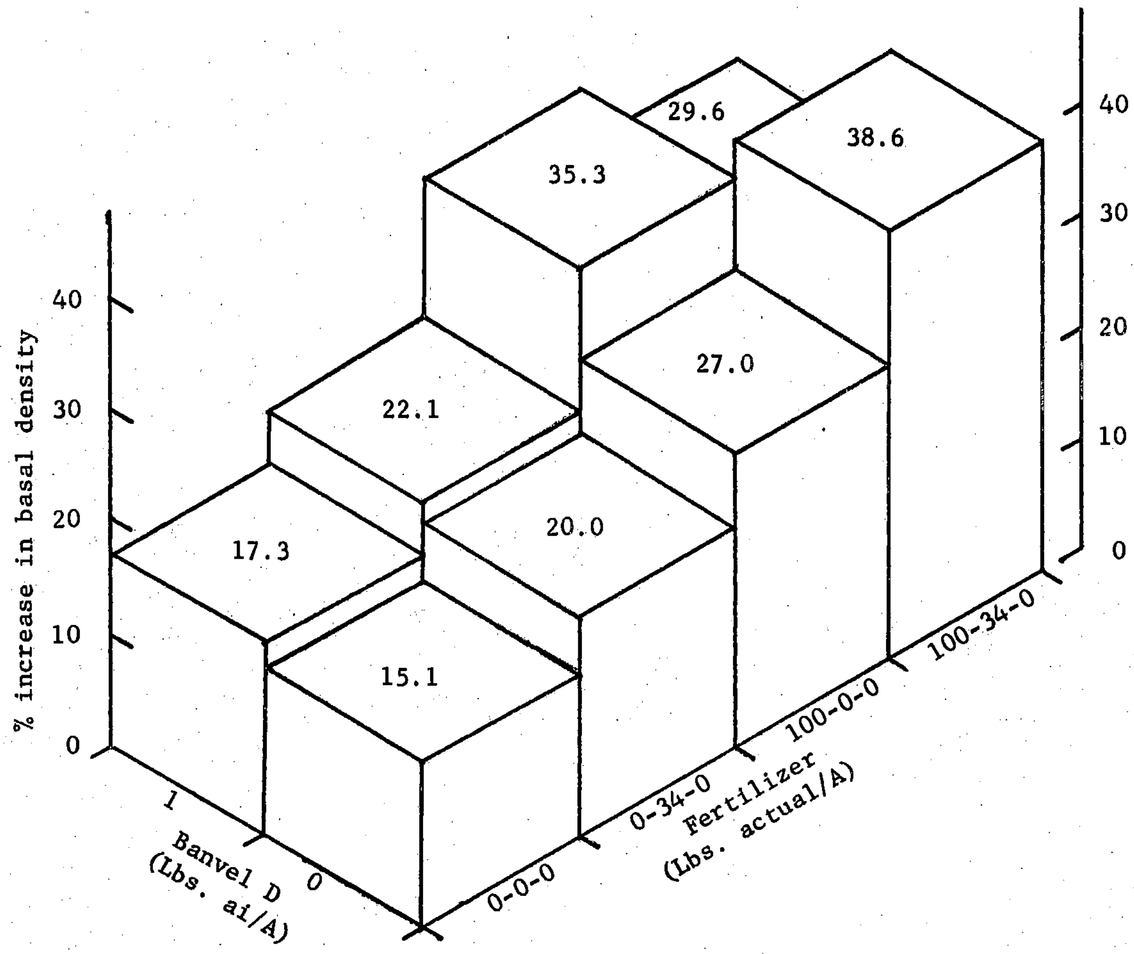

Figure 2. The Effect of Fertilizer and Herbicide on Percent Basal Density of Grasses on the Eufaula Experiment (Averaged over Three Levelr of Gypsum).

The statistical analyses of data from the Shawnee experiment indicates nitrogen fertilization to be highly significant in increasing the mean basal density of bermudagrass as illustrated in Figure 3. There was also a significant difference due to herbicide x nitrogen x phosphorus interaction. No significant difference in percent basal density as influenced by phosphorus fertilization or herbicide application was detected. There was a large infestation of prairie three-awn in the plots which the Banvel D did not take out. This could possibly have hampered the effect of the herbicide in this experiment.

The statistical analysis of data from the Buffalo cut slope experiment shows no significant difference in basal density of side-oats grama and weeping lovegrass to nitrogen or phosphorus fertilization or slope exposure as shown in Figure 4. The percent basal density actually decreased on the two slopes after treatment. Laboratory tests indicate that there was an iron deficiency on the slopes due to the high carbonate content of the soil which may partially account for the lack of response. However, the bunchgrasses (weeping lovegrass and sideoats grama) on the cut slopes should not be expected to respond like bermudagrass in just one growing season. Also, the nitrogen fertilized plots became infested with Russian thistle and this could possibly have an influence on the lack of response to nitrogen fertilization in this experiment.

The statistical analyses of data taken from the Buffalo fill slope experiment indicates nitrogen fertilization to be highly significant in increasing the mean ground cover of bermudagrass as illustrated in Figure 5. The bermudagrass in the nitrogen treated plots was already beginning to cover the small ditches that had been formed

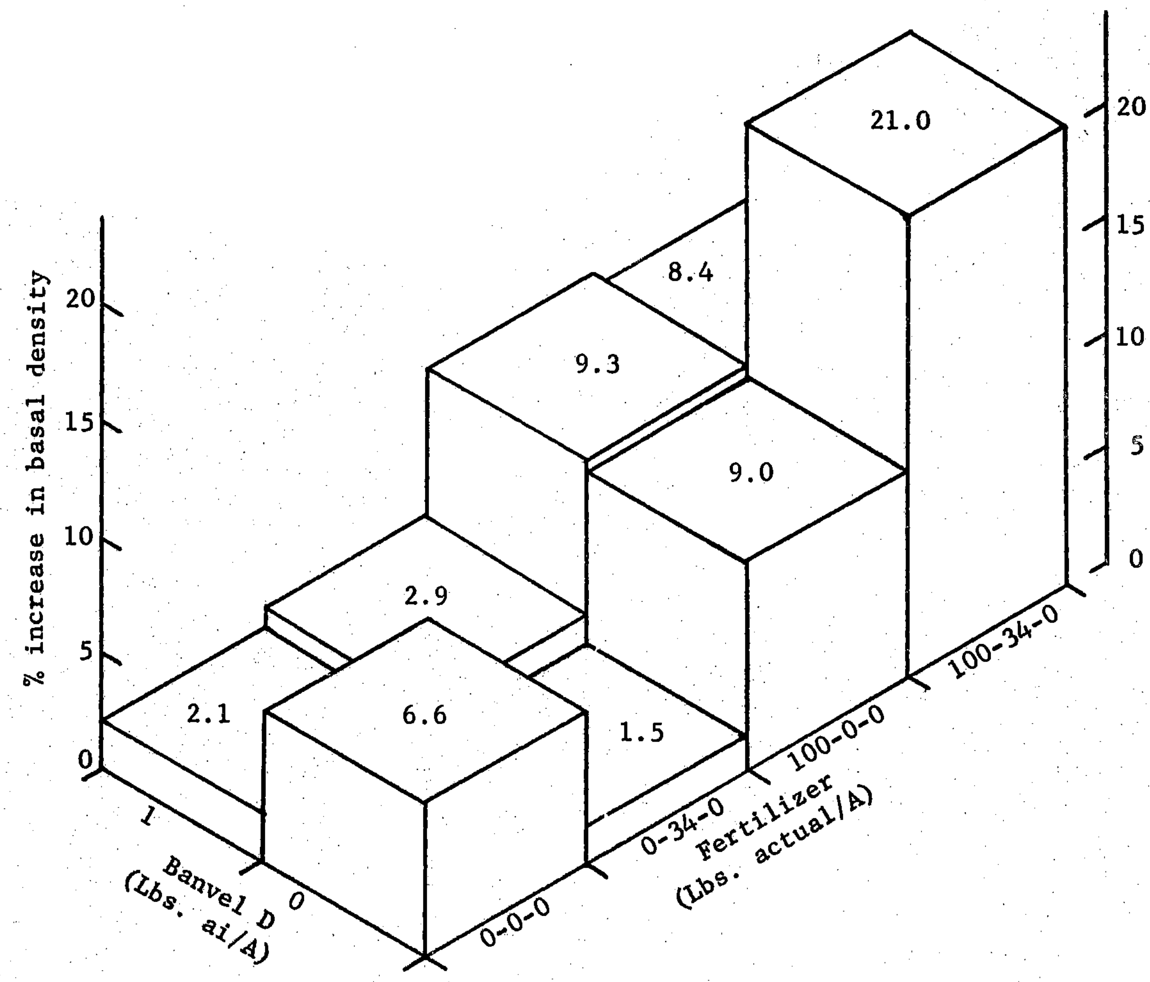

Figure 3. The Effect of Fertilizer and Herbicide on Percent Basal Density of Bermudagrass on the Shawnee Experiment.

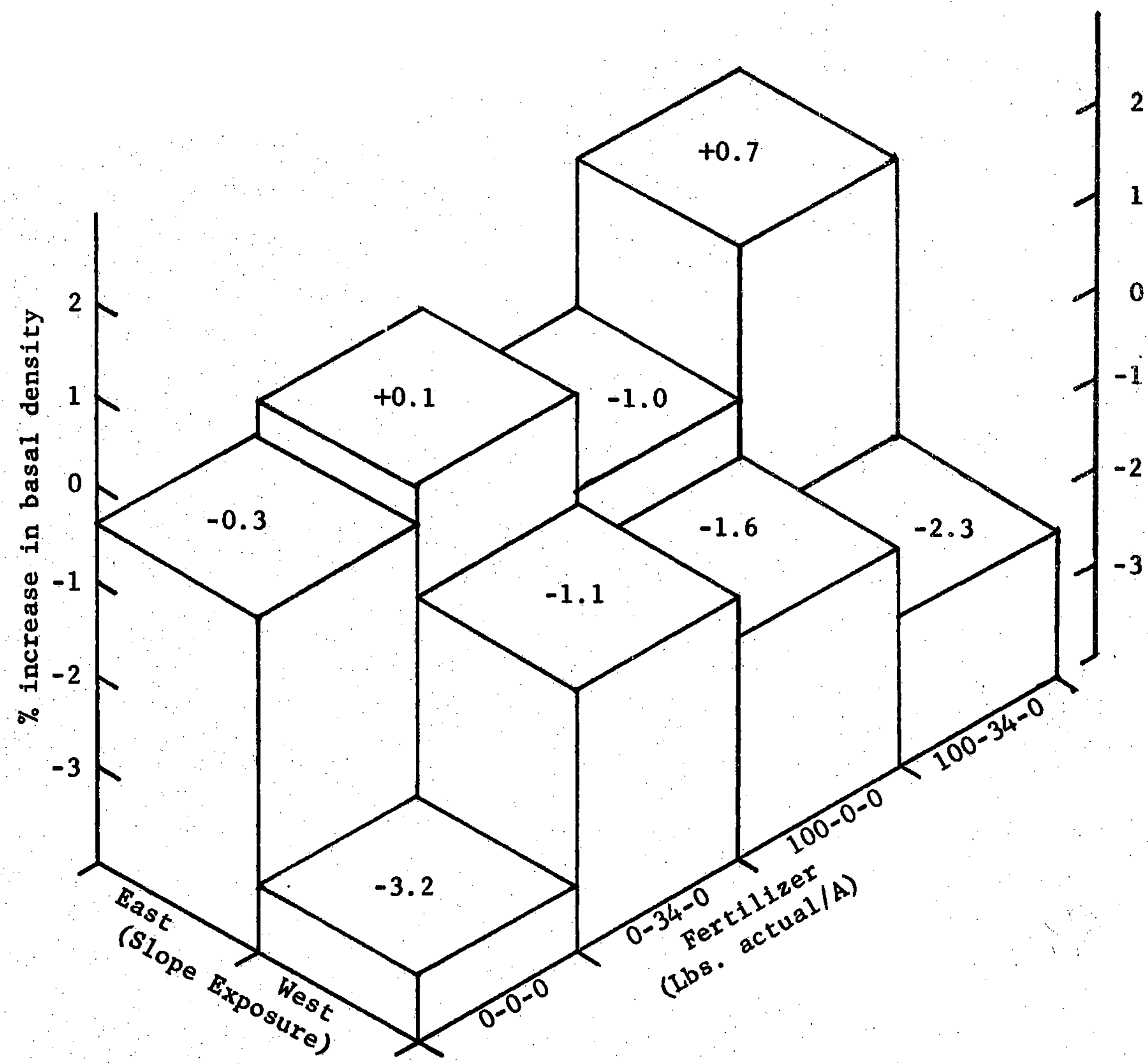

Figure 4. The Effect of Fertilizer and Slope Exposure on Percent Basal Density of Grasses on the Buffalo Cut Slope Experiment.

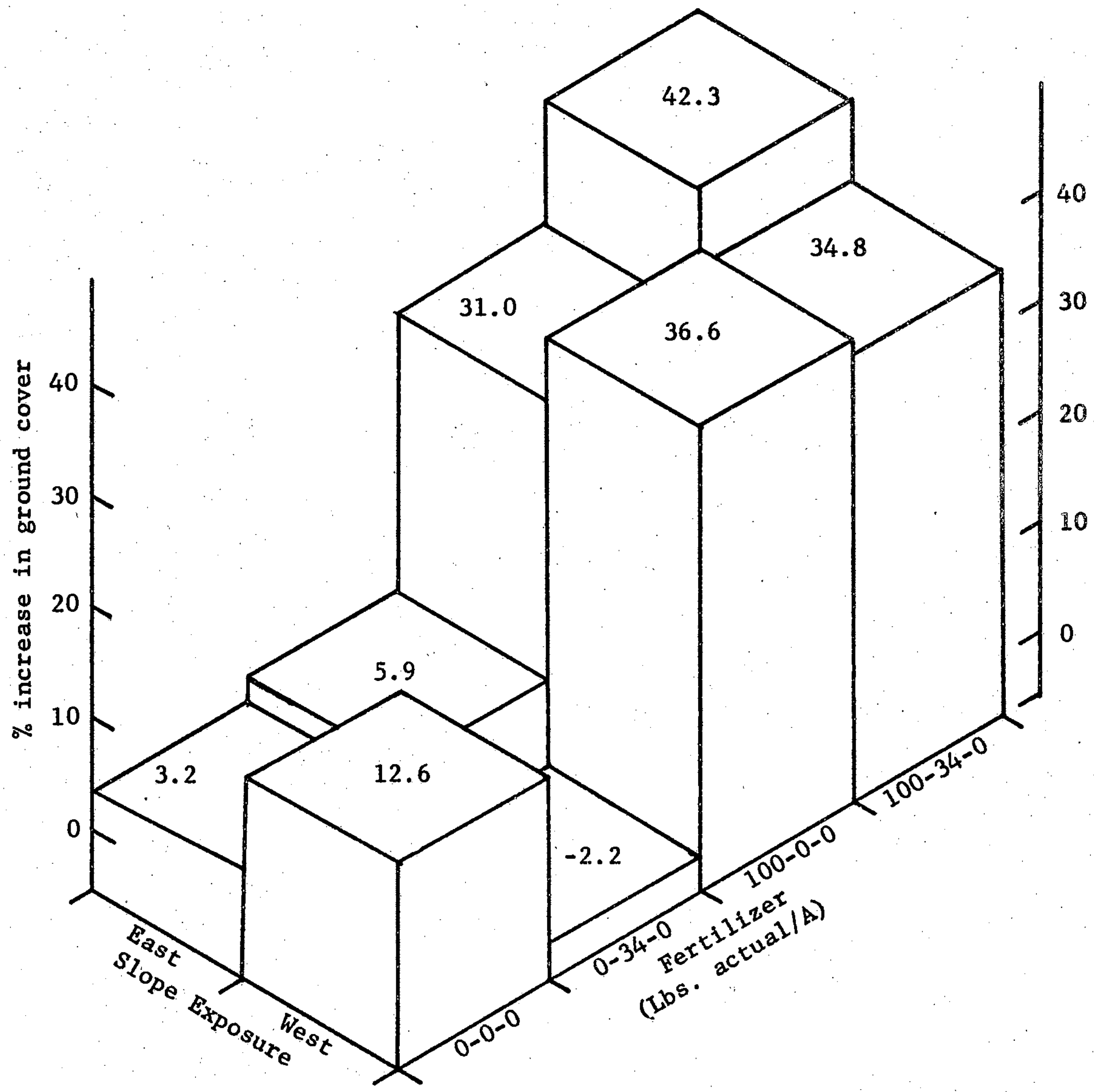

Figure 5. The Effect of Fertilizer and Slope Exposure on Percent Ground Cover of Bermudagrass on the Buffalo Fill Slope Experiment.

before the experiment was started. There was no significant difference due to slope exposure or phosphorus fertilization.

Laboratory analyses of soil samples taken from all research locations are shown in Table V. There was a wide variation in the analysis of the plots of each experiment, probably due to the disturbed nature of the experiment areas. Levels of pH, as determined by both H_2O paste and KCl methods, ranged from slightly acid for the Eufaula and Shawnee experiments to basic for the two Buffalo experiments. Paste pH results consistently averaged about one pH level higher than results obtained by the KCl method. Levels of available phosphorus were low in nearly all plots with only a few over 25 pounds per acre. Available potassium was sufficient in nearly every plot with a few low at 70 pounds per acre. Sodium content of the soils was relatively low.

CHAPTER V

SUMMARY AND CONCLUSIONS

Nitrogen and phosphorus fertilizer, gypsum, and herbicide were evaluated for their effect on establishment and maintenance of a vegetative ground cover for erosion control on three highway areas in Oklahoma. The effect of east-west slope exposure on vegetative cover was measured at one location.

The use of 100 pounds of nitrogen per acre as ammonium nitrate resulted in a significant increase in percent basal density and percent ground cover of bermudagrass at the Eufaula, Shawnee, and Buffalo fill slope experiments. Weeping lovegrass and buffalograss at the Eufaula experiment and lovegrass and sideoats grama at the Buffalo cut slope experiment did not show a significant response to nitrogen fertilization during the growing season.

The use of 80 pounds of P_2O_5 per acre as treble superphosphate (34 pounds actual phosphorus per acre) did not give a significant increase in percent basal density or percent ground cover at any location. Buffalograss at the Eufaula experiment did show a significant response to nitrogen x phosphorus interaction although the total basal density of buffalograss declined during the growing season.

The herbicide treatment of one pound Banvel D per acre was not significant in increasing the percent basal density of grasses at either the Eufaula or the Shawnee experiment. Nor did the application of one or two tons of gypsum per acre at the Eufaula experiment show a significant increase in percent basal density of the grasses. Weeping lovegrass did show a significant response due to gypsum x herbicide interaction at the Eufaula experiment, however.

There was a significant increase in percent basal density of bermudagrass due to nitrogen x phosphorus x herbicide interaction at the Shawnee experiment, but not at the Eufaula experiment. This would tend to indicate that possibly herbicide should be applied with fertilizers for the best vegetative cover.

Neither the east or west slope exposure had a significant influence on the vegetative cover of the slopes at the two Buffalo experiments.

The determination of fertility levels in these highway areas emphasizes the need for proper adjustments of required nutritonal elements for adequate and economical production of vegetation for erosion control. Although soil analysis indicated that potassium was adequate in most of the plots, phosphorus levels were sub-minimal. The results of these four experiments have shown that nitrogen fertilization is necessary for proper vegetation establishment and maintenance. The effects of phosphorus fertilization, although not significant during one growing season, could possibly show up in future years as an improvement in the overwintering ability of grasses or their drought tolerance.

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APPENDIX

TABLE I

AN ANALYSIS OF VARIANCE OF THE EFFECT OF FERTILIZER, GYPSUM AND HERBICIDE TREATMENTS ON THE MEAN BASAL DENSITY OF GRASS VARIETIES ON U. S. 69 NEAR EUFAULA

Bermudagrass

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	95	6884.52				
Replications	3	475.48	158.49	3.83	4.76	
Gypsum (G)	2	216.77	108.38	2.62	5.14	
Error (a)	6	248.32	41.39			
Herbicide (H)	1	65.01	65.01	0.75	5.12	
G x H	2	438.79	219.39	2.45	4.26	
Error (b)	9	781.52	86.84			
Nitrogen (N)	1	1014.00	1014.00	20.11**	4.02	7.15
G x N	2	34.52	17.26	0.34	3.17	
H x N	1	38.76	38.76	0.79	4.02	
Phosphorus (P)	1	49.59	49.59	0.98	4.02	
G x P	2	194.17	97.09	1.93	3.17	
H x P	1	165.38	165.38	3.28	4.02	
N x P	1	6.51	6.51	0.13	4.02	
G x H x N	2	98.47	49.24	0.98	3.17	
G x H x P	2	98.23	48.62	0.96	3.17	
G x N x P	2	120.57	60.28	1.20	3.17	
H x N x P	1	112.67	112.67	2.23	4.02	
G x H x N x P	2	3.07	1.53	0.03	3.17	
Error (c)	54	2723.69	50.44	8.78		

Weeping Lovegrass

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	95	1074.64				
Replications	3	353.68	117.89	8.78*	4.76	9.78
Gypsum (G)	2	10.56	5.28	0.39	5.14	
Error (a)	6	80.60	13.43			

TABLE I (Continued)

Weeping Lovegrass (Continued)

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Herbicide (H)	1	15.84	15.84	1.54	5.12	
G x H	2	127.56	63.78	6.20*	4.26	8.02
Error (b)	9	92.53	10.28			
Nitrogen (N)	1	0.84	0.84	0.14	4.02	
G x N	2	7.75	3.88	0.63	3.17	
H x N	1	12.76	12.76	2.06	4.02	
Phosphorus (P)	1	8.17	8.17	1.32	4.02	
G x P	2	1.08	0.54	0.09	3.17	
H x P	1	1.04	1.04	0.17	4.02	
N x P	1	12.04	12.04	1.94	4.02	
G x H x N	2	3.27	1.64	0.26	3.17	
G x H x P	2	3.40	1.70	0.27	3.17	
G x N x P	2	7.77	3.89	0.63	3.17	
H x N x P	1	0.17	0.17	0.03	4.02	
G x H x N x P	2	1.02	0.51	0.08	3.17	
Error (c)	54	334.56	6.20			

Buffalograss

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	95	261.76				
Replications	3	26.13	8.71	1.35	4.76	
Gypsum (G)	2	6.63	3.32	0.51	5.14	
Error (a)	6	38.64	6.44			
Herbicide (H)	1	1.38	1.38	0.48	5.12	
G x H	2	7.04	3.52	1.22	4.26	
Error (b)	9	25.99	2.89			
Nitrogen (N)	1	1.90	1.90	0.89	4.02	
G x N	2	4.89	2.45	1.14	3.17	
H x N	1	0.02	0.02	0.01	4.02	
Phosphorus (P)	1	0.44	0.44	0.21	4.02	
G x P	2	1.10	0.55	0.26	3.17	
H x P	1	0.32	0.32	0.15	4.02	
N x P	1	9.07	9.07	4.24*	4.02	7.15
G x H x N	2	7.80	3.90	1.82	3.17	
G x H x P	2	1.69	0.85	0.40	3.17	
G x N x P	2	4.63	2.32	1.08	3.17	

TABLE I (Continued)

Buffalograss (Continued)

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
H x N x P	1	0.32	0.32	0.15	4.02	
G x H x N x P	2	8.22	4.11	1.92	3.17	
Error (c)	54	115.55	2.14			

Total Grasses

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	95	7005.46				
Replications	3	406.77	135.59	3.14	4.76	
Gypsum (G)	2	378.32	189.16	4.38	5.14	
Error (a)	6	259.24	43.21			
Herbicide (H)	1	9.38	9.38	0.09	5.12	
G x H	2	190.33	95.16	0.90	4.26	
Error (b)	9	900.30	100.03			
Nitrogen (N)	1	1155.09	1155.09	22.52**	4.02	7.15
G x N	2	31.83	15.91	0.31	3.17	
H x N	1	5.51	5.51	0.11	4.02	
Phosphorus (P)	1	88.17	88.17	1.72	4.02	
G x P	2	186.63	93.32	1.82	3.17	
H x P	1	130.67	130.67	2.55	4.02	
N x P	1	3.76	3.76	0.07	4.02	
G x H x N	2	100.69	50.35	0.98	3.17	
G x H x P	2	141.60	70.80	1.38	3.17	
G x N x P	2	124.16	62.08	1.21	3.17	
H x N x P	1	119.26	119.26	2.33	4.02	
G x H x N x P	2	5.19	2.60	0.05	3.17	
Error (c)	54	2768.56				

TABLE II

AN ANALYSIS OF VARIANCE OF THE EFFECT OF FERTILIZER AND HERBICIDE TREATMENTS ON THE MEAN BASAL DENSITY OF BERMUDAGRASS ON U. S. 177 NEAR SHAWNEE

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	23	1346.49				
Replications	2	72.38	36.19	0.50	19.00	
Herbicide (H)	1	87.21	87.21	1.19	18.51	
Error (a)	2	146.11	73.05			
Nitrogen (N)	1	457.19	457.19	18.45**	4.75	9.33
H x N	1	28.71	28.71	1.16	4.75	
Phosphorus (P)	1	17.94	17.94	0.72	4.75	
H x P	1	17.09	17.09	0.69	4.75	
N x P	1	93.02	93.02	3.75	4.75	
H x N x P	1	129.50	129.50	5.23*	4.75	9.33
Error (b)	12	297.34	24.78			

TABLE III

AN ANALYSIS OF VARIANCE OF THE EFFECT OF FERTILIZER TREATMENTS AND SLOPE EXPOSURE ON MEAN BASAL DENSITY OF GRASS VARIETIES ON EAST-WEST FACING CUT SLOPES ON S. H. 34 NEAR BUFFALO

Weeping Lovegrass

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	23	580.17				
Replications	2	111.39	55.69	1.90	19.00	
Slope (S)	1	96.33	96.33	3.28	18.51	
Error (a)	2	58.76	29.38			
Nitrogen (N)	1	0.75	0.75	0.03	4.75	
S x N	1	0.33	0.33	0.02	4.75	
Phosphorus (P)	1	1.69	1.69	0.08	4.75	
S x P	1	4.69	4.69	0.22	4.75	
N x P	1	13.02	13.02	0.61	4.75	
S x N x P	1	35.02	35.02	1.63	4.75	
Error (b)	12	258.19	21.52			

Sideoats Grama

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	23	44.16				
Replications	2	1.64	0.82	1.00	19.00	
Slope (S)	1	10.08	10.08	12.33	18.51	
Error (a)	2	1.64	0.82			
Nitrogen (N)	1	1.33	1.33	0.59	4.75	
S x N	1	1.33	1.33	0.59	4.75	
Phosphorus (P)	1	0.52	0.52	0.23	4.75	
S x P	1	0.52	0.52	0.23	4.75	
N x P	1	0.02	0.02	0.01	4.75	
S x N x P	1	0.02	0.02	0.01	4.75	
Error (b)	12	27.06	2.26			

TABLE III (Continued)

Total Grasses

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	23	567.65				
Replications	2	91.95	45.97	1.38	19.00	
Slope (S)	1	44.08	44.08	1.32	18.51	
Error (a)	2	66.70	33.35			
Nitrogen (N)	1	0.08	0.08	0.003	4.75	
S x N	1	0.33	0.33	0.01	4.75	
Phosphorus (P)	1	0.33	0.33	0.01	4.75	
S x P	1	8.33	8.33	0.33	4.75	
N x P	1	14.08	14.08	0.55	4.75	
S x N x P	1	36.75	36.75	1.45	4.75	
Error (b)	12	305.02	25.42			

TABLE IV

AN ANALYSIS OF VARIANCE OF THE EFFECT OF FERTILIZER TREATMENTS AND SLOPE EXPOSURE ON MEAN GROUND COVER OF BERMUDAGRASS ON EAST-WEST FACING FILL SLOPES ON S. H. 34 NEAR BUFFALO

Source	d.f.	S. S.	M. S.	F (Cal.)	F (Tab.) 5%*	F (Tab.) 1%**
Total	23	3686.73				
Replications	2	2.97	1.49	0.25	19.00	
Slope (S)	1	0.07	0.07	0.01	18.51	
Error (a)	2	12.10	6.05			
Nitrogen (N)	1	2931.26	2931.26	74.69**	4.75	9.33
S x N	1	2.20	2.20	0.06	4.75	
Phosphorus (P)	1	1.37	1.37	0.04	4.75	
S x P	1	174.41	174.41	4.44	4.75	
N x P	1	87.74	87.74	2.24	4.75	
S x N x P	1	3.58	3.58	0.09	4.75	
Error (b)	12	471.03	39.25			

TABLE V

SOIL ANALYSES OF HIGHWAY RESEARCH AREAS

Location	Plot	pH (H_2O)	pH (KCl)	Pounds Available Per Acre P	Pounds Available Per Acre K	Parts Per Million Na	Parts Per Million Ca	Parts Per Million Mg
Eufaula	101	6.7	5.6	11.3	310	785	1450	1500
	102	6.5	5.5	7.5	270	595	1425	1310
	103	6.4	5.5	7.5	285	695	1450	1370
	104	6.6	5.6	7.5	300	770	1540	1400
	105	6.2	5.3	7.5	285	610	1150	950
	106	5.9	5.1	7.5	285	355	1065	670
	107	6.3	5.3	7.5	240	310	725	510
	108	6.1	5.2	11.3	240	345	830	605
	109	6.4	5.3	3.8	285	770	1490	1370
	110	6.1	5.0	3.8	300	580	1480	1340
	111	5.8	5.0	7.5	285	570	1450	1400
	112	5.4	4.5	3.8	285	550	1380	1370
	113	6.3	5.2	3.8	285	535	1220	840
	114	6.3	5.4	3.8	270	450	1200	685
	115	6.3	5.3	7.5	220	355	850	590
	116	6.4	5.5	3.8	220	465	1110	810
	117	6.3	5.4	3.8	270	645	1490	1305
	118	6.7	5.8	3.8	270	595	1480	1275
	119	6.8	5.9	3.8	285	770	1425	1400
	120	6.7	5.7	3.8	285	730	1425	1430
	121	6.7	5.7	3.8	255	610	1265	890
	122	6.8	5.9	7.5	240	710	1380	875
	123	6.7	5.9	7.5	220	490	970	735
	124	5.7	4.9	7.5	650	320	1110	950
	201	6.8	5.8	3.8	140	410	805	700
	202	6.6	5.8	3.8	150	410	900	670
	203	6.5	5.5	3.8	140	280	690	525
	204	6.6	5.6	7.5	140	425	935	700
	205	6.4	5.3	7.5	140	400	935	700
	206	6.4	5.4	3.8	140	475	970	765
	207	6.4	4.9	7.5	100	135	470	330
	208	5.5	4.2	7.5	120	100	425	365
	209	6.5	5.1	7.5	90	75	340	235
	210	6.5	5.3	7.5	90	60	390	175
	211	6.2	5.0	7.5	70	60	290	195

TABLE V (Continued)

Location	Plot	pH (H_2O)	pH (KCl)	Pounds Available Per Acre P	Pounds Available Per Acre K	Parts Per Million Na	Parts Per Million Ca	Parts Per Million Mg
Eufaula (Continued)	212	6.5	5.1	11.3	70	75	310	220
	213	5.7	4.7	7.5	100	255	725	590
	214	6.2	5.2	7.5	100	240	700	560
	215	6.3	5.1	7.5	70	65	275	195
	216	6.0	4.9	3.8	80	65	265	195
	217	6.3	5.0	7.5	80	95	280	195
	218	6.7	5.4	7.5	80	100	370	285
	219	6.3	5.1	7.5	80	70	275	160
	220	6.5	4.9	7.5	70	95	320	250
	221	6.2	5.0	7.5	150	410	925	715
	222	6.2	5.1	11.3	150	320	865	625
	223	6.3	5.0	3.8	100	95	340	330
	224	6.3	5.0	7.5	70	65	280	210
	301	6.0	5.3	11.3	250	400	1270	840
	302	5.5	4.9	7.5	250	280	985	730
	303	5.6	4.8	7.5	340	300	985	920
	304	5.4	4.5	7.5	310	320	985	920
	305	5.0	4.1	7.5	330	265	960	855
	306	5.8	5.1	7.5	330	290	1450	985
	307	5.5	4.7	7.5	380	255	970	875
	308	5.1	4.2	11.3	330	215	850	795
	309	5.2	4.4	3.8	340	350	960	895
	310	5.1	4.2	3.8	340	275	960	895
	311	5.0	4.1	7.5	250	215	885	715
	312	5.4	4.6	7.5	340	320	985	920
	313	5.5	4.6	3.8	300	320	1310	935
	314	5.3	4.3	11.3	440	205	935	795
	315	5.5	4.6	7.5	360	240	950	795
	316	5.6	4.6	7.5	280	230	885	750
	317	5.3	4.3	7.5	470	230	925	840
	318	5.2	4.0	11.3	520	215	935	855
	319	5.2	4.1	18.9	560	200	910	825
	320	5.3	4.2	7.5	460	200	900	795
	321	5.3	4.2	7.5	460	200	900	795
	322	5.2	4.2	15.1	560	140	875	750
	323	5.2	4.1	11.3	470	145	865	730
	324	5.3	4.2	7.5	310	180	850	730
	401	5.2	4.2	3.8	225	250	460	430
	402	5.5	4.3	30.2	180	55	320	300
	403	5.6	4.4	49.0	110	65	375	350
	404	5.4	4.6	11.3	800	165	865	795
	405	5.2	4.1	7.5	550	160	725	635

TABLE V (Continued)

Location	Plot	pH (H_2O)	pH (KCl)	Pounds Available Per Acre P	Pounds Available Per Acre K	Parts Per Million Na	Parts Per Million Ca	Parts Per Million Mg
Eufaula (Continued)	406	5.2	4.1	18.9	510	105	620	560
	407	5.0	4.0	7.5	475	180	790	780
	408	6.2	5.2	7.5	270	435	960	890
	409	6.2	5.2	7.5	90	40	235	115
	410	6.1	5.0	18.9	90	40	210	85
	411	6.0	5.1	7.5	80	30	210	330
	412	5.5	4.6	7.5	255	65	375	330
	413	4.9	4.0	11.3	475	120	645	635
	414	5.1	4.2	18.9	475	120	645	625
	415	4.9	4.1	37.7	540	180	815	810
	416	6.3	5.3	11.3	240	310	690	685
	417	6.1	5.1	105.6	90	35	220	160
	418	6.1	5.1	7.5	90	45	220	175
	419	6.1	4.9	7.5	90	40	220	175
	420	6.1	4.9	22.6	90	50	265	135
	421	5.1	4.1	45.2	595	155	645	590
	422	5.7	4.7	11.3	350	320	950	875
	423	5.3	4.3	11.3	305	205	755	715
	424	6.1	5.0	7.5	135	200	500	400
Shawnee	101	7.7	6.7	3.8	270	435	1025	920
	102	7.5	6.5	3.8	255	330	865	795
	103	7.4	6.3	3.8	255	400	790	765
	104	7.1	6.1	3.8	225	190	700	605
	105	6.6	5.6	7.5	210	95	575	510
	106	6.7	5.6	7.5	210	85	625	525
	107	6.6	5.6	3.8	210	90	635	560
	108	7.0	6.0	3.8	200	90	690	590
	201	7.6	6.5	3.8	240	155	1100	670
	202	7.8	6.7	3.8	240	240	980	655
	203	7.0	5.9	3.8	255	320	960	795
	204	6.7	5.7	3.8	225	265	775	670
	205	6.5	5.5	7.5	210	130	680	485
	206	6.7	5.8	7.5	210	110	660	450
	207	7.2	6.3	3.8	210	90	1065	510
	208	7.6	6.8	3.8	200	80	940	400
	301	6.8	6.0	3.8	285	155	960	765
	302	6.8	5.9	3.8	315	155	1110	765
	303	6.1	5.2	3.8	300	85	700	560
	304	6.5	5.5	3.8	300	120	780	590
	305	6.3	5.4	7.5	285	85	660	590
	306	6.6	5.8	7.5	240	60	740	510

CHAPTER V (Continued)

Location	Plot	pH (H_2O)	pH (KCl)	Pounds Available Per Acre P	Pounds Available Per Acre K	Parts Per Million Na	Parts Per Million Ca	Parts Per Million Mg
Shawnee (Continued)	307	7.0	6.3	7.5	270	80	1310	605
	308	7.0	6.3	7.5	255	45	660	465
Buffalo Cut Slope (East Exp.)	101	8.0	7.4	49.0	165	80	1250	860
	102	8.0	7.4	7.5	180	105	1200	990
	103	8.1	7.3	41.5	180	165	1450	860
	104	8.1	7.2	11.3	200	205	1515	1050
	201	7.8	7.2	7.5	255	270	1825	1310
	202	7.9	7.2	7.2	180	135	1250	730
	203	7.8	7.1	3.8	180	245	1495	1240
	204	7.9	7.2	7.5	210	185	1515	1050
	301	7.8	7.1	7.5	180	135	1400	1180
	302	8.0	7.4	7.5	200	80	1200	800
	303	7.8	7.2	11.3	210	50	1220	960
	304	7.8	7.2	7.5	300	40	1425	630
Buffalo Cut Slope (West Exp.)	101	7.9	7.4	15.1	210	115	1330	590
	102	8.0	7.4	15.1	210	105	1265	560
	103	8.2	7.5	7.5	210	85	1250	560
	104	8.1	7.5	3.8	165	85	1200	635
	201	8.2	7.5	11.3	165	75	1110	620
	202	8.0	7.4	15.1	165	95	1220	840
	203	8.0	7.5	3.8	165	70	1175	715
	204	8.1	7.4	11.3	150	60	1065	715
	301	8.1	7.3	3.8	150	55	1065	685
	302	8.0	7.4	15.1	150	45	1045	715
	303	8.0	7.4	15.1	150	60	1130	700
	304	7.9	7.4	3.8	150	70	1110	715
Buffalo Fill Slope (East Exp.)	104	7.7	7.1	11.3	180	50	1200	685
	201	7.7	7.1	7.5	180	35	1200	540
	301	7.7	7.1	7.5	200	55	1220	495
Buffalo Fill Slope (West Exp.)	102	7.8	7.1	22.6	225	40	1250	285
	203	7.7	7.0	30.2	225	40	1250	330
	301	7.7	7.0	15.1	210	52	1290	300

VITA

Larry Dean Maddux

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF FERTILIZER, GYPSUM, AND HERBICIDE ON ESTABLISHMENT AND MAINTENANCE OF A VEGETATIVE GROUND COVER FOR EROSION CONTROL ON OKLAHOMA HIGHWAYS

Major Field: Agronomy

Biographical:

Personal Data: Born at Watonga, Oklahoma, July 5, 1943, the son of Roy and Dorothy Maddux.

Education: Graduated from Watonga High School, Watonga, Oklahoma, in May, 1961; received Bachelor of Science degree in Agriculture Education at Oklahoma State University in May, 1965; completed the requirements for a Master of Science degree in May, 1967.

Experience: Reared on a wheat and Grade-A dairy farm near Watonga, Oklahoma; worked as a farm laborer during the summers of 1959 through 1963; employed as a field-man by Stanford-Vadder Entomology Service of Plainview, Texas during the summer of 1964; employed as a research assistant by the Agronomy Department while a graduate student at Oklahoma State University from May, 1965 to May, 1967.

Member: American Society of Agronomy and Soil Science Society of America.