REVEGETATION OF STRIP
MINE SPOILS

By

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CHAPTER I

INTRODUCTION

Surface mining is an important means of extracting minerals to meet our nation's energy and material needs. About 0.14 percent of the total land area of the United States had been disturbed by surface mining prior to 1965 (33). Approximately one-third of the above 3.2 million acres disturbed by surface mining has been "adequately reclaimed," either by natural forces or by man's own efforts. Of the approximately 1.1 million acres "adequately reclaimed", 46 percent was stabilized by natural processes, 51 percent reclaimed by the mining industry and individual landowners, and the remaining 3 percent by some level of government.

Strip mining of coal accounted for approximately 41 percent of the total acreage surface mined in the United States prior to 1965 (33). Currently the future appears promising for the coal industry. Energy demands are expected to triple within the next 30 years, oil and gas reserves are being used faster than new ones are being found, nuclear development is behind schedule, and the United States possesses abundant coal reserves. States with coal readily accessible from the surface will undoubtedly experience an increase in coal strip mining. Oklahoma is one such state with the eastern one-third of the state well supplied with large reserves of bituminous coal. In addition, the recently completed McClellan-Kerr Arkansas River Navigation

System provides an economical means of transporting the coal to foreign and domestic markets. At the present time, coal from Oklahoma is being shipped to Japan via the navigation system.

Roughly 21 percent of the total area of Oklahoma (approximately 14,550 square miles) is underlain by coal-bearing rocks of Pennsylvanian Age with 17 of Oklahoma's 77 counties having coal present at the land surface (31). Reserves of low and medium-volatile butuminous coals, which are particularly useful as a smokeless heating fuel and for making coke, are concentrated in Haskell and Leflore Counties (Figure 1).

Figure 1. Dragline Near Stigler, Oklahoma Removing Over 90 Feet of Overburden for an 18 Inch Seam of Coal.

Surface mining coal has become increasingly important in Oklahoma and accounted for 99 percent or more of Oklahoma's coal production during the years 1964-67 (18). The surface mining system used in Oklahoma is called "area strip mining", and is best suited to relatively flat terrain. In this type of surface mining draglines or shovels are used to make a trench or "box cut" through the overburden to expose a portion of the coal deposit, which is then removed. Succeeding parallel cuts are made and the spoil (overburden) is deposited in the cut just previously made. The final cut leaves an open trench as deep as the thickness of the overburden plus the thickness of the coal seam. The open trench is bounded on one side by the last spoil bank and on the other by the undisturbed highwall. An area strip mined in this manner usually resembles the ridges of a gigantic washboard or plowed field.

If special steps are not taken during the strip mining operation, such as stockpiling the topsoil, the soil profile will be inverted to a large degree. The topsoil is usually placed near the bottom of the preceeding cut with the parent material and rock from underlying formations piled on top. The rock is usually a poor substitute for the topsoil. Besides usually being deficient in nutrients essential for good plant growth, the fragmented rock may range in size from fine gravel to boulder size. Furthermore, some rocks produce harmful acid on exposure.

Twenty-four thousand acres of land had been strip mined for coal in 15 Oklahoma counties prior to 1968 with over half of these acres in Haskell, Rogers, Craig, and Wagoner Counties (18). Most of the 24,000 acres have been allowed to revegetate on their own, since the mining companies had no obligation for land restoration prior to 1968. The natural revegetation is varied and scattered but numerous areas are still almost completely devoid of plant life.

The major objectives of this thesis were: 1) Develop an awareness and basic understanding of the different environmental conditions encountered by plants on strip mine spoils, especially those conditions detrimental to plant establishment and growth, and 2) Determine the potential for revegetating Eastern Oklahoma coal strip mine spoils. Sub-objectives of (2) included (a) Identifying grass and/or legume species potentially suitable as revegetation species and (b) Determining treatments necessary for initial plant establishment.

CHAPTER II

LITERATURE REVIEW

All 50 states have acreages that have been disturbed by some form of surface mining. Revegetation of strip mined areas is a complex and difficult task at best. Just as there are many varied and different soils in the United States, there are also many types of spoil materials exposed to various environments. A review of the diverse chemical, physical, and biological conditions encountered on strip mine spoils plus past revegetation efforts provides considerable insight and understanding of the revegetation task.

Acidity

Jemison (17) stated that acidity is one of two major chemical problems associated with coal strip mine spoils, the other is low fertility. The most acid material is usually in the coal itself, in the overlying bone coal, and in bony and shaly inclusions in the coal seam, some seams being characteristically associated with higher levels of acidity than others.

Barnhisel and Massey (1) in Kentucky, found that in addition to the strong acidity of certain spoil materials, Fe, Mn, Cu, Ni, and Zn approached toxic levels and posed serious problems in the establishment of plant cover on spoils. Grandt (12) noted that the primary source of toxicity on strongly acid areas is caused by elements or salts brought into solution by strong acidity rather than the "acidity" per se. Toxic aluminum and manganese are most limiting to plant growth on acid spoils.

Struthers (25) explained that soil acidity caused by exchangeable or adsorbed ions, in which salts are not involved is very different from spoil bank acidity which involves free sulfuric acid. Acidity in strip mine spoils originates from pyrite particles in the rock, which decompose when exposed to air and moisture forming ferric sulfate and sulfuric acid. The sulfuric acid attacks other rock fragments and forms soluble salts. If enough limestone and other basic materials are present in the rock, the acid is neutralized, and mostly neutral salts are formed. Without sufficient lime, sulfate salts of iron and aluminum are produced causing the acidity often found in spoil banks. Blevins, Bailey, and Ballard (2) described the reaction involving the decomposition of pyrite in the absence of calcium carbonate as follows:

$$1\ FeS_2 + H_2O + 7\frac{1}{2} \qquad\qquad Fe_2\ (SO_4)_3 + H_2\ SO_4$$

Struthers and Vimmerstedt (28) concluded that the high concentration of salts, especially if acidic, is the chief cause of poor plant survival on spoil banks. Gypsum, at moderate concentrations in spoils is not harmful, but if gypsum reaches the saturation point, it reduces the moisture available to plants for growth.

Lysimeter studies in Ohio on 4 different classes of spoil materials based on spoil pH indicated that pyrite oxidation and concomitant weathering of other minerals decreases with time (38). Spoils were classified according to the following criteria:

Toxic - pH of surface material less than 4.0 on more than 75% of the area.

Acid - pH from 4.0 to 6.9 on over half of the surface area.

Marginal - one-half to three-quarters of the surface material with a pH below 4.0, the remainder acid, calcareous, or mixed.

Calcareous - pH above 7.0 on over half of the surface area.

Initially the toxic spoils yielded 4 times as much total salts as the marginal spoil, and about 20 to 25 times as much as the acid and calcareous spoils. At the end of 8 years there was considerable reduction in total salt yield from the toxic spoils, with a less marked reduction for the other spoil types. Devoting extra care to minimize erosion and maximize infiltration on original toxic spoil banks was recommended (38).

Struthers (27) pointed out that except under very acid conditions, plants can utilize nearly all of the kinds of salts produced. Proper placement or chemical treatment of potentially toxic materials within the spoil bank is the best way to insure adequate plant cover (1, 17). Acid producing layers should be buried deep within the spoil banks or large amounts of limestone added to at least partially neutralize the acids.

Sutton (29) cautioned that lime treatments may be useful in establishing vegetation on small specialized areas that are toxic, however, both he and Kohnke (19) noted that it usually will not be economically feasible to adequately lime areas capable of producing large quantities of acid. A field study by Sutton (29) indicated that when very acid layers are limed, the lime should be mixed thoroughly with the spoil materials and incorporated deeper than 6 to 8 inches to allow for the possible capillary effect of acidic materials below the limed layer.

The amount of liming materials needed to neutralize very strongly acid spoils is enormous. For example, Einspahr, McComb, Reicher, and Sharader (9) noted in their studies of Iowa spoil banks that a gray shale which contained 2 percent oxidizable sulfur would require approximately 62 tons of calcium carbonate per acre to neutralize all the sulfuric acid formed in the surface 6 2/3 inches. This was assuming that all the sulfur was in a form that would be oxidized to sulfuric acid and no leaching losses.

Kohnke (19) concluded that the only practical method is to wait until most of the sulfides have been oxidized and the resulting acid leached out. According to Sutton (30) studies conducted in Ohio showed that large quantities of acid and salts can be removed by leaching with water. However, the infiltration of water into toxic spoil banks is very slow.

Nutrients

Rogers (22) studied the strip mined lands of the Western Interior Coal Province (Missouri, Iowa, Oklahoma, Arkansas, Kansas, and Nebraska). It was noted that the availability of mineral nutrients essential for plant growth varies considerably in strata overlying coal seams. These strata, randomly mixed in the stripping operation, produced spoil banks which varied greatly in chemical composition from area to area and from spot to spot within an area.

Einspahr (8) studied shale-derived soils in Iowa. His studies indicated that soils derived from Pennsylvanian Age parent materials commonly found in the strip mined areas of Iowa inherently will be soils with a low level of fertility. This is also true in Oklahoma where Garner (10) found that the Pennsylvanian Age spoils of Oklahoma are deficient in nutrients.

Barnhisel and Massey (1) reported that low levels of calcium, potassium, phosphorus, and nitrogen contributed to sparse plant stands and retarded plant growth on Kentucky strip mine spoils. Although he listed low fertility as a major chemical problem on spoils, Jemison (17) stated that many, if not all, of the nutrients other than nitrogen are commonly present in spoil and become available as the rock fragments break down under weathering action.

Schessler and Druege (23) did not consider low nutrient availability of some spoils as being a serious problem since according to them the nutrient demand of many species used for revegetation is not high and enough nutrients generally are available in spoils for growth. Struthers (25) reported that soluble mineral nutrients were generally more abundant in spoils than in Ohio soils.

Young (43) studied the ecology of roadside treatment, He found that when fertility is a limiting factor the interaction of fertility and water can lower plant tolerances to drouth to lethal levels.

Particle Sizes

Most spoils are classified as Entisols (recent soils). Entisols are mineral soils without natural genetic horizons or with only the beginnings of such horizons. Kohnke (19) suggested that the rock material in most spoil banks is the beginning of the normal process of soil formation (soil at zero time). According to Schessler and Droege (23), studies have revealed that soil size particles - those with diameters of 2 mm. or less - comprise between 17 and 57 percent of the materials in spoil banks in the United States.

Grandt and Lang (14) stated that in general, the greater the percentage of particles less than or equal to 2 mm., the greater the opportunities for successful reclamation. Further the texture of spoils has an important bearing on aeration and moisture conditions (3, 22).

Weathering

Rogers (22) discussed the weathering of spoil bank surfaces and stated that the surfaces weather largely as a result of the interaction of physical, chemical, climatic, and biological factors. Disintegration is caused principally by freezing and thawing, by wetting and drying, by the beating of rain drops, by the action of winds, and by the pressures of growing plant roots; and generally takes place quite rapidly. Chemical decomposition, on the other hand, is primarily due to the leaching of soluble compounds, and is relatively slow. Cementing agents within rocks vary in chemical composition and solubility which results in rocks decomposing at different rates. The soluble compounds and the smaller-sized particles are leached into the spoil or deposited in the bottoms between the ridges (22).

Schessler and Droege (23) stated that raw spoil bank surfaces weather comparatively quickly, both physically and chemically, due to exposure to the elements and the relative small size of constituent fragments. Disintegration proceeds rapidly during the first 3 to 5 years then slows drastically, whereas chemical decomposition takes place more slowly. In general sandstones and shales break down quickly, while limestones, igneous and metamorphic rocks break down less easily and more slowly (23).

Topography

Doerr (7) stated that mining equipment and methods influence the character of the stripped terrain almost as significantly as structure and stratigraphy. For instance, when draglines or power shovels are used singly a high percentage of the rock strata immediately above the coal is placed on top of the spoil banks. This usually creates sharp serrate ridges or conical banks, which, because of their steep slopes, are quickly eroded.

Kohnke (19) pointed out that where the overburden has been removed with a power shovel the ridges are of approximately the same height for some distance but where a dragline is used the ridges are composed of a series of hillocks. Since these machines are operated to deposit the overburden as far from the exposed coal as possible, no uniform spreading of the spoil material over the area is attained. Each bucket load is dropped on or near the preceding one and the earth and stones slide down on both sides forming a ridge. The natural angle of repose of this material is usually from 80 to 90 percent. The stonier the overburden the steeper is the angle of repose. Considerable settling usually occurs during the first year or two, causing a decrease in the percent slope of the ridges. Very shaley spoils may remain as 80 percent slopes for 25 years (19).

Rogers (22) found that the actual width, height, and steepness of spoil bank ridges vary with the character and thickness of the overburden, the width of the cut, the type of stripping equipment used, and the age of the spoil banks. The first ridge or spoil bank which is called the outside bank usually contains a larger proportion of soil sized particles (< 2 mm) and is usually higher than the other ridges since it is piled on the unstripped ground. The final cut or strip, generally left unfilled, is a long deep pit with a vertical highwall on one side and a steep spoil bank on the other side.

Stability

The instability of slopes on spoil banks is often a serious problem in revegetation work (37, 23, 3). For example, in hilly country where contour stripping is practiced, spoil material may slump, and slide all the way to the valley bottom according to Vimmerstedt (37). Bramble and Ashley (3) noted in their research work that steep slopes and loose surface material on spoil banks account for a great deal of downslope movement when combined with frost and water action.

Erosion and Sedimentation

Erosion and sedimentation are closely associated with the instability of slopes on spoil banks. Curtis (6) stated that erosion and sedimentation are possibly the most serious problems on surface mined lands. He suggested a simple terracing treatment of the spoil surface as a method of cutting erosion and storm runoff peaks in half. Vogel (39) stated that erosion and sedimentation are especially troublesome in the Appalachian Region where strip mining occurs on steep mountain slopes. Vimmerstedt and Struthers (38) warned that if erosion on acid spoils is not prevented continual exposure of fresh, relatively unweathered spoil material will prolong acid and soluble salt production.

Schessler and Droege (23) reported that in general sandy spoils are more susceptible and shales the least vulnerable to erosion. Erosion destroys vegetation by removing soil from around plant roots on the upper spoil bank slopes and by burying plants under sediment deposits on the lower areas.

Microclimate

Microclimate is important to plant survival and growth and many times it is far from ideal on spoil banks (23, 3, 39). High winds together with high temperatures cause excessive soil moisture lossess from spoils. Vogel (39) stated that although rainfall in Appalachia is usually abundant, physical characteristics of certain spoils cause desert-like micro-environmental conditions that adversely affect seed germination and seedling growth. Bramble and Ashley (3) reported soil temperatures on spoils ranged up to 130°F on clear summer days in Pennsylvania. This occurred principally on dark colored spoils with southern exposures. Planted red pine seedlings, 2 years old, were affected by direct heat injury. Furthermore most spoil banks are exposed to the full sweep of wind from at least one direction which causes plants to suffer from drouth injury and winter killings.

Grading

Spoil bank grading is a controversial aspect of strip mine reclamation and therefore, revegetation. Excessive bank compaction caused by grading can limit the survival and growth of vegetation (5, 11, 12, 23). Compaction reduces the infiltration capacity of the spoil and inhibits root penetration by plants.

Chapman (5) reported that special attention must be given the textural classes and moisture content of the soil size material of spoils in order to accurately predict the effects of grading spoils on planted trees. If spoil banks with more than 15 percent clay in the soil fraction of the spoil are completely leveled several detrimental effects may occur. The detrimental effects listed included:

1. reduced pore space
2. reduced water infiltration and percolation
3. increased runoff and erosion
4. decreased availability of essential nutrients
5. partial exclusion of biotic life
6. increased spoil toxicity

Grandt and Lang (14) stated that limited revegetation experiments with grasses and legumes on graded mined lands in Illinois have in general given good results. Results of experiments on leveled areas indicated that grading has several beneficial effects: a better seedbed can be prepared, less seed is required per acre, thicker stands can be obtained, weeds can be controlled more easily and excess forage can be harvested as hay as well as pasture. Grandt and Lang (14) tempered their optimism towards grading spoils by listing drainage as a possible problem since slight depressions caused by unequal settling of the spoils can fill with water and drown out growing plants. In this case either surface or internal drainage must be provided. Doerr (7) noted that graded spoil banks in Oklahoma are normally less compact, initially, than surrounding unmined areas.

Kohnke (19) stated that in planning the grading of spoil banks prime consideration should be given to the eventual land use and drainage system desired. Pastureland should not be steeper than 25 percent which would permit the safe operation of agricultural machinery, while the slope should be no more than 10 percent for cropland and orchards to avoid erosion hazards. Slopes as great as 70 percent are suitable for forests.

Structure

Soil structure on the over-all aggregation or arrangement of soil solids affects water movement, heat transfer, aeration, bulk density, and porosity. Wilson (41) in studies on coal strip mine spoils in West Virginia found that the percentage of aggregation was of the following order; nonvegetated < vegetated < undisturbed. The type of vegetation on the spoils is also an important factor in aggregation. In general aggregation on the spoils increased in the following order: nonvegetated < pine < locust < forage grasses and legumes.

Fauna and Flora

The soil fauna and flora are indispensable in their influence on higher plants. Three very important beneficial processes they accomplish are: (1) organic matter decomposition, (2) inorganic transformations and (3) nitrogen fixation. Having sufficient numbers of soil fauna and flora present in spoils to accomplish these and other beneficial processes is desirable.

Vimmerstedt (36) pointed out that the strip mining process destroys the soil flora and fauna so that recently mined or fresh spoil approaches sterility. However, readily-dispersed soil organisms, such as bacteria, fungi, and arthropods, re-establish themselves soon after a source of food is provided, while earthworms and other organisms move back much more slowly.

Wilson (42), working in West Virginia, found that the numbers of microorganisms in spoil are influenced by a number of environmental factors, including pH, energy sources, nutrients, moisture, and temperature. Nonvegetated acid spoil contains some microorganisms but a vegetated similar spoil of the same pH contains a much larger microbial flora. Data indicated that vegetation exerts a greater influence upon the microfloral of a spoil than does pH; however, it must be remembered that vegetation is influenced by the pH.

Revegetation

Frequently the plant environment varies from one mined area to another and even within an area. This has led to individualized or specific area revegetation research.

Smith, Tryon, and Tyner (24) compared 70 to 130 year old shaly Pennsylvanian Age iron ore spoils near Morgantown, West Virginia, with natural contiguous soils of the same area. Natural soil proved superior to old spoils in bulk density (lower), porosity (higher), soil structure development, infiltration, nitrogen or organic matter accumulation especially near the surface, surface texture (more loamy), and smoother land surfaces. Conversely the mine spoils were superior in depth for plant rooting, total available water holding capacity, certain plant nutrients, and gentler slopes on spoil benches. Other comparisons including forest site quality, pH, and mineralogy were not found to be greatly different between natural soils and mine spoils. Results of the properties investigated demonstrated that spoils may be equal or superior immediately for perennial legumes or other perennials with moderate nitrogen requirements, but are likely to be inferior for annual cultivated crops or perennials sensitive to nitrogen deficiencies.

Tyner and Smith (32) focused on the revegetation of strip mined coal lands in West Virginia with forage species. Spoil reaction appeared to be the chief factor determining the case of revegetation while the physical properties of spoils seemed to be of secondary importance. Field experiments with very strongly to strongly acid spoils indicated that following lime and fertilizer applications a number of grass and legume species would grow successfully including; alsike clover, white clover, hop clover, birdsfoot trefoil, Korean or sericea lespedeza and orchard grass, redtop, tall meadow oatgrass, ryegrass, and timothy. These same species plus red clover were successfully grown on moderately to slightly acid spoils while sweet clover, red clover, and alfalfa additionally were successfully established on moderately acid to alkaline spoils.

Field experiments by Grandt and Lang (14) demonstrated that grasses and legumes can be successfully established on most of the strip mined lands in Illinois. Of more than 2,000 spoil samples tested, 73 percent had a pH above 7.0 and 90 percent a pH above 5.5. The spoil materials, were "very high" in available phosphorus and "high" in available potassium. Organic matter and nitrogen were extremely low or entirely lacking. Legume species listed as well adapted included alfalfa, birdsfoot trefoil, red clover, sweet clover, lespedeza, and Kudzu. Grasses that established most rapidly included tall fescue, orchard grass, and bromegrass while Kentucky bluegrass, Thimothy, redtop, and reed canary grass established more slowly.

Einspahr, McComb, Riecken, and Sharader (9) divided Iowa spoil bank areas into seven principal types of spoil material and tested each type for suitability as a medium for plant growth. Based upon field trials, greenhouse work, and chemical and physical analyses, Wisconsin loess, Kansas glacial till acid buff shales, calcareous black shales, and Pleistocene and Pennsylvanian sands were best suited for plant growth. Toxic and acid gray shales and brownstone shales were largely unsuited for plant growth. The poor growth on these two abundant spoil materials appeared to be associated with low pH, high soluble salts and high levels of active iron and aluminum. Twelve legume and four grass field trials were conducted. Legume species that produced good stands included sweet clover, lespedeza, alfalfa, and birdsfoot trefoil. Grasses that formed well were smooth brome, orchard grass, intermediate wheatgrass, Canada wildrye and timothy.

Struthers (26) noted that species that are most productive on farm land have in general proven to be best also for strip mine use. Legumes rated as satisfactory in trial plots included sweet clover, alfalfa, trefoil, and sericea and Korean lespedeza. Orchard grass, brome, tall fescue, redtop, and ryegrass rated high for both stand and vigor in spring seeding field trials. Weeping lovegrass was well adpated to sandy acid spoils while furnishing excellent surface protection and erosion control (26).

Vogel and Berg (40) concentrated on identifying grasses and legumes adapted to acid strip mine spoils. Both field and greenhouse experiments were conducted. Three perennial grasses performed well in field trials: weeping lovegrass, Blackwell switchgrass, and Kentucky 31 fescue. Birdsfoot trefoil and sericea lespedeza grew and nodulated well on several field plots. Weeping lovegrass provided initial cover on extremely acid spoils faster than any other perennial grass or legume.

Vogel (39) recognized the utility of weeping lovegrass for vegetating strip mine spoils in Appalachia. Although relatively short-lived, weeping lovegrass worked well in combination with slower developing, long-lived grasses and legumes. It provided the desired quick cover during the first growing season without crowding out the companion species, which later obtained dominance.

In Ohio officials of Hanna Coal (15) stated that plantings of Penngift Crownvetch have proven most successful of the species tried. The crownvetch is usually seeded in combination with faster growing grasses and legumes since it is slow to establish sometimes taking 3 to 4 years for 100% cover.

Lang (20) noted that intermediate and crested wheatgrass appeared to be the best adapted of the cool season species seeded on Wyoming strip mine spoils. Precipitation is normally low on the spoils thus necessitating the use of drough tolerant species.

Hyde (16) reported on mined land revegetation research in Southeastern Kansas. Sixteen species of grasses and legumes were planted on small plots. Results were incomplete; however, K-31 tall fescue had previously proven satisfactory and early observations on smooth brome were encouraging. Fawn fescue looked good, El Reno Sideoats Grama and Blackwell Switchgrass both germinated, and Cicer Milkvetch appeared to be establishing well.

CHAPTER III

MATERIALS AND METHODS

A coal strip mined area near Stigler, Oklahoma in Haskell County was selected as the site of a revegetation study. It is hoped that by learning about the revegetation of the Stigler strip mined area the information and knowledge acquired can be applied in revegetating other strip mined areas in Eastern Oklahoma.

The northern half of Haskell County is included in the 42 inch annual precipitation belt, while the southern half of the county falls into the 44 inch classification. The mean annual temperature of the county as a whole is 62^{o}F. Haskell county occupies approximately 385,000 total acres which means the 4,322 acres disturbed by surface mining prior to 1968 represents slightly over 1.1 percent of the county.

The coal bearing rocks of Haskell County, as in the rest of Oklahoma, are of Pennsylvanian age. The spoil banks around Stigler are composed principally of shales and small amounts of soil occasionally outcropping on the spoil surface.

A new soils mapping unit, Kanima soils, has been originated by Soil Conservation Service personnel which describes soils formed on soil banks (See Appendix A).

In a preliminary survey of the Stigler area samples from the upper 6 inches of spoil banks were collected from five different sites. Several characteristics of these sites are listed in Table I.

TABLE I

SELECTED CHARACTERISTICS OF STIGLER, OKLAHOMA AREA SPOIL BANKS

Site	Location	Approx. Age (yrs.)	Slope %	Parent Material	pH	Reaction with HCl
1	14-9N-20E	15	70	Shale	8.1	+
2	5-9N-21E	45	51	Shale	7.6	-
3	4-9N-21E	2	3	Shale	8.5	+
4	34-10N-21E	6	60	Shale	7.1	+
5	26-10N-21E	3	0-1	Shale	8.2	+

From this it is seen that the spoils of the Stigler area typically are basic calcareous Pennsylvanian Age shales.

Greenhouse Study

Spoil material for a greenhouse study was collected from the upper 6 inches of a spoil bank in the NE ¼ Sec 34, T10N, R21E of Haskell County. The spoil bank was approximately six years old with 60 percent slope. Soil testing laboratory results indicated the spoil material had a pH of 7.6; 6 lb/A available phosphorus; and 230 lb/A available potassium. Five lb/A available phosphorus is rated as "very low" while 230 lb/A available potassium is rated as "high". Organic matter was not present in the spoil material; however, carbon was present in the shale. The nitrogen content of the spoil was limited to the small amount included in scattered coal fragments.

Discarded vegetable cans with capacities of approximately 3.5 quarts were rinsed and each can lined with a polyethylene bag. The cans were then filled with spoil material to about 2 inches of the top of each can. An average of 6.3 lb of spoil material was placed in each can.

Twelve species of grasses and legumes were grown in two separate plantings. Species were selected on the basis of adherence to one or more of the following criteria: (1) Satisfactory performance on strip mine spoils in other states; (2) Adaptability to Eastern Oklahoma soils and climatic conditions (3) Desirable species with revegetation potential (4) Perennial as opposed to annual species. It was assumed that several of the species selected probably would not perform well in the greenhouse study and/or field demonstration but still merited consideration and study as potential revegetation species. Included in the first planting were: Old World Bluestem mixture; Vine Mesquite; Emerald Crownvetch; Kanlow Switchgrass; and Morpa Weeping Lovegrass. Five treatments with 4 replications of each treatment were applied to each species.

Included in the second planting were: Sericea Lespedeza: Sideoats Grama; Kentucky 31 Fescue; Korean Lespedeza; Common Bermudagrass; Linn Perennial Ryegrass; and Cody Alfalfa (Figure 2). Five treatments, each replicated 3 times, were applied to each species.

Approximately the same number of seeds were planted in each can of spoil material of a particular species, the number of seeds varying for each species. Usually this was one-quarter teaspoon of the smaller seeds or 1 teaspoon of the larger seeds. Legume seeds were inoculated.

Figure 2. Plants Being Grown in the Greenhouse

The treatments for both plantings included a check, 0-0-0; nitrogen, N-0-0; phosphorus, 0-P-0; nitrogen and phosphorus, N-P-0; and a complete fertilizer treatment, N-P-K. Cans were randomly chosen for application of each of the 5 treatments. Each nutrient was applied at a level adequate to insure that it was present in sufficient quantity for good plant growth and not limiting to plant growth. Ammonium nitrate (NH_4NO_3) was utilized as a source of nitrogen; phosphorus acid (H_3PO_4) furnished phosphorus; and potassium chloride (KCl) provided potassium. Each chemical was dissolved in appropriate amounts of water and applied with a pipette (Table II).

Later one can from each of the 5 treatments applied to the grasses and legumes was chosen at random. The plant growth in the treatments of each species were then photographed as shown in Figure 3. Plants were harvested by clipping the tops approximately

TABLE II

FERTILIZER APPLICATION RATES USED IN GREENHOUSE STUDY

Species	lb/A		
	N	P_2O_5	K_2O
Old World Bluestem mixture	100	100	100
Vine Mesquite	100	100	100
Emerald Crownvetch	100	150	200
Kanlow Switchgrass	100	100	100
Morpa Weeping Lovegrass	100	100	100
Sericea Lespedeza	100	150	200
Sideoats Grama	100	100	100
Kentucky 31 Fescue	200	100	100
Korean Lespedeza	100	150	200
Common Bermudagrass	200	100	100
Linn Perennial Ryegrass	200	100	100
Cody Alfalfa	100	150	200

Figure 3. Kanlow Switchgrass Grown in the Greenhouse Under 5 Treatments, Left to Right, 0-0-0, N-0-0, 0-P-0, N-P-0, and N-P-K.

one-quarter inch above the surface of the spoil material, dried in an oven at 165°F, and weighed. The spoil material was emptied from the cans to compare the root systems produced by each of the five treatments. Planting, fertilizing, photographing, and harvesting dates of both greenhouse plantings are given in Table III.

Field Demonstration

Seven grasses: Morpa Weeping Lovegrass, Old World Bluestem mixture, Sideoats Grama, Kanlow Switchgrass, Kentucky 31 Fescue, Linn Perennial Ryegrass, and Common Bermudagrass and four legumes: Korean Lespedeza, Cody Alfalfa, Emerald Crownvetch, and Sericea Lespedeza were seeded on top a partially leveled spoil bank in NE ¼ Sec. 34, T10N, R21E of Haskell County. The spoil bank top was nearly

TABLE III

TIME INTERVALS OF GREENHOUSE STUDY

	First Planting	Second Planting
Planted	3-28-72	5-13-72
Fertilized	4-19-72	5-27-72
Photographed	5-31-72	6-17-72
Harvested	6-3-72	6-27-72

level (0-1%) to gently sloping (1-3%) and had essentially the same reaction (pH) and nutrients available as the spoil material used in the greenhouse study. (pH: 7.6; available P: 5lb/A; available K: 230 lb/A).

Two experimental tracts on the spoil bank staked in 5'x5' plots were heavily seeded, (approximately three times the normal seeding rates for unmined lands) raked lightly with a leaf rake to cover the seeds, and replicated 4 times for each species (Figure 4). One check plot was included in each replication. Thirteen hundred fifty pounds per acre of 16-48-0 commercial fertilizer were applied to two randomly chosen rows of each experimental tract planted. Later the experimental tracts and individual plots were photographed (Table IV).

Figure 4. Field Demonstration Staked in 5' x 5' Plots.

TABLE IV

TIME INTERVALS OF FIELD DEMONSTRATION

	Experimental Tract #1	Experimental Tract
Planted	3-31-72	4-22-72
Fertilized	4-22-72	4-22-72
Photographed	6-29-72	6-29-72
Photographed	6-28-74	6-28-74

CHAPTER IV

RESULTS AND DISCUSSION

Greenhouse Study

Detailed numerical results of the greenhouse study are reported in Tables VII and VIII of the Appendix. Mean dry weights of plant tops are recorded in Tables 5 and 6.

Morpa Weeping Lovegrass, Kanlow Switchgrass, Old World Bluestem mixture, Sericea Lespedeza, Korean Lespedeza, and Cody Alfalfa conspicuously out-produced the other species when no fertilizer was applied (check treatment) as shown in Figures 5 and 6. From this it would seem these species have utility for planting on low fertility spoils especially if little or no fertilizer was to be applied.

A comparison of species response to the nitrogen treatment as shown in Figures 7 and 8 was inconclusive since the legumes were able to obtain nitrogen as a result of the nitrogen fixation process. Legumes generally produced more topgrowth than grasses when treated with phosphorus only as shown in Figures 9 and 10. This was expected since fixed nitrogen was available to the legumes and not to the grasses. When both nitrogen and phosphorus were supplied (N-P and N-P-K treatments) topgrowth production of grasses was generally as great or greater than that of legumes as shown in Figures 11, 12, 13 and 14.

Comparisons of treatments on all species planted are shown in

TABLE V

MEAN DRY WEIGHT OF PLANT TOPS (GRAMS/POT) GROWN IN SPOIL AT 5 FERTILITY LEVELS IN GREENHOUSE (FIRST PLANTING)

Species	0-0-0	N-0-0	0-P-0	N-P-0	N-P-K
Old World Bluestem mixture	3.3	13.3	2.9	28.7	27.6
Vine Mesquite	0.6	1.3	0.7	3.3	2.9
Emerald Crownvetch	2.2	2.6	5.0	5.6	3.6
Kanlow Switchgrass	4.1	6.2	4.0	18.0	14.5
Morpa Weeping Lovegrass	5.5	9.0	5.1	16.2	15.3
Mean 1 (All Species)	3.1	6.5	3.5	14.4	12.8
Mean 2 (Grasses)	3.4	7.5	3.2	16.6	15.1

TABLE VI

MEAN DRY WEIGHTS OF PLANT TOPS (GRAMS/POT) GROWN IN SPOIL AT 5 FERTILITY LEVELS IN GREENHOUSE (SECOND PLANTING)

Species	0-0-0	N-0-0	0-P-0	N-P-0	N-P-K
Sericea Lespedeza	5.8	5.9	7.9	8.4	8.6
Sideoats Grama	1.1	1.1	1.3	11.7	11.5
Kentucky 31 Fescue	1.8	4.3	2.2	15.7	14.1
Korean Lespedeza	8.4	6.9	13.2	14.9	13.6
Common Bermudagrass	0.6	0.9	1.0	14.3	14.3
Linn Perennial Ryegrass	2.0	3.9	1.8	13.0	12.8
Cody Alfalfa	5.4	6.2	12.4	12.7	14.1
Mean 1 (All Species)	3.6	4.2	5.7	13.0	12.7
Mean 2 (Grasses)	1.4	3.4	1.6	13.7	13.2
Mean 3 (Legumes)	6.5	6.3	11.2	12.0	12.1

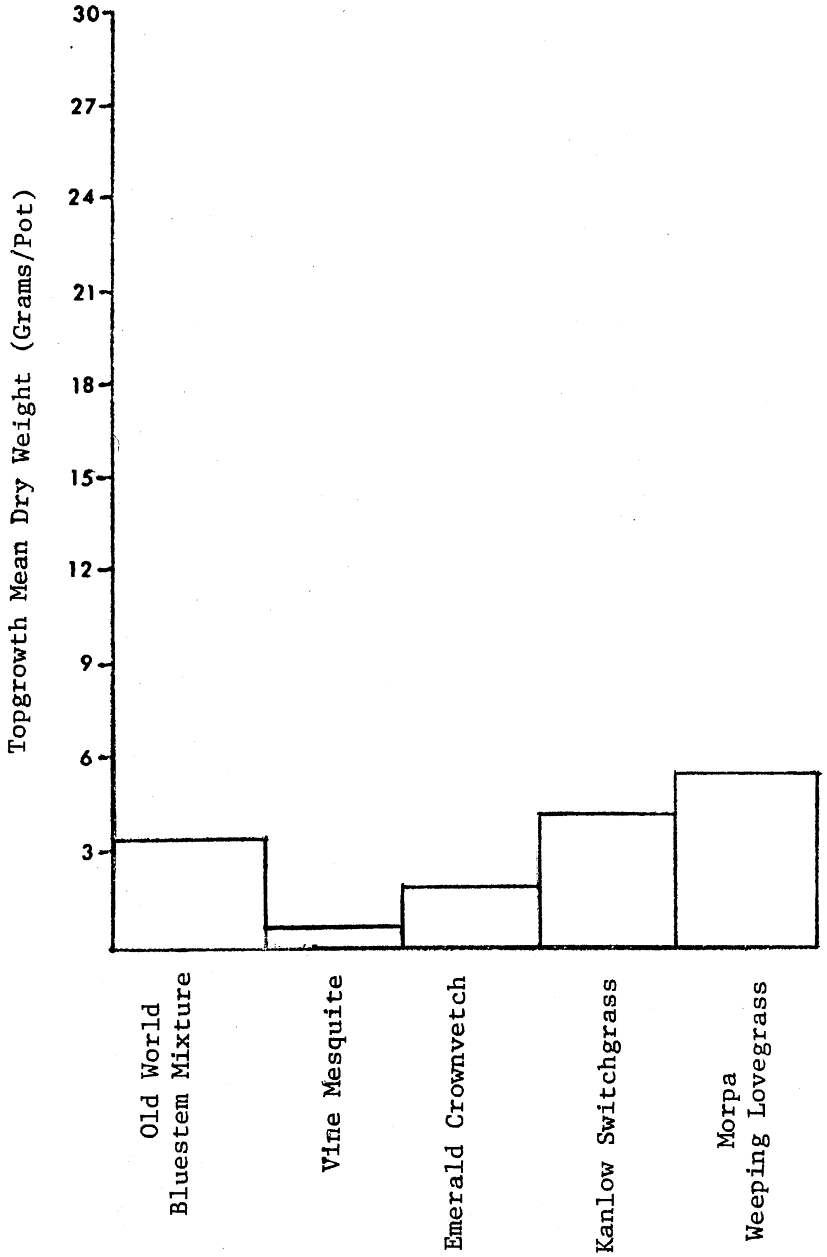

Figure 5. Plant Response to Check Treatment (First Planting).

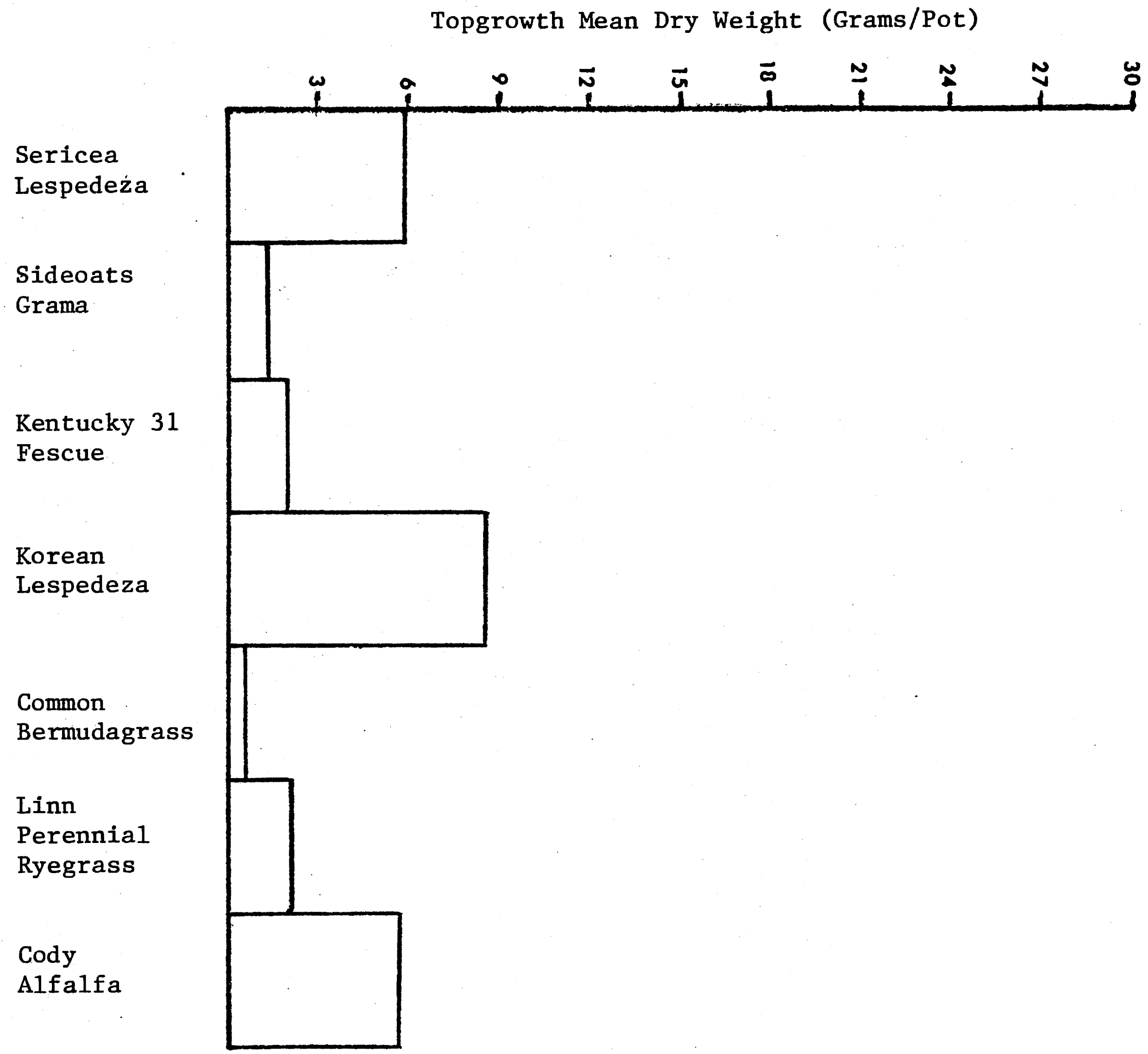

Figure 6. Plant Response to Check Treatment (Second Planting).

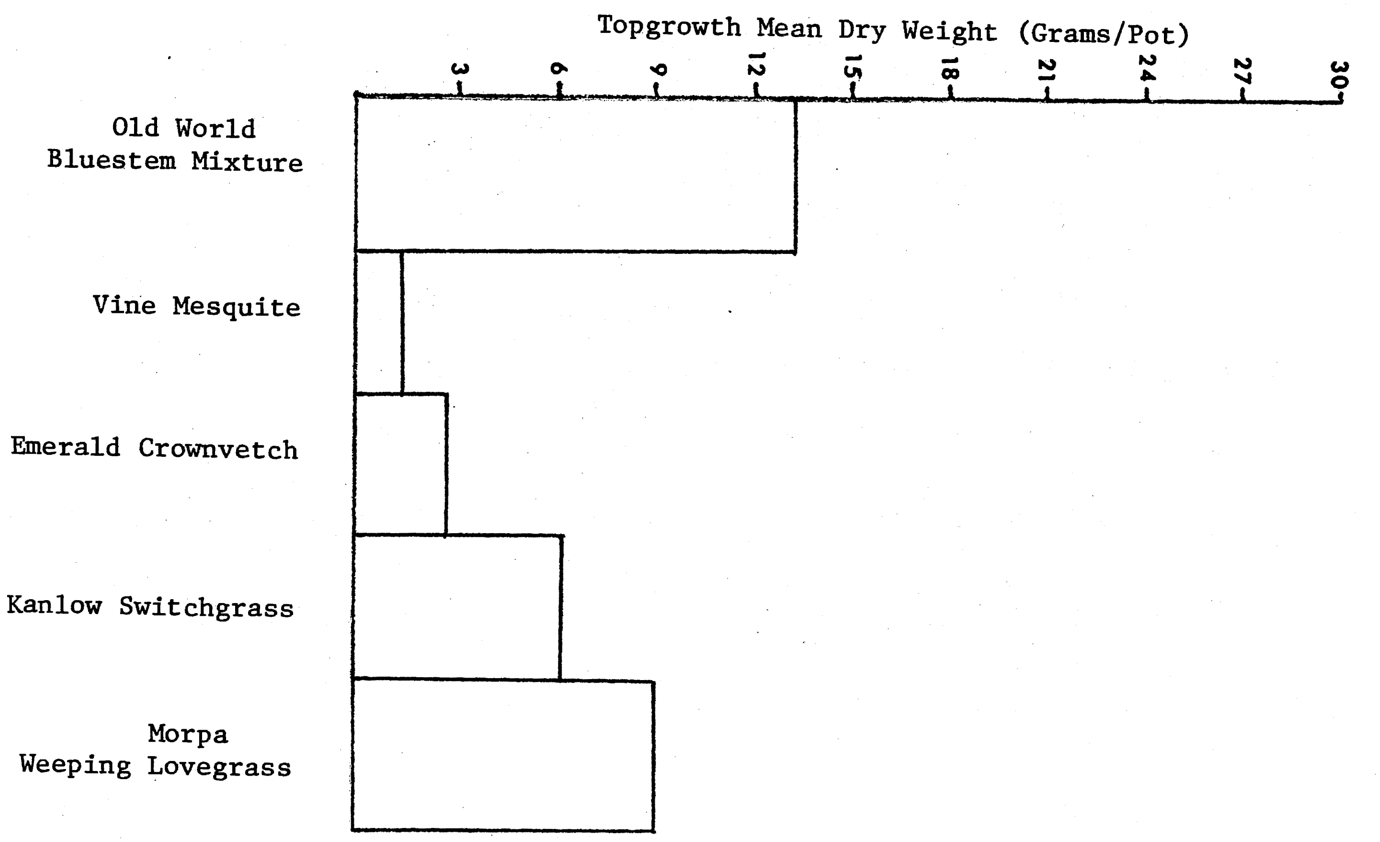

Figure 7. Plant Response to Nitrogen Treatment (First Planting).

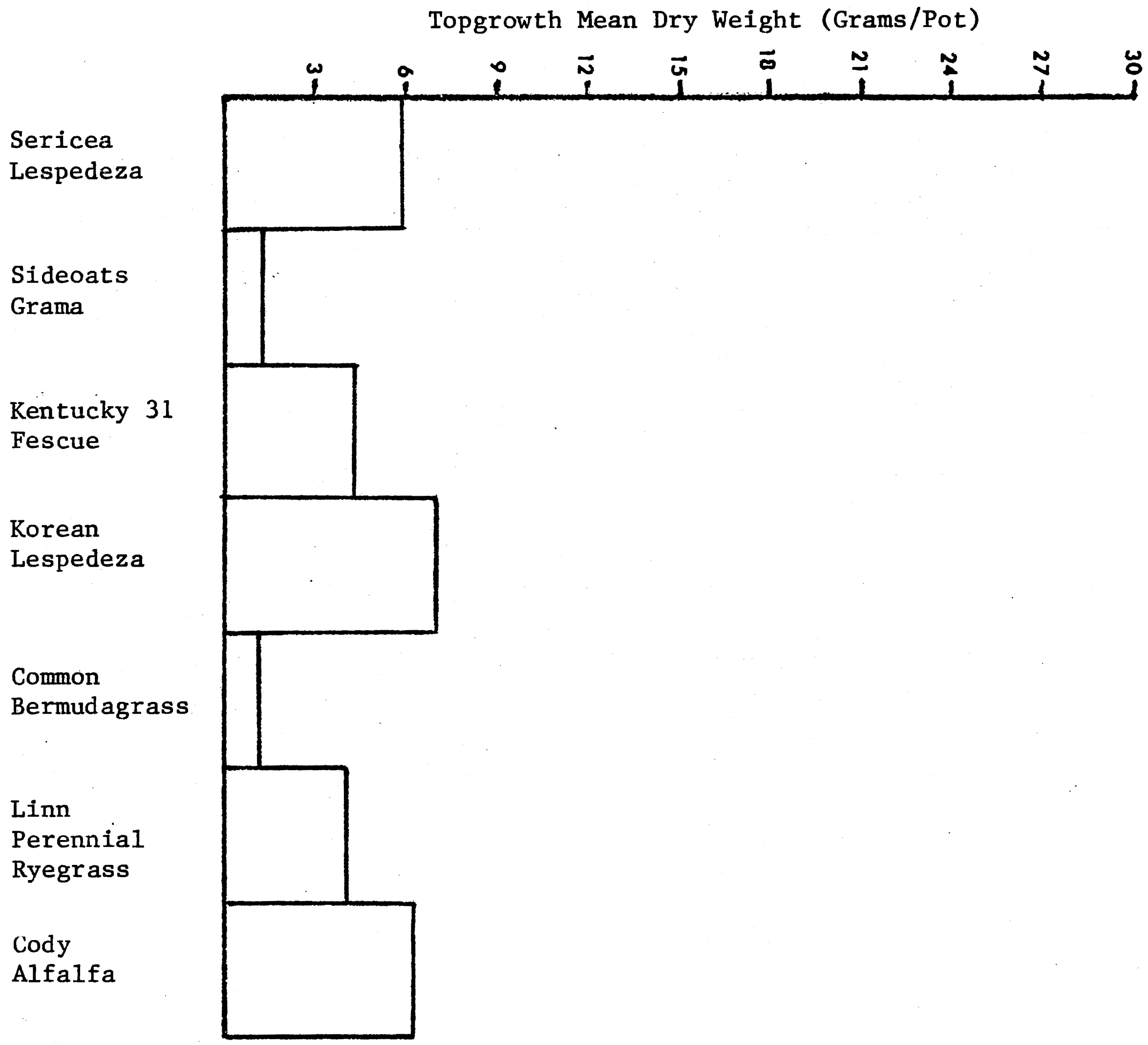

Figure 8. Plant Response to Nitrogen Treatment (Second Planting).

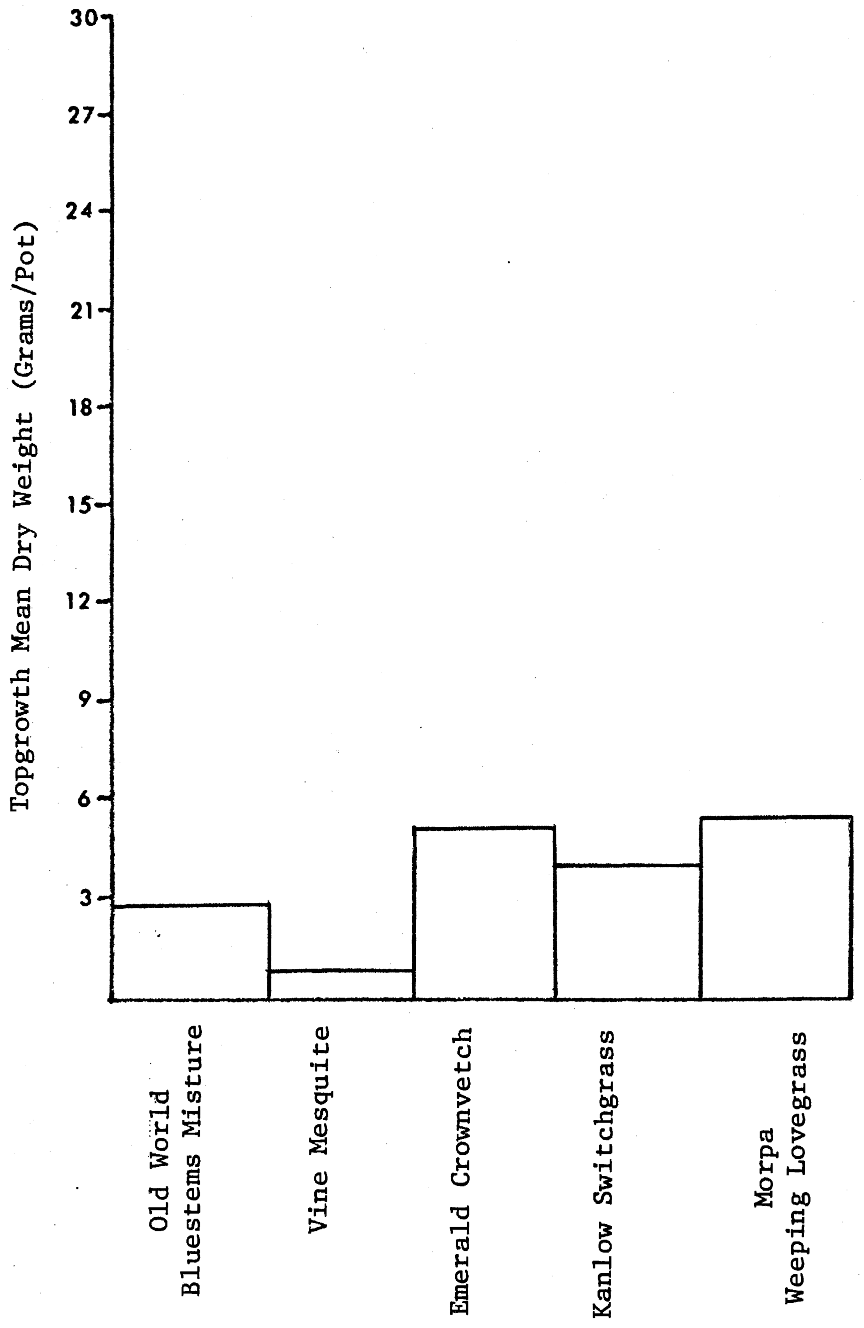

Figure 9. Plant Response to Phosphorus Treatment (First Planting).

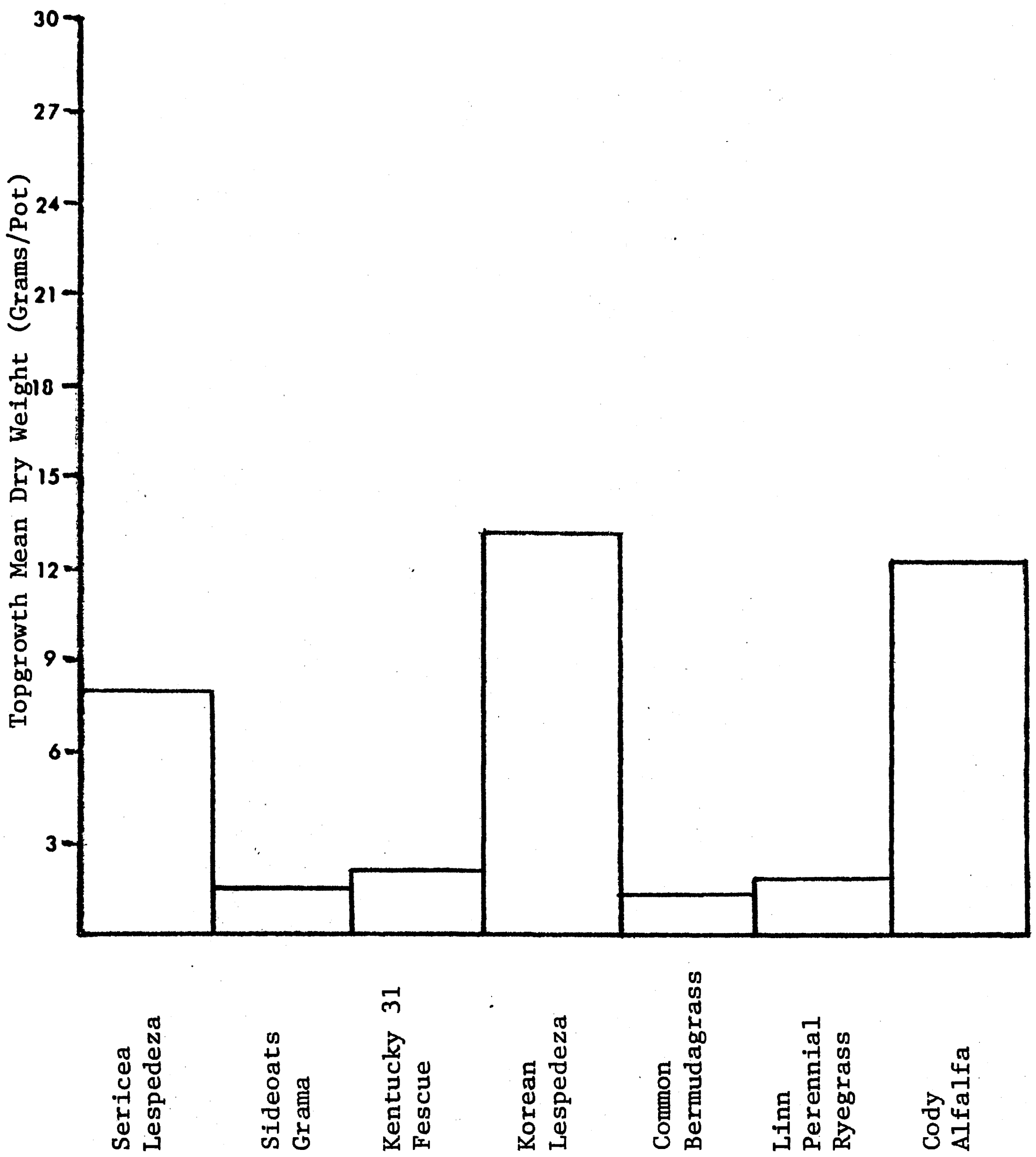

Figure 10. Plant Response to Phosphorus Treatment (Second Planting).

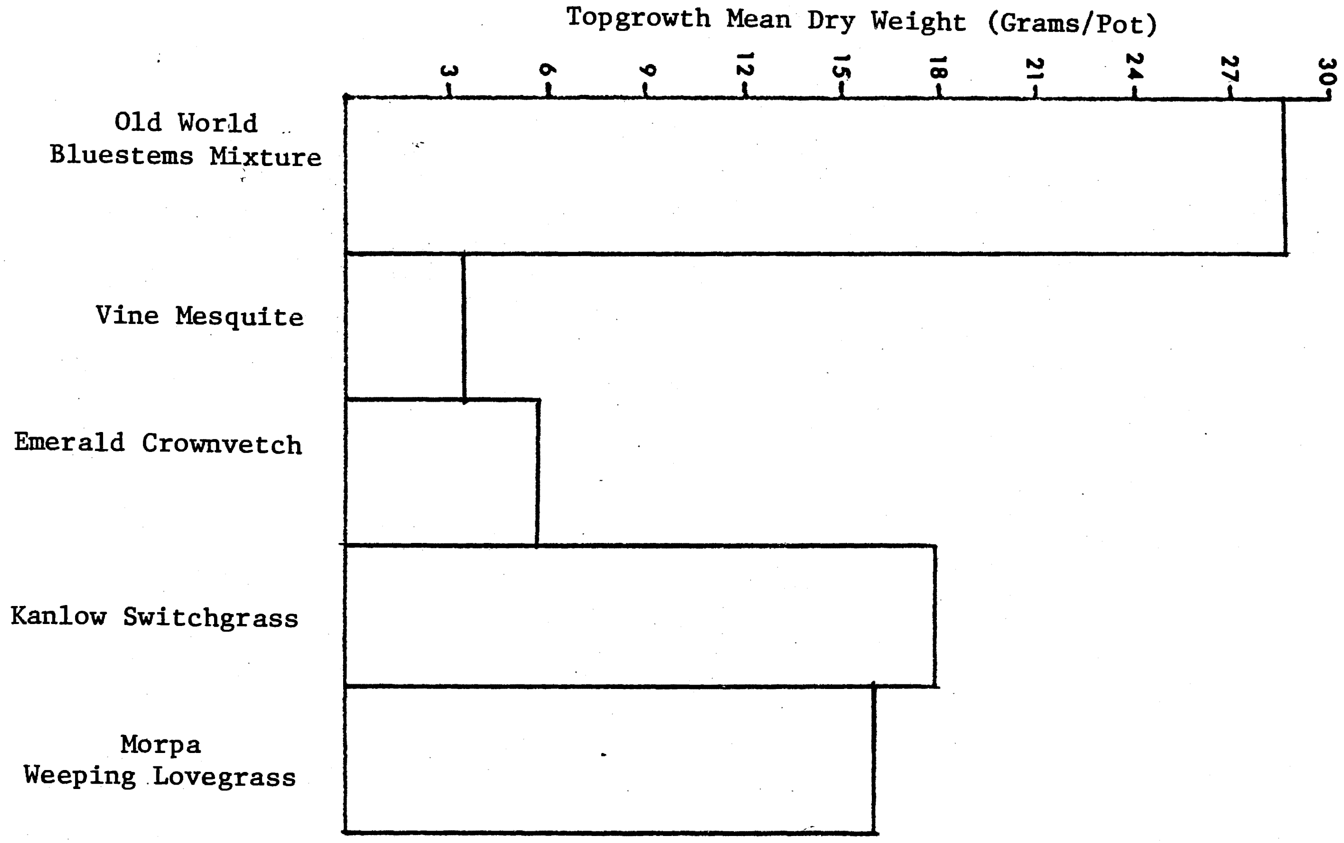

Figure 11. Plant Response to Nitrogen-Phosphorus Treatment (First Planting).

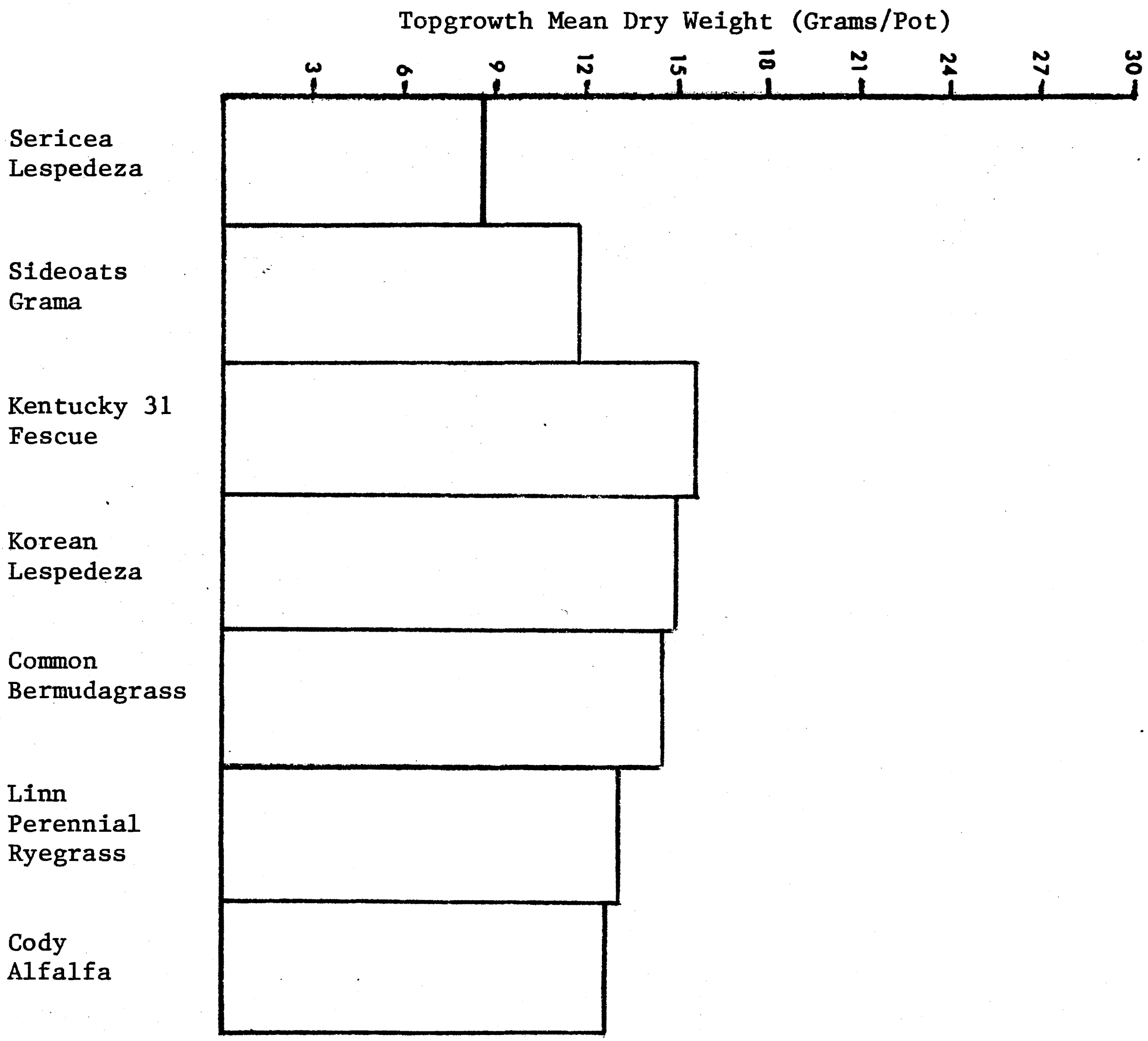

Figure 12. Plant Response to Nitrogen-Phosphorus Treatment (Second Planting).

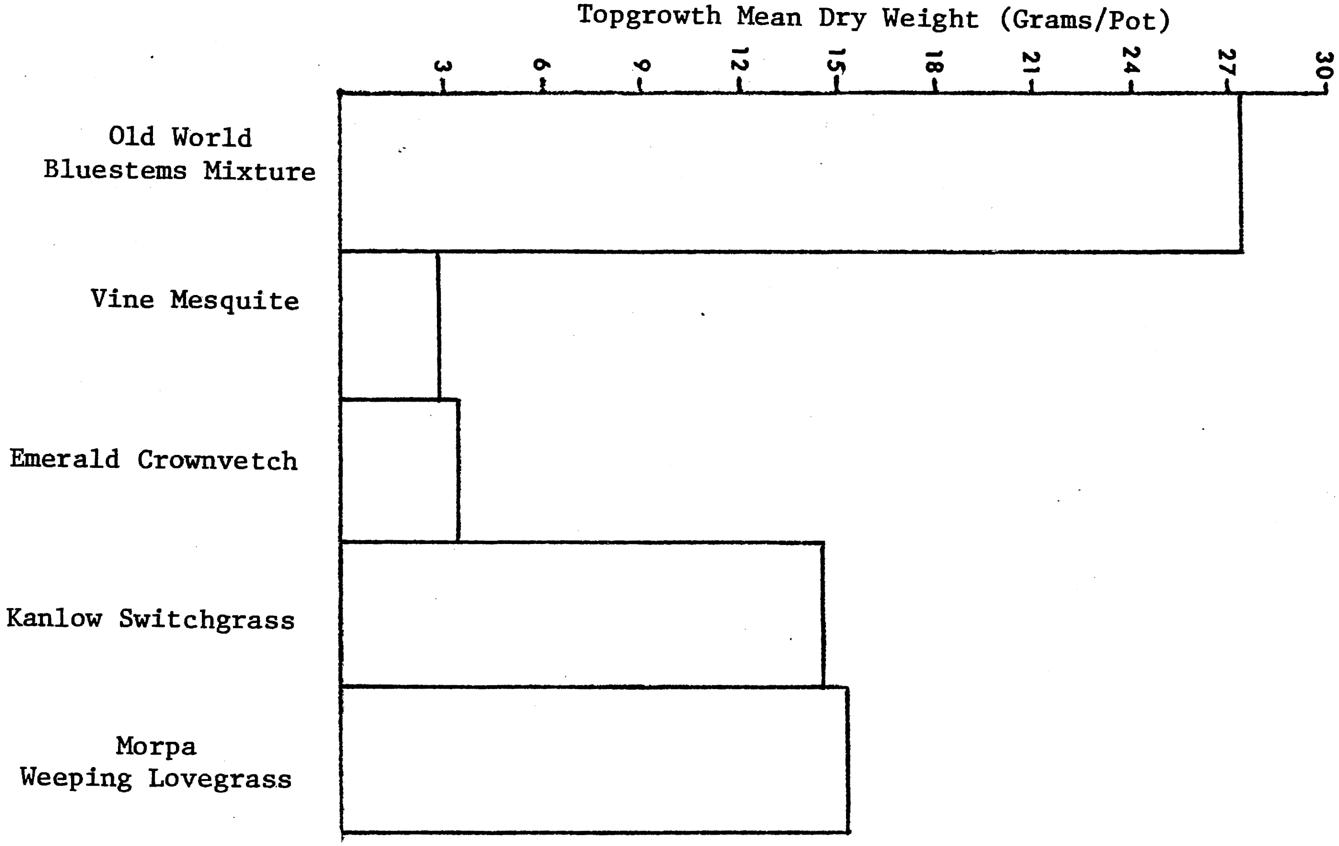

Figure 13. Plant Response to Nitrogen-Phosphorus-Potassium Treatment (First Planting).

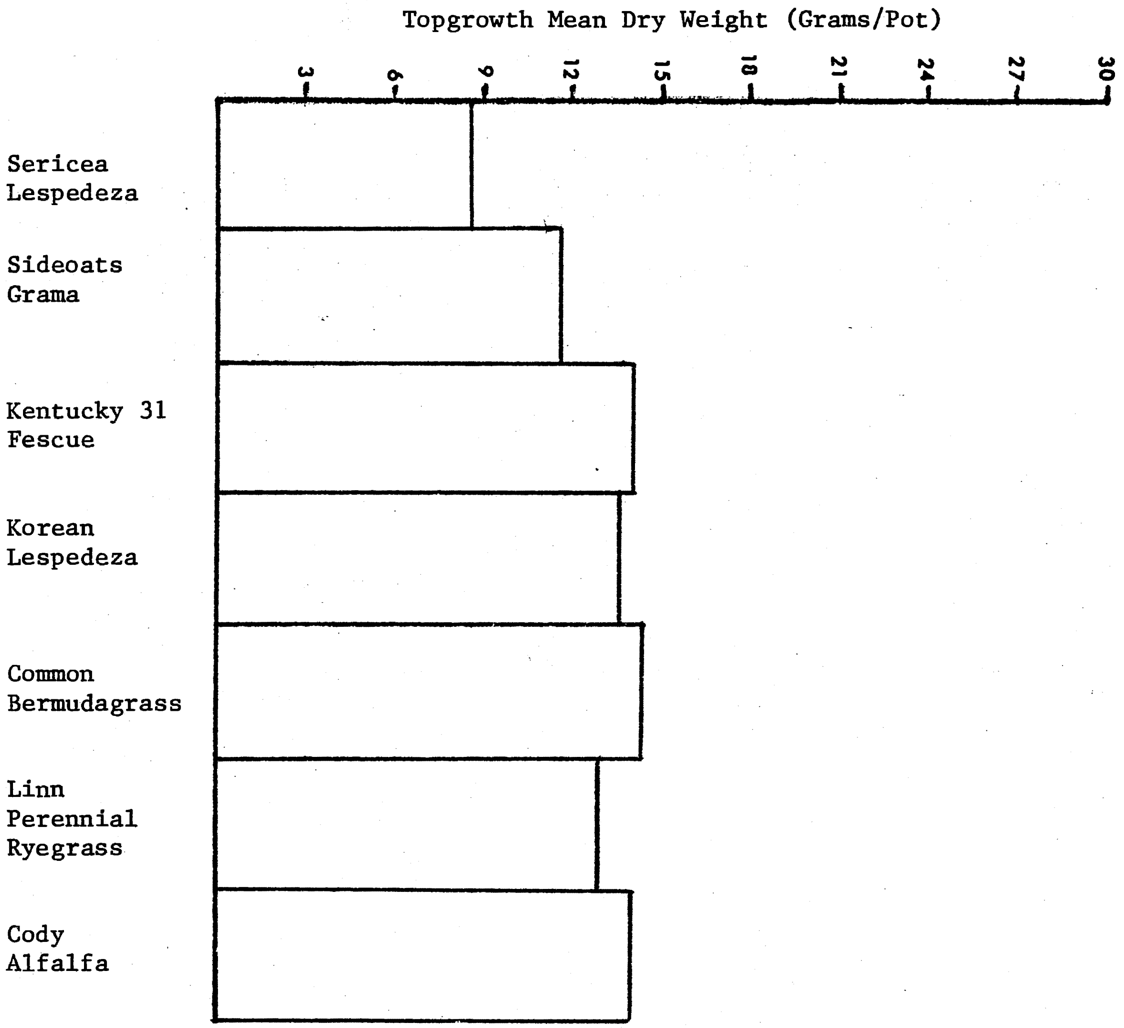

Figure 14. Plant Response to Nitrogen-Phosphorus-Potassium Treatment (Second Planting).

Figures 15 and 16. Marked responses to treatments including both nitrogen and phosphorus are obvious. A less marked response is shown to the nitrogen treatment in the first planting and the phosphorus treatment of the second planting. These two latter responses are explained in part by the fact that four of five species in the first planting were grasses and the legumes of the second planting grew quite well. Grasses are known to respond particularly to nitrogen while legumes respond especially to phosphorus. Comparisons of treatments on grasses are shown in Figures 17 and 18 while Figure 19 compares treatments on legumes.

It is apparent that most of the grasses responded to the nitrogen treatment. Sideoats Grama and Common Bermudagrass were exceptions. The grasses did not respond to the phosphorus treatments, while the nitrogen-phosphorus treatment and the complete fertilizer treatment gave similar and the greatest responses on the grasses. The addition of potassium did not increase the response of the grasses. As a *general rule, both nitrogen and phosphorus should be applied to the spoil when growing grasses. As expected the legumes did not respond to the nitrogen treatment. *However, they did respond to the treatments containing phosphorus. The responses to these three treatments were usually similar in magnitude and should be interpreted to be due to phosphorus only. Generally, phosphorus should be applied to the spoil when growing legumes.

After clipping the plant tops, the spoil material was emptied from the cans to observe the roots. On both grasses and legumes the root system produced by treatment containing phosphorus appeared to be more extensive than the root systems produced by the check and

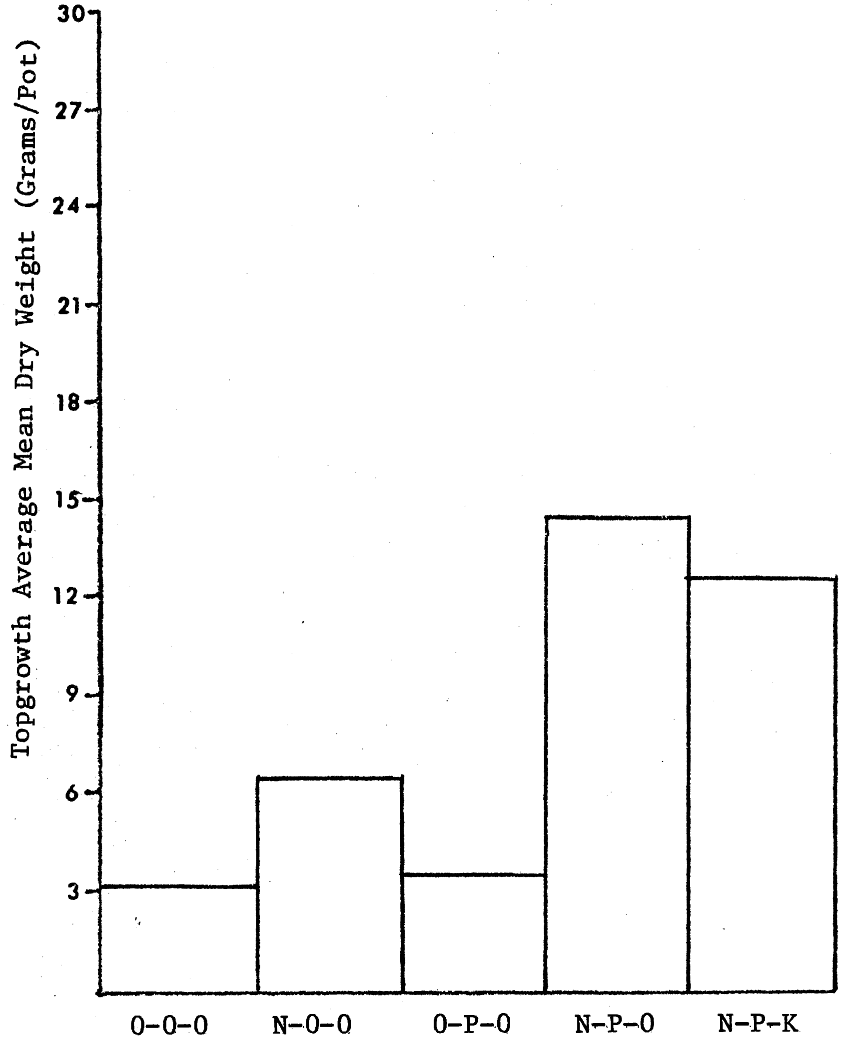

Figure 15. Comparison of Fertility Treatments on all Species (First Planting).

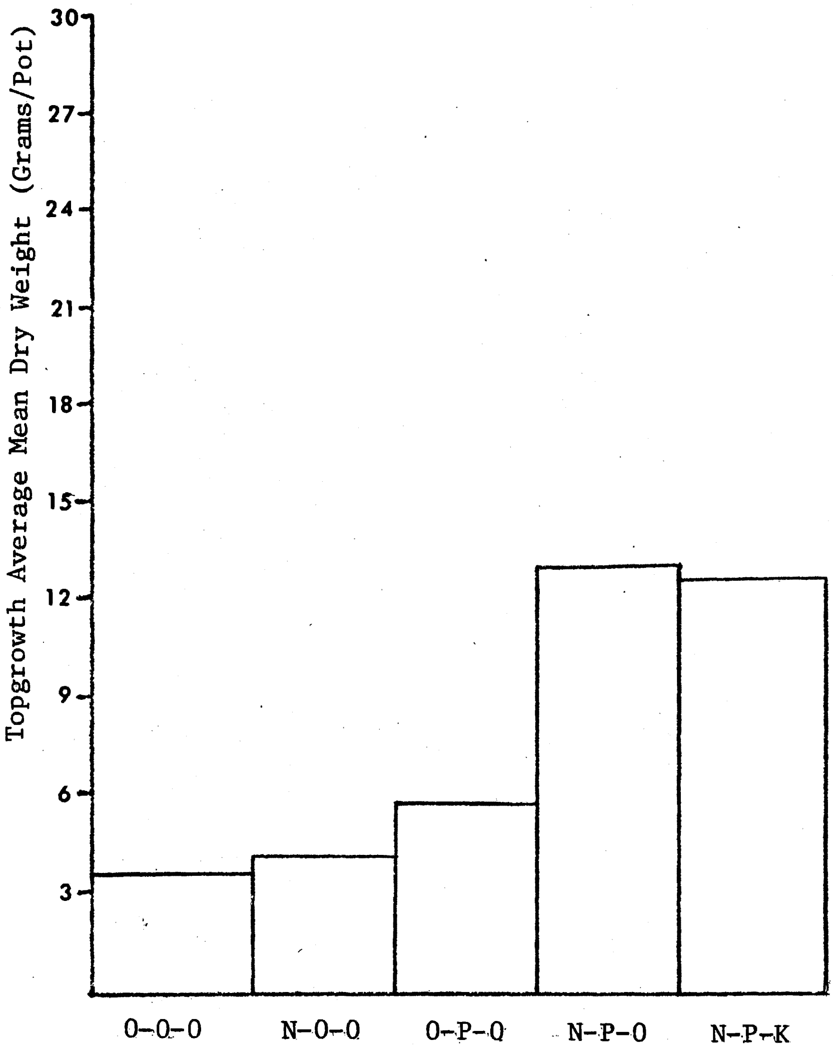

Figure 16. Comparison of Fertility Treatments on all Species (Second Planting).

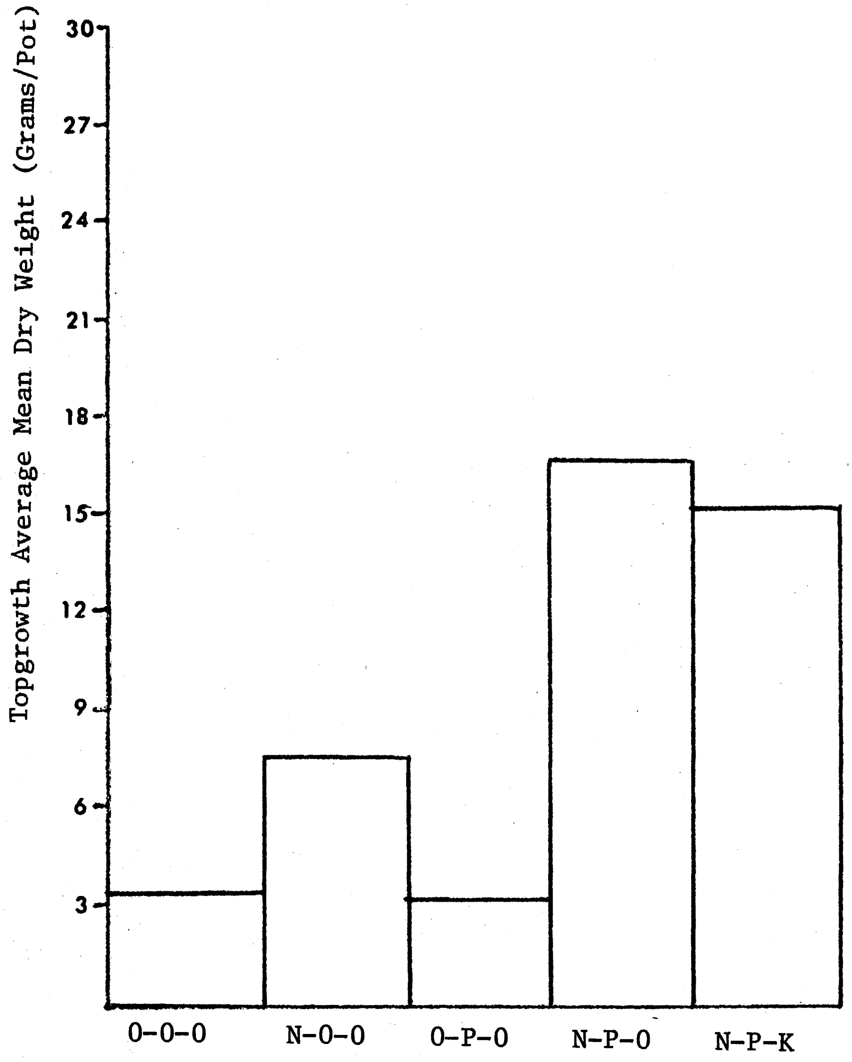

Figure 17. Comparison of Fertility Treatments on Grasses (First Planting).

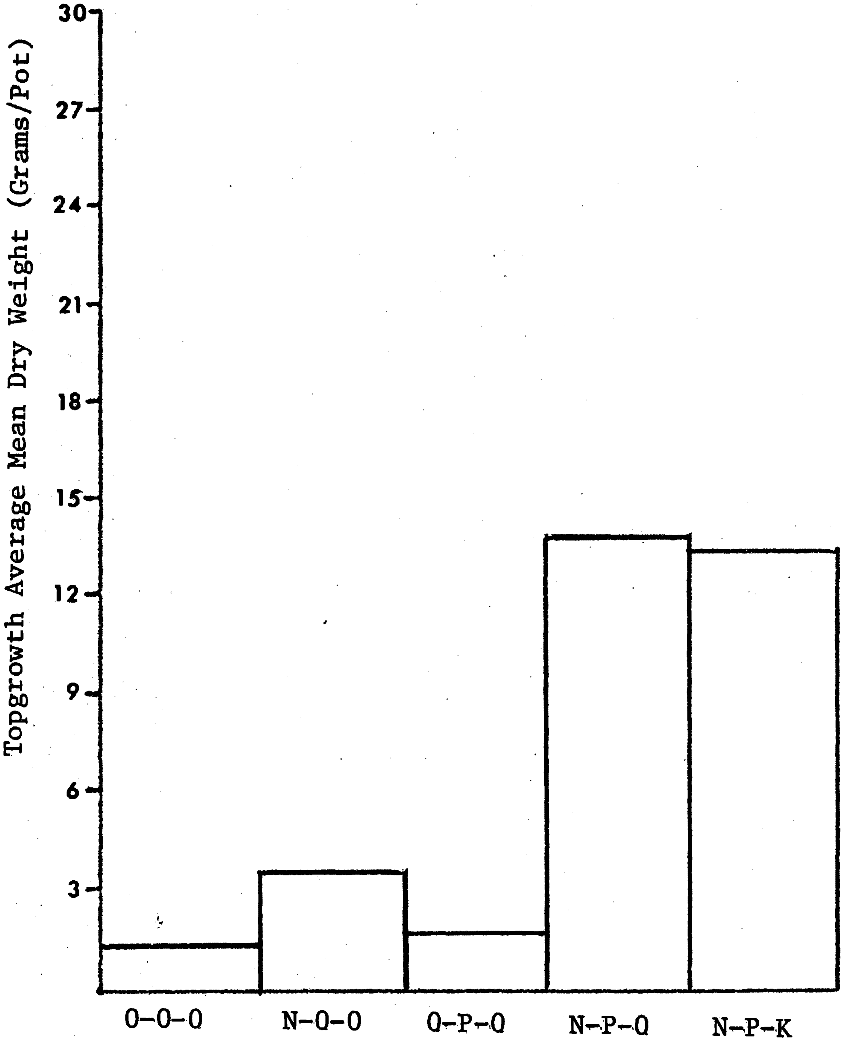

Figure 18. Comparison of Fertility Treatments on Grasses (Second Planting).

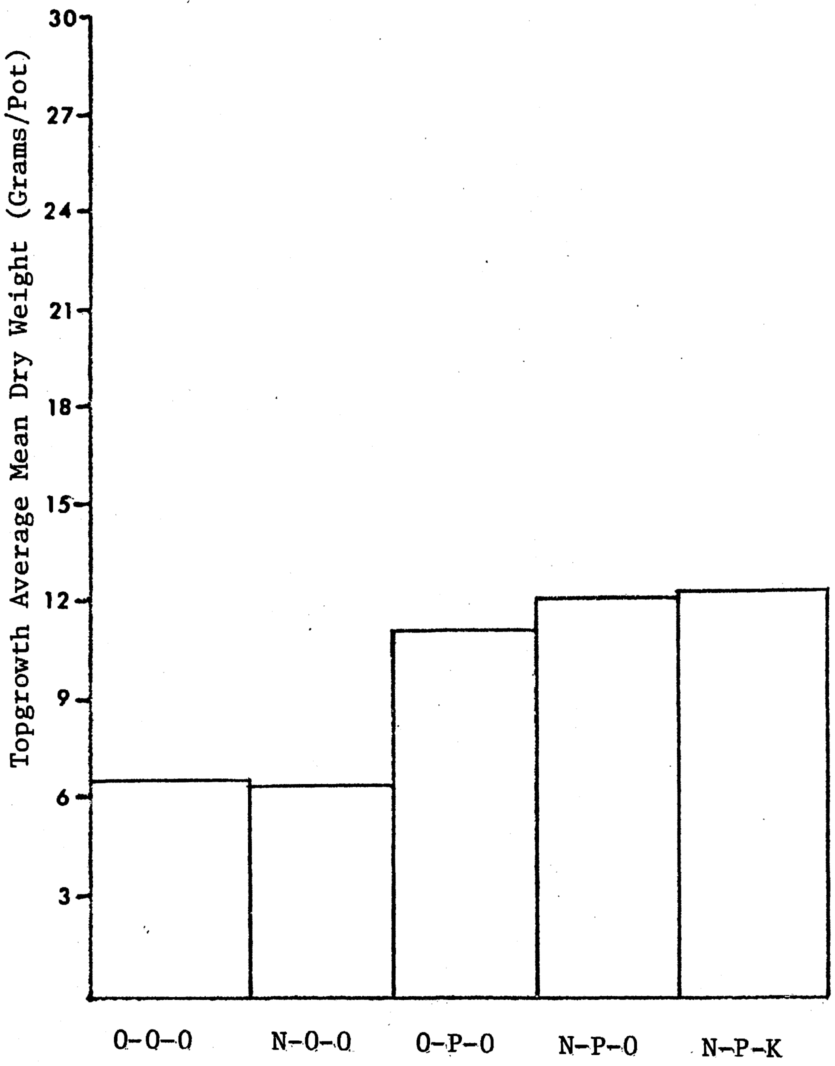

Figure 19. Comparison of Fertility Treatments on Legumes (Second Planting).

nitrogen treatments. On grasses the nitrogen treatment appeared to produce a more extensive root system than the check. Nodules on legume roots from treatments not containing nitrogen, appeared to be larger and more numerous than those from treatments containing nitrogen.

By analyzing the results of the greenhouse study, the suitability potential of each grass and legume species for revegetating the strip mine spoils was determined. Ratings were defined according to data and visual comparisons. Dry matter production "means" from Tables V and VI and vigor of sufficiently fertilized (complete treatment) plants were used as bases of comparisons. The four grass and 1 legume species grown in the first greenhouse planting were classified according to the following ratings:

Rating	Interpretive Dry Matter Production (gms/pot)
"very good"	>25
"good"	15-25
"fair"	5-15
"poor"	<5

The Old World Bluestem mixture received a "very good" rating since it grew vigorously and produced extensive foliage. Kanlow Switchgrass and Morpa Weeping Lovegrass merited "good" ratings as both grew well and produced large quantities of vegetation. Emerald Crownvetch's "fair" rating and Vine Mesquite's "poor" rating are not particularly surprising considering that Crownvetch usually needs at least 2 years to become established and Vine Mesquite had little opportunity (time and space) to spread as it normally would. The

Crownvetch plants grew erratically with replications of several treatments producing both large vigorous plants and smaller less vigorous plants. The Vine Mesquite plants lacked vigor besides producing relatively little vegetative growth.

The second greenhouse planting included four grass and three legume species. Plants were grown for a period two-thirds as long as the first greenhouse planting. The same objective ratings were used while the interpretive dry matter production figures for the first greenhouse planting were adjusted downward by approximately one-third:

Rating	Interpretive Dry Matter Production (gms/pot)
"very good"	>16
"good"	10-16
"fair"	3-10
"poor"	<3

Kentucky 31 Fescue, Common Bermudagrass, Korean Lespedeza, Linn Perennial Ryegrass, Cody Alfalfa, and Sideoats Grama exhibited "good" suitability potentials. These grass and legume species grew vigorously and produced large quantities of vegetation. Sericea Lespedeza received a "fair" rating due to a reduction in vigor and dry matter production when compared to the "good" rated species.

Although the plant environment in the greenhouse is much nearer the ideal than that on the spoils, the suitability potentials for growing the tested species on the strip mine spoils were more clearly identified.

Field Demonstration

The field demonstration served as the final step in identifying grass and legume species with high stability potentials for revegetating the strip mine spoils. A subjective ranking relative to initial cover obtained by seeding eleven species on the leveled spoil bank top follows:

1. Morpa Weeping Lovegrass
2. Old World Bluestem mixture
3. Sideoats Grama
4. Kanlow Switchgrass
5. Korean Lespedeza
6. Kentucky 31 Fescue
7. Linn Perennial Ryegrass
8. Cody Alfalfa
9. Emerald Crownvetch
10. Sericea Lespedeza
11. Common Bermudagrass

Some of the conditions unfavorable to plant establishment and growth on the spoil bank included:

1) A lack of soil-sized material (<2 mm) at the spoil surface and therefore
2) A deficiency of moisture at the spoil surface
3) An inadequate supply of nutrients (unfertilized plots)
4) High surface temperatures due to the shale fragments' dark coloring (black, gray, and brown)
5) Very little precipitation during germination (below average).

Grasses and legumes potentially suitable as revegetation species should demonstrate tolerance towards the adverse growing conditions encountered on spoils. Plant vigor, persistence, propagation, and establishment are among the important qualities to be considered when evaluating a species performance. In reality plant performance on the spoil bank is the ultimate test.

As expected, plants on fertilized plots were usually larger, more vigorous, and more numerous than plants on unfertilized plots thus substantiating the fertility results of the greenhouse study. Specifically nitrogen and phosphorus should be applied to the spoil when growing grasses and phosphorus applied when growing legumes.

A subjective ranking in descending order according to plant performance on fertilized plots after 2 years on the spoil bank follows (see Figure 20).

(1) Morpa Weeping Lovegrass - Numerous, vigorous plants were present on the plots. Plants were observed growing on the leveled spoil bank top as far as 200 yards from the original plantings as well as on the approximately 60% side slopes of the spoil bank and the two adjacent valleys. Morpa Weeping Lovegrass appeared to be well established and spreading prolifically.

(2) Emerald Crownvetch - Vigorous, healthy looking plants furnished the most dense and complete ground coverage of the species planted. Crownvetch often needs 3-4 years to become completely established; however, after only 2 years Emerald Crownvetch appeared to be establishing well and beginning to spread both by rhizomes and seeds. A few

Figure 20. Overall View of Field Demonstration After 2 Years on the Spoil Bank.

small plants were observed growing as far as 30 yards from the original plantings.

(3) Cody Alfalfa - Scattered vigorous plants were observed on the fertilized and unfertilized plots. Unfertilized plants were smaller than plants on fertilized plots; however the absence of fertilizer appeared to have less effect on Cody Alfalfa than on any other species planted.

(4) Sideoats Grama - Several plants in relatively good stands were observed; however, the plants appeared to be suffering from a lack of moisture causing early maturation and consequent drying of the plants. A few larger and still quite green plants were observed growing in the two adjacent valleys where more moisture was available. These plants had

obviously spread from seeds produced by plants on the leveled spoil bank top plots.

(5) Kentucky 31 Fescue - A few to several plants more or less scattered over the plots were observed. Plants were not especially vigorous, nevertheless, long term species establishment seemed probable but not certain.

(6) Sericea Lespedeza - Few plants, variable in size and lacking vigor, were observed. Long term species establishment is in doubt.

(7) Linn Perennial Ryegrass - Very few plants were observed. Plants lacked vigor and did not appear to be particularly adapted to the growing conditions encountered on the spoil bank.

(8) Common Bermudagrass - Occasional plants were observed; however, these infrequent plants lacked vigor.

Although Korean Lespedeza, Old World Bluestem mixture and Kanlow Switchgrass germinated on the spoil bank these species did not persist and were not present on the spoil bank 2 years after planting.

Morpa Weeping Lovegrass and Emerald Crownvetch overwhelmingly proved to be the most adapted species of those tried on the spoil bank. Both established exceptionally well displaying vigorous prolific plants (See Figure 21).

Fertilized plots of Emerald Crownvetch had Morpa Weeping Lovegrass plants in varying numbers intermixed with the crownvetch plants. This of course was due to the propagation by seed production of nearby weeping lovegrass plants. The combination of Morpa Weeping Lovegrass and Emerald Crownvetch appeared to be a very good combination and

Figure 21. Morpa Weeping Lovegrass and Emerald Crownvetch After 2 Years on the Spoil Banks.

merits consideration as such to be tried on a larger scale on the Stigler area strip mine spoils and on strip mine spoils in other areas of Eastern Oklahoma.

Morpa Weeping Lovegrass ideally would establish quickly and function to a degree as a "nurse" crop until Emerald Crownvetch becomes established. In all likelihood the crownvetch plants would eventually assume dominance and crowd out most of the weeping lovegrass plants. This is not particularly discouraging; however, since crownvetch (symbiotic bacteria) can fix nitrogen from the air; whereas, weeping lovegrass plants are unable to do this and must be supplied with nitrogen fertilizer or obtain a portion of the nitrogen fixed by the crownvetch plants.

CHAPTER V

SUMMARY AND CONCLUSIONS

The environment encountered by plants on strip mine spoils varies according to a combination of factors. The type of spoil including the inherent chemical, physical, and biological characteristics of the spoil and climatic conditions of the area affect revegetation efforts.

Coal strip mine spoils in the Stigler, Oklahoma area, the site of the revegetation study, typically are basic, calcareous Pennsylvanian Age shales. All coal bearing formations in Oklahoma are Pennsylvanian Age.

The spoil material collected for the greenhouse study tested "very low" in available phosphorus and "high" in available potassium. Nitrogen content was limited to the small amount in scattered coal fragments. In general, nitrogen and phosphorus should be applied to the spoils when grasses are to be grown while only phosphorus will be required for legumes.

Grass and legume species exhibiting "very good" or "good" revegetation suitability potentials in the greenhouse study included: Old World Bluestem mixture, Morpa Weeping Lovegrass, Kanlow Switchgrass, Kentucky 31 Fescue, Common Bermudagrass, Korean Lespedeza, Linn Perennial Ryegrass, Cody Alfalfa, and Sideoats Grama. Emerald Crownvetch and Sericea Lespedeza each displayed "fair" suitability potentials while Vine Mesquite exhibited "poor" suitability potential.

Two years after seeding 8 grass and legume species had survived and remained on the spoil bank. They were ranked according to performance on the spoil bank as follows:

1) Morpa Weeping Lovegrass
2) Emerald Crownvetch
3) Cody Alfalfa
4) Sideoats Grama
5) Kentucky 31 Fescue
6) Sericea Lespedeza
7) Linn Perennial Ryegrass
8) Common Bermudagrass

An advisable legume-grass mixture for revegetating Eastern Oklahoma strip mine spoils is Emerald Crownvetch and Morpa Weeping Lovegrass. Basic treatments for initial establishment include:

1) Prepare a seedbed (if feasible)
2) Fertilize according to soil (spoil) tests
3) Broadcast Emerald Crownvetch (scarified and inoculated seed) and Morpa Weeping Lovegrass seed at higher than normal seeding rates (after the last killing frost in the spring but before May 1 if the 2 species are seeded at the same time).
4) Cover the seeds lightly
5) Protect the plants during establishment.

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APPENDIX A

DESCRIPTION AND CHARACTERIZATION OF KANIMA SOILS

Kanima Soils

The dominant soils of this mapping unit typically have very dark grayish brown shaly silty clay loam A horizons about 6 inches thick that contains 20 percent shale fragments and very dark grayish brown shaly silty clay loam C horizons that contains 70 percent shale fragments.

Typifying Pedon: Kanima shaly silty clay loam.

(Colors are for moist soil unless otherwise noted)

A	0-6"	Very dark grayish brown (2.5YR 3/2) shaly light silty clay (69-OK-31-7-1) loam; massive; hard, friable; 20 percent shale fragments and 1 percent coal fragments; neutra; diffuse wavy boundary. (4 to 12 inches thick).
C	6-72"	Very dark grayish brown (2.5YR 3/2) shaly light silty clay (69-OK-31-7-2) loam; few pockets of yellowish brown (10YR 5/4) shaly silty clay loam; massive; friable; 70 percent very dark gray (N/3) shale fragments increasing to 85 percent at 72 inches and 2 percent coal fragments; neutral.

Type Location: Haskell County, Oklahoma; about 3 miles south of Tamaha; 2100 feet south and 1300 feet west of the northeast corner of Section 8, T. 10 N., R. 22 E.

Range in Characteristics: All horizons are shaly silty clay loam or shaly silt loam, and range from slightly acid through moderately alkaline. Coal fragments range from a trace to 5 percent. The A horizon is dark grayish brown (10YR 4/2; 2.5Y 4/2), very dark grayish brown (10YR 3/2; 2.5Y 3/2) or dark brown (10YR 4/3). Where the A horizon has values of 3, the C horizon has values of 3 or less. Percent of shale fragments in the A horizon ranges from 15 to 85 percent, typically 15 to 50 percent. The C horizon is very dark grayish brown (2.5Y 3/2; 10YR 3/2), dark grayish brown (10YR 4/2; 2.5Y 4/2), grayish brown (10YR 5/2) or brown (10YR 4/3, 5/3). Some pedons have pockets of shaly soil material with higher chroma. The percent of shale in the C horizon ranges from 35 to 90 percent; average amount of shale of the horizon ranges from 60 to 90 percent. Color of shale is very dark grayish brown (10YR 3/2; 2.5Y 3/2), dark grayish brown (2.5Y 4/2), olive gray (5Y 4/2), olive (5Y 4/3), dark olive gray (5Y 3/2) or very dark gray (10YR 3/2; 5Y 3/1). The C horizon is subdivided in some areas because of differences in shale percentages.

Competing Series and Their Differentiae: There are no competing soils in this county.

Setting: Kanima soils are gently sloping to very steep spoil banks of shale displaced in strip mining operation. The climate is warm and humid; average annual precipitation is 42 inches, and mean annual air temperature is 62°F. at the type location.

Principal Associated Soils: These are the Collinsville, Liberal, Stigler, Tamaha and Vian soils. Collinsville soils have a mollic epipedon. Liberal, Stigler, Tamaha and Vian soils all have developed B2t horizons.

Drainage and Permeability: Well drained. Runoff is slow to rapid, depending on amount of compaction, age, or amount of weathering and slope. Permeability is moderate and moderately rapid, depending on percent of coarse fragments.

Use and Vegetation: Limited use. Vegetation depends on age of spoil banks. Some of the older spoil banks have elm, hackberry, sycamore, cottonwood, sumac, and black locust trees with a sparse to moderate understory of grasses, weeds, and sweet clover.

Distribution and Extent: In all parts of county except mountain areas.

APPENDIX B

RESULTS OF GREENHOUSE STUDY

TABLE VII

DRY WEIGHT OF PLANT TOPS (GRAMS/POT) GROWN IN SPOIL AT 5 FERTILITY LEVELS IN GREENHOUSE (FIRST PLANTING)

Species	0-0-0	N-0-0	0-P-0	N-P-0	N-P-K
Old World Bluestem Mixture	3.1	14.6	2.4	27.7	27.1
	3.0	13.9	3.7	33.5	25.9
	2.6	12.1	2.6	25.1	33.1
	4.6	12.4	3.0	28.3	24.4
Vine Mesquite	0.7	1.2	0.8	4.2	2.9
	0.5	1.4	0.8	3.1	2.6
	0.5	1.7	0.5	3.1	3.2
	0.5	0.9	0.6	2.9	2.7
Emerald Crownvetch	2.2	2.6	3.6	6.5	4.4
	3.0	3.0	5.6	6.4	3.6
	1.9	3.3	2.7	5.6	3.4
	1.5	1.5	8.0	3.7	3.0
Kanlow Switchgrass	4.5	6.5	4.0	21.9	12.4
	3.2	5.8	3.7	16.1	14.7
	3.2	6.2	4.4	18.7	12.8
	5.5	6.1	3.9	15.1	17.9
Weeping Lovegrass	3.7	8.9	3.9	13.3	15.5
	6.7	10.4	5.4	16.2	13.8
	7.1	7.6	4.7	17.7	14.4
	4.5	8.9	6.3	17.4	17.4

TABLE VIII

DRY WEIGHT OF PLANT TOPS (GRAMS/POT) GROWN IN SPOIL AT 5 FERTILITY LEVELS IN GREENHOUSE (SECOND PLANTING)

Species	0-0-0	N-0-0	0-P-0	N-P-0	N-P-K
Sericea	5.8	6.0	8.3	8.7	8.5
Lespedeza	6.4	5.3	7.8	9.1	8.6
	5.2	6.5	7.5	7.5	8.8
Sideoats	1.2	1.2	1.6	13.1	11.9
Grama	0.8	1.1	1.2	11.5	10.6
	1.2	1.0	1.0	10.9	12.1
Kentucky 31	2.5	4.0	2.0	14.4	13.8
Fescue	1.9	4.5	2.8	15.4	13.9
	1.1	4.4	1.8	17.3	14.6
Korean	9.7	7.3	12.7	15.1	14.4
Lespedeza	8.2	7.1	12.1	15.0	14.1
	7.3	6.4	14.7	14.6	12.2
Common	0.6	0.9	1.0	15.6	13.3
Bermudagrass	0.4	0.9	1.1	13.6	13.8
	0.7	0.8	0.9	13.7	15.9
Linn	2.5	4.6	1.7	14.0	12.1
Perennial	1.1	3.4	1.4	12.5	13.3
Ryegrass	2.5	3.8	2.4	12.4	13.0
Cody	4.8	6.1	11.2	13.4	14.5
Alfalfa	5.4	6.9	11.3	12.7	12.4
	5.9	5.7	14.7	12.1	15.3

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VITA

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