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IMPROVING TREE GROWTH ON POOR AND MEDIUM SITES THROUGH THE USE OF LEGUMES

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PROGRESS REPORT SUMMARY

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Research Triangle Park, N.C.
August 1980

IMPROVING TREE GROWTH ON POOR AND MEDIUM SITES

THROUGH THE USE OF LEGUMES

by

Jacques R. Jorgensen

About 8 million acres of Sandhills run from central Florida to North Carolina. Vegetation in this area is often sparse due to low moisture-holding capacity and low nutrient content of the soil. The objective of this study is to improve the productivity of these sites through the use of legumes to fix nitrogen and by limited fertilization to supply some nutrients essential for both planted trees and legumes.

Two sites, a low quality deep sand and a medium quality loamy Redbay soil were planted to pine, fertilized and sown to legumes in the winter and spring of 1980. Ground rock phosphate at a rate of 112 kg/ha of P and K at a rate of 56 kg/ha were applied to plots planted to loblolly pine on the Redbay soil and to loblolly and Choctawhatchee sand pine on the deep sand. In April, virgata, sericea, and bicolor lespedezas were sown on disked strips on the deep sand. The same three lespedezas in addition to Kobe were sown on the Redbay soil. Treatments were evaluated in late July 1980, at which time all legumes had been successfully established. On disked strips on the deep sand, there were an average of nine legume seedlings per .09 m^2 area and on the Redbay soil 14. Plants were taller on the Redbay soil than on deep sand, with virgata lespedeza being shortest and bicolor the tallest on each site. Undisked tree rows had less than one legume plant per .09 m^2 area. The addition of K fertilizer had no influence on the number of legumes or on their size.

Loblolly pine had 75 percent survival on the Redbay soil, but 85 percent on the deep sand. Sand pine on the deep sand had 82 percent survival. The difference in survival between the two sites was significant at the 5 percent level. There was no significant difference between survival of loblolly pine and sand pine on the deep sand. Neither were there survival differences due to fertilizer or legume treatment on either site.

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INTRODUCTION

Forest trees respond to nitrogen more than to any other element. However, response to any one element will be limited by deficiencies of other nutrients, and non-nutritional influences such as moisture and sunlight.

At the present time there is a tendency for supplemental fertilization to be carried out on those sites that have a growth potential limited only by those factors that can be economically manipulated. Does this imply that all other sites will eventually be relegated to "LIM" (low intensity management) land where, in many instances, even wildlife, wilderness, and aesthetic values are low? Probably not, but intensive management practices on these sites may be delayed by economics. Perhaps with innovative techniques including adapted species, soil-nutrient conservation, and specialized forest management the economic and non-economic returns from this land can be improved.

About 3.2 million ha (8 million acres) of Sandhills in the Southeast run from central Florida to North Carolina. This area is sometimes referred to as a rain desert. In many areas annual rainfall approaches or exceeds 125 cm (50 inches), but due to the low moisture-holding capacity of the soil, vegetation is often sparse.

ABSTRACT

The Sandhills of the Southeast have vegetation that is often sparse due to the soil's low moisture-holding capacity and lack of nutrients. The objective of this research is to improve the productivity of these sites through the use of legumes and limited fertilization.

Two sites, a low productivity deep sand and a moderately productive loamy soil were planted to pine, fertilized, and sown to legumes in the winter and spring of 1980. Phosphorus and K were applied to plots of loblolly pine on the loamy soil and to loblolly and Choctawhatchee sand pines on the deep sand. Virgata, sericea, and bicolor lespedezas were sown on disked strips on the deep sand, with Kobe being added on the loam soil.

By late July 1980, all legumes were successfully established. Disked strips on the deep sand had nine legume seedlings per .09 m^2 area and the loamy soil had 14.

Loblolly pine had 75 percent survival on the loamy soil, and 85 percent on the deep sand. Sand pine on the deep sand had 82 percent survival. The difference in survival due to site was significant at the 5 percent level.

Fertilizer and legume treatments had no effect on tree survival.

Keywords: Biological nitrogen fixation, legumes, biomass production, loblolly pine, sand pine, lespedezas, site productivity, phosphorus fertilization.

Much of the sandhill area was originally covered with open, low volume stands of longleaf pine (Pinus palustris Mill.)--a species not only adapted to poor droughty soils, but also resistant to fire, which may have eliminated some species that had a higher growth potential. It is this land that presents some of the greatest challenges to forest management in the South.

OBJECTIVES

The objectives of this study are to determine if the forest productivity of poor (excessively well drained) and medium quality sites can be improved. Site improvements will be undertaken through the use of legumes to fix nitrogen and improve nutrient cycling, and by limited fertilization to supply some nutrients essential to both the planted trees and legumes. The best adapted pine species other than longleaf will be planted on each site. It is assumed that increased tree productivity will be accompanied by improved wildlife habitat, but no estimates of the degree of improvement are contemplated in this study.

METHODS

Experimental Area Description and Location

The experimental areas are located on the Savannah River Project (SRP), south of Aiken, South Carolina (Fig. 1). Two experimental sites were selected. One site, consisting of a Redbay-like soil, had its loblolly pine (P. taeda L.) stand cut and removed within the last year. On this site, inclusive of the experimental area, loblolly pine was planted in the spring of 1980 without benefit of site preparation other than clearcutting. The second site, a deep sand exceeding 120 cm (48 inches) in depth, had been covered with longleaf but was clearcut recently and the site prepared for replanting by windrowing. The area, exclusive of that reserved for the study, was planted to longleaf.

Plot Preparation, Plot Layout, Fertilizer, and Legume Treatments

Plots were laid out in January 1980. Redbay area plots were 33.8 m (111 feet) wide and 31 m (102 feet) long with an area of 0.105 ha (0.26 acres) (Fig. 2). Due to a limited number of sand pine seedlings, plots on the deep sand area were smaller 20.1 m (66 feet) wide and 31.1 m (102 feet) long with an area of 0.063 ha (0.16 acres) (Fig. 3). Plots were laid out in a completely randomized manner with three replications, in most instances (Table 1). In addition to the replicated plots several smaller plots, not part of the study design, were established on each site to provide some indication of the effects of site preparation and fertilization on legume growth.

Year-old pine seedlings were planted on both study areas in February 1980. Except for the site preparation done to regenerate both clearcut areas, no further preparation was done prior to planting. Seedlings were planted in rows spaced approximately 3.4 m (11 feet) apart with a within-row spacing of 1.8 m (6 feet). The Redbay area was planted to loblolly pine seedlings obtained from the same source as other SRP planting. The deep sand area was planted primarily to Choctawhatchee sand pine (P. *clausa* var. *immuginata* Ward) obtained from a private nursery in north Florida. A few plots were planted with loblolly obtained from SRP sources.

On April 2-3, 1980, ground rock phosphate (13.5% P) and KCl were broadcast on both sites. The GRP was applied at a rate equivalent to 112 kg of P/ha and K at a rate of 56 kg/ha. Except for plots that received no P, GRP was applied to all plots. Potassium was applied to half of each plot regardless of P fertilization.

On April 3-4, 1980, following fertilizer distribution, plots were disked to incorporate fertilizer into the soil and to prepare a seedbed. Disking was done with a crawler tractor pulling a 1.8 m bedding disk set not to produce a mound. The slightly over 1.8 m width of the disked strip left from 0.3 to 0.6 m uncultivated between the disked area and the row of trees. Disking was done only once with over 95 percent of the soil being disturbed on the deep sand and about 90 percent disturbed on the Redbay area. The lower rate of disturbance on the Redbay was due to accumulations of needles from crown residues and concentrations of woody waste. In neither area did weeds, grasses, or sprouts interfere with the disking.

Legume seed were inoculated with an appropriate rhizobium using 'Pelgel' as a sticker within 24 hours of sowing. Pelletized, preinoculated (coated) bicolor lespedeza seed were also inoculated, since the time between coating and planting exceeded that expected for survival of the inoculum.

In the afternoon following disking, legume seed were sown with a cyclone seeder at a rate of 22 kg of seed/ha. Sown seed were concentrated on the freshly disked strips with a relatively small proportion falling on the undisked row area. At the time of sowing, soil was moist and the disking had produced many cracks and crevices into which the seed fell making it unnecessary for a second disking to cover the seed. Weather on April 3-4, 1980, was overcast with a light rain at times--ideal for sowing seed and preserving the rhizobium inoculum.

Legumes used in the study were:

Bicolor lespedeza (Lespedeza bicolor Trucz.) - A shrubby, woody perennial valuable for browse and seed production. Both coated and uncoated seed were sown. Commercial seed production is limited.

Sericea lespedeza 'Serala' (L. cuneata (Dum.) G. Don) - A herbaceous perennial often utilized for its soil-improving ability. Wildlife value is limited by high tannin content of seed and forage. Seed are commercially produced.

L. thunbergii (DC.) Nakai - Seed produced by this perennial are utilized by wildlife. Forage has limited utilization by wildlife. Good soil improving ability. Commercial seed production is limited.

Japanese or common lespedeza 'Kobe' (L. striata (Thunb. ex Murr) Hook. and Arn.) - Low-growing annual. Valuable for soil improvement ability and for the seed and forage it can provide wildlife. Seed are commercially produced.

Virgata lespedeza 'Ambro' (L. virgata) - A recent release by the Soil Conservation Service. A perennial that is somewhat less aggressive than sericea lespedeza. There are no published reports of its wildlife value. Seed are not yet commercially available in quantity.

'Clanton' tickclover (Desmodium paniculatum (L.) DC.) - A selection made by Soil Conservation Service. Forage and seed of this perennial are utilized by wildlife. Annual tickclovers have been utilized for soil improvement in the past. No commercial seed production. Unless an improved system of seed harvest can be developed, the seed will be too expensive for use in forestry.

Seed were sown 4 to 6 weeks later than optimum due to delays in study financing, transporting the ground rock phosphate, and to travel restrictions. The distribution of plots by treatment is shown in Table 1.

Study Measurements

Initial measurements of tree survival and legume stocking on replicated plots were made July 28 and 29, 1980.

On the deep sand, beginning with the second row within a plot and with the fourth tree within each row, trees were examined to determine if they were alive, dead, or missing or had any Nantucket pine tipmoth (Rhyacionia frustrama) damage. In most plots on this site the central four rows were tallied with the number of trees ranging from 32 to 43 and an average of 37 per plot. The first and last trees in each row were marked with a plastic flag on a wire pin. Similar tree measurement procedures were carried out on the Redbay site, except that on the larger plots more rows of trees were measured. On these plots the number of trees ranged from 55 to 81 with an average of 62. Tree height was not measured since the trees had not finished height growth when survival measurements were made.

Legume stocking and height of legumes were measured within the central area of each replicated plot. On the deep sand site four .09 m^2 area plots were randomly located on the disked strips. Opposite these plots, but on the undisked area containing the trees, four similar plots were located. Due to larger plots on the Redbay site, eight .09 m^2 area plots were located on the disked strips and eight on adjacent undisked areas of each replicated plot, using the same procedures for location as on the deep sand. The number of sown legumes within each .09 m^2 area plot was counted and the average height estimated to the nearest 2.5 cm. If there were over 20 plants per .09 m^2 area this was noted without further counting.

RESULTS AND DISCUSSION

Pines

Weather through March of 1980 favored the survival of planted pine seedlings. Beginning in April, however, there were periods of drought that decimated several plantings on the SRP area. Average loblolly survival on the Redbay site was 76 percent, but on the seemingly more severe deep sand, survival was better, averaging 85 percent for loblolly and 82 percent for sand pine (Table 2). The difference between sites was significant at the 5 percent level. Within sites there were no significant differences in survival due to fertilizer or legume treatment, or between pine species on the deep sand site. In an area adjacent to the deep sand site that had been production planted, survival of longleaf averaged 23 percent in an inventory of 83 plants.

The superior survival of trees on the deep sand may have been due to the more complete site preparation and/or to hand planting instead of the machine planting used on the Redbay area. Site preparation on the Redbay area, simply clearcutting and machine planting, allowed for more competitive weed and sprout growth than did the windrowing and rootraking on the deep sand.

No height measurements of the pines were made since growth for 1980 was not yet complete. General observations suggested loblolly planted on the Redbay site were taller than those planted on the deep sand, with sand pine being shorter than the loblolly.

Tipmoth damage was relatively minor, although more severe on loblolly than on sand pine. Only about 1 percent of the sand pine suffered any tipmoth infestation. On the deep sand 10 percent of the loblolly pine were damaged. On the Redbay area only two plots, believed to be representative, were tallied for tipmoth and on these 22 percent of the trees were damaged.

Legumes

Both sites were successfully stocked with legumes, although there were fewer plants per unit area on the deep sand than on the Redbay site (Table 2). On the disked strips of the deep sand, bicolor, virgata, and sericea averaged 5, 6, and 12 plants per .09 m^2 area respectively, whereas on the Redbay soil stocking was higher with 12, 11, 12, and 18 plants per .09 m^2 area, respectively, for bicolor, virgata, sericea, and Kobe. Ten percent of the .09 m^2 area plots on disked strips on the deep sand had no legumes, but only 2 percent on the Redbay site were without plants. Forty-two percent of the disked .09 m^2 area sericea plots on the deep sand and 29 percent on the Redbay area held over 20 plants. Seventeen percent of the disked virgata plots, and none of the bicolor plots on the deep sand had over 20 plants per .09 m^2 area whereas on the Redbay area 25 percent of the virgata, 38 percent of the bicolor, and 88 percent of the Kobe sample had high plant populations. Typical stands of bicolor, virgata, and sericea on the deep sand are shown in figures 4, 5, and 6.

Distribution of legumes was greatly affected by disking and by the sowing process which attempted to concentrate the seed on the disked areas between the rows of trees (Fig. 7). On both sites one plant per .09 m^2 area was found on the undisked areas in which the trees were planted. In most instances the 1 to 1.3 m width of the undisked strip protected the seedlings from competition with legumes. The control of competition through the use of selective seeding and site preparation methods may be critical to initial tree survival and growth, especially on droughty sites, if legumes are to be used as a source of site improvement.

Neither K fertilization nor coating had any effect on the number of plants established or on their vigor.

Nonreplicated observation plots of virgata, bicolor, and sericea lespedezas on the Redbay area established without disking or fertilization contained only occasional patches of legumes. On the same area, where sericea was planted on disked areas without P fertilization, the stand was poor, but Kobe, virgata, and bicolor lespedezas all produced acceptable stands. Unreplicated *L. thunbergii* and *D. paniculatum* plots that had been disked and fertilized had acceptable stands of the legumes. Unfertilized observation plots of sericea and virgata on the deep sand had plant population equal to or better than were found on fertilized plots.

Legume height was related to species and influenced to some extent by site, but it was not affected by K treatment. Bicolor plants were the largest averaging 30 cm tall on both sites, but plants ranging up to 100 cm tall were common especially on the deep sand. There were no important differences in height of sericea due to site, but virgata plants averaged 15 cm tall on the Redbay and only 8 cm on the deep sand. Virgata plants on the deep sand were pale green or yellowish, whereas on the Redbay site they were greener and more robust. Kobe plants on Redbay site were dark green and healthy.

In general, lespedezas planted on the Redbay soil were adversely affected by competition from annual and perennial weeds and woody sprouts. Although stocking on the Redbay site was superior or equal to that on the deep sand, seedling establishment was probably hindered by the lower degree of site preparation compared to that on the deep sand. Few legumes were found where there were accumulations of pine needles or woody residues. These materials increased the difficulty of disking and reduced mineral soil disturbance from over 95 percent on the sand to about 90 percent on the Redbay.

Root systems of legumes grown on the deep sand were examined. All three species had nodules, but there were differences in nodule number, size, and color. Bicolor lespedeza had relatively few large, round nodules that were pink inside indicating a potential for N fixation (Fig. 8). Sericea nodules were small and elongated with interiors less pink than those of the bicolor. Virgata nodules were tiny and mostly greenish or yellowish inside, indicating little N-fixation potential. Nodule color seemed to be correlated with plant vigor, with bicolor the most vigorous and virgata the least. Bicolor also had the deepest root system of the three lespedezas. Most nodules were within 10 cm of the soil surface.

On both sites, but especially on the deep sand, wild legumes were common. On the deep sand Partridge pea (Cassia fasciculata Michaux) was outstanding with its display of yellow flowers (Figs. 9 & 10). The trailing vines of milkpea (Galactia sp.) were also common. These plants were also found on the Redbay soil, but were accompanied by numerous sicklepod (Cassia obtusifolia L.). Several other legumes were also found on both sites, but their populations were relatively small. Roots of partridge pea had numerous nodules with bright red interiors, indicating a high potential for N fixation. Roots of the other species were not examined. Partridge pea is a valuable wildlife plant for both seed and forage. Seed of milkpea are utilized by birds. Sicklepod seed are poisonous and the plant is not desirable for wildlife.

PROJECTION

The second growing season will be critical for both legumes and trees. Should the trees survive and grow through this period they will be beyond the danger of overtopping by all legumes except bicolor. Their root systems should also have occupied a sufficiently large volume of soil to withstand moisture competition from the few legumes now established in the disked strips and from those that seed into the area in the ensuing years. Except for the annual Kobe, there will be relatively little legume seed produced until the second year.

The suitability of these sites for the maintenance of legume stands will become evident after the first growing season. When the legumes were first established, site preparation provided competition control and enhanced legume growth. Beginning with the second season native weeds and sprouts may be sufficiently vigorous to suppress the weaker legumes, virgata in particular. The reseeding annual, Kobe, faces not only severe competition from late-growing weeds, but its seed are prime food for birds and small animals. These animals are attracted to clearcuts and could conceivably decimate the small plots that have been established.

During the next reporting period, measurements will be made to establish baseline data for the projected increase in site productivity. Nutrient status of the soil will be measured to determine the influence of any fertilizer applications, and to provide a basis for the determination of any nitrogen increases due to biological fixation. Pine seedling heights will be measured, and data subjected to statistical analysis to determine the influence of experimental treatment. Pine foliage will be sampled and analyzed to determine treatment effect on seedling nutrient status.

In late 1981 biomass and soils will be sampled and analyzed and estimates made of the quantities of nitrogen added to the site through biological fixation. Additional plots, similar to those already established, may be laid out during 1980-81 to incroporate additional promising nitrogen-fixing plants into the present experimental design.

Table 1. Distribution of plots and subplots by treatment

Legume	Redbay soil site	Deep sand site	
	Loblolly pine	Sand pine	Loblolly pine
	Treatment [1/]		
Sericea	3DPK, 3DP, 1D[2/], 1[2/], 1DK[2/]	3DPK, 3DP, 1D[2/]	3DPK, 3DP
Virgata	3DPK, 3DP, 1D[2/], 1[2/]	3DPK, 3DP, 1D[2/]	
Bicolor, uncoated	3DPK, 3DP	3DPK, 3DP	
Bicolor, coated	3DPK, 3DP, 1D[2/], 1[2/]	3DPK, 3DP	
Kobe	3DPK, 3DP, 1D[2/]		
Thunbergii	1DPK[2/], 1DP[2/]		
Desmodium	1DPK[2/], 1DP[2/]		
No legume	3DPK, 3DK, 3DP, 3D	4DPK, 4DP, 2DK, 3D	2DPK, 2DP, 1DK,1

[1/] Treatment code: 1, 2, 3, 4, = number of plots or subplots with treatment
D = disked
P = phosphorus applied
K = potassium applied.
No letters indicate no disking or fertilizer applications.

[2/] Plot not part of replicated study design

Table 2. Tree and legume data, July 29, 1980

Species			Trees		Legumes			
Tree	Legume	Fertilizer[1/]	Survival	Tipmoth damage	Disked area Number	Disked area Height	Undisked area Number	Undisked area Height
			--------%--------		(per $0.09m^2$)	--cm--	(per $0.09m^2$)	--cm--
			Deep Sand Site					
Sand pine	Bicolor	GRP	84	2	5	30	2	20
	Virgata	"	88	0	6	8	1	10
	Sericea	"	74	1	13	20	1	20
	None	"	85	0	-	-	-	-
	"	None	80	0	-	-	-	-
Average			82	1				
Loblolly pine	Sericea	GRP	85	10	10	23	2	13
	None	"	84	10	-	-	-	-
"	"	None	86	10	-	-	-	-
Average			85	10				
			Redbay Site					
Loblolly pine	Bicolor	GRP	80	-	12	30	1	20
	Virgata	"	85	-	11	15	1	13
	Sericea	"	77	-	12	25	1	15
	Kobe	"	72	-	18	18	1	10
	None	"	76	-	-	-	-	-
	"	None	70	-	-	-	-	-
Average			76	-				

1/ Ground rock phosphate (GRP) applied at the rate of 112 kg P/ha.

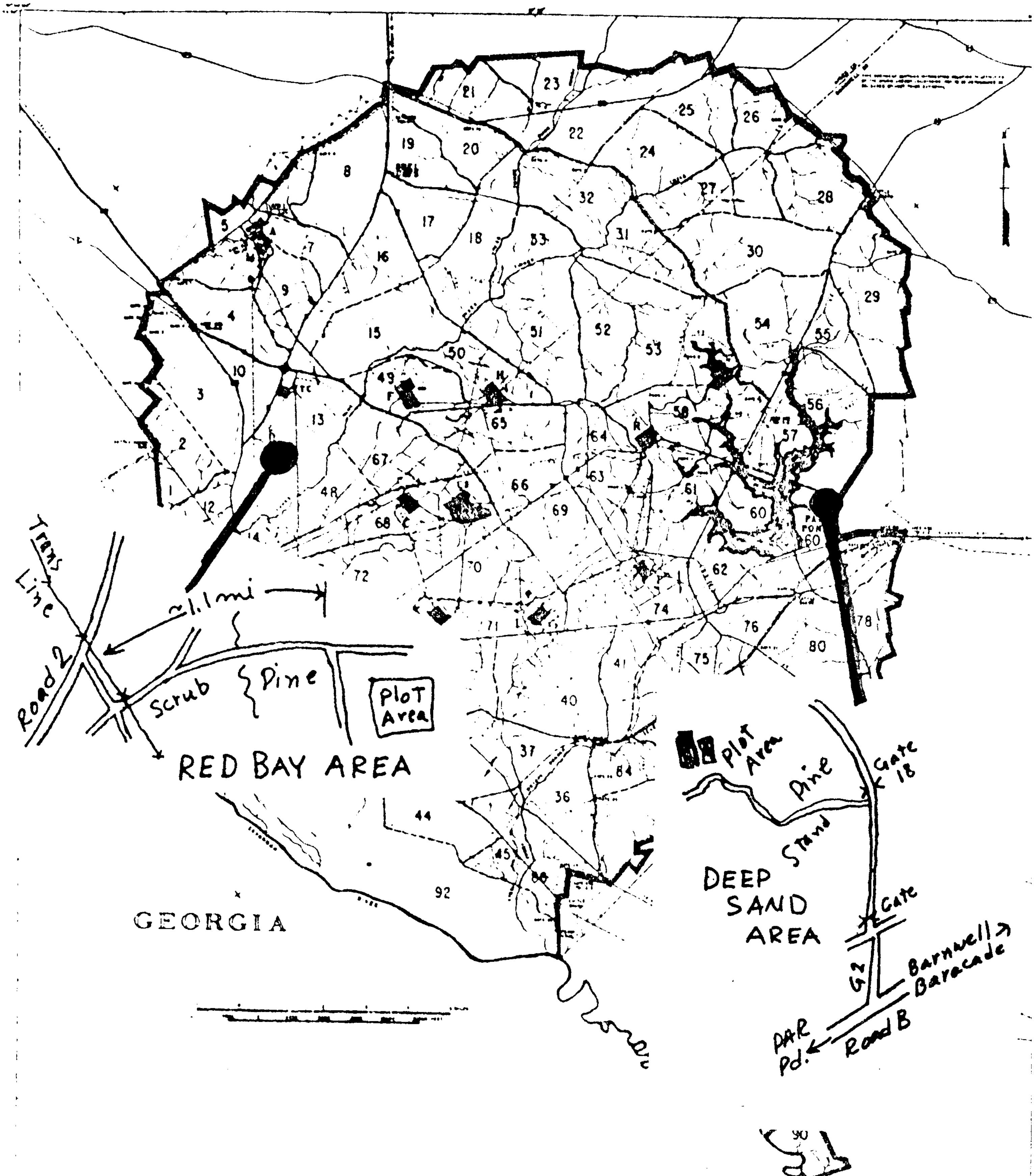

Figure 1. Experimental site locations.

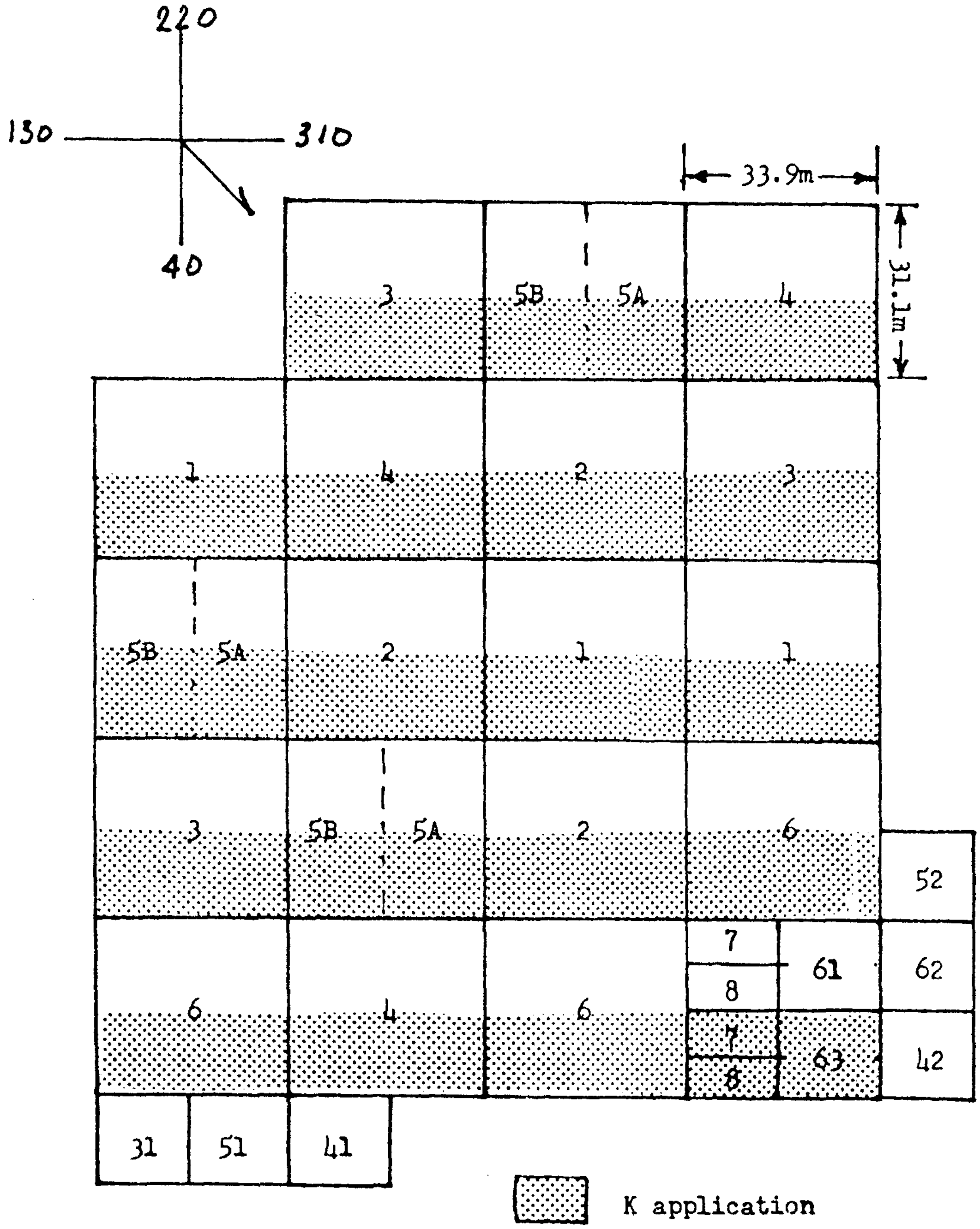

Figure 2. Experimental layout on Redbay soil area.

Treatment descriptions, Redbay soil area

Treatment	Description
1.	Disked, no P, K on half plot, no legume.
2.	Disked, P on plot, K on half plot, no legume.
3.	Disked, P on plot, K on half plot, 'Kobe' lespedeza.
4.	Disked, P on plot, K on half plot, virgata lespedeza.
5A.	Disked, P on plot, K on half plot, uncoated bicolor lespedeza.
5B.	Disked, P on plot, K on half plot, coated bicolor lespedeza.
6.	Disked, P on plot, K on half plot, sericea lespedeza.
7.	Disked, P on plot, K on half plot, L. thunbergii.
8.	Disked, P on plot, K on half plot, D. paniculatum
31.	Disked, no P, no K, 'Kobe' lespedeza.
41.	Disked, no P, no K, virgata lespedeza.
51.	Disked, no P, no K, bicolor lespedeza.
61.	Disked, no P, no K, sericea lespedeza.
42.	Not disked, no P, no K, virgata lespedeza.
52.	Not disked, no P, no K, bicolor lespedeza.
62.	Not disked, no P, no K, sericea lespedeza.
63.	Disked, no P, K, sericea lespedeza.

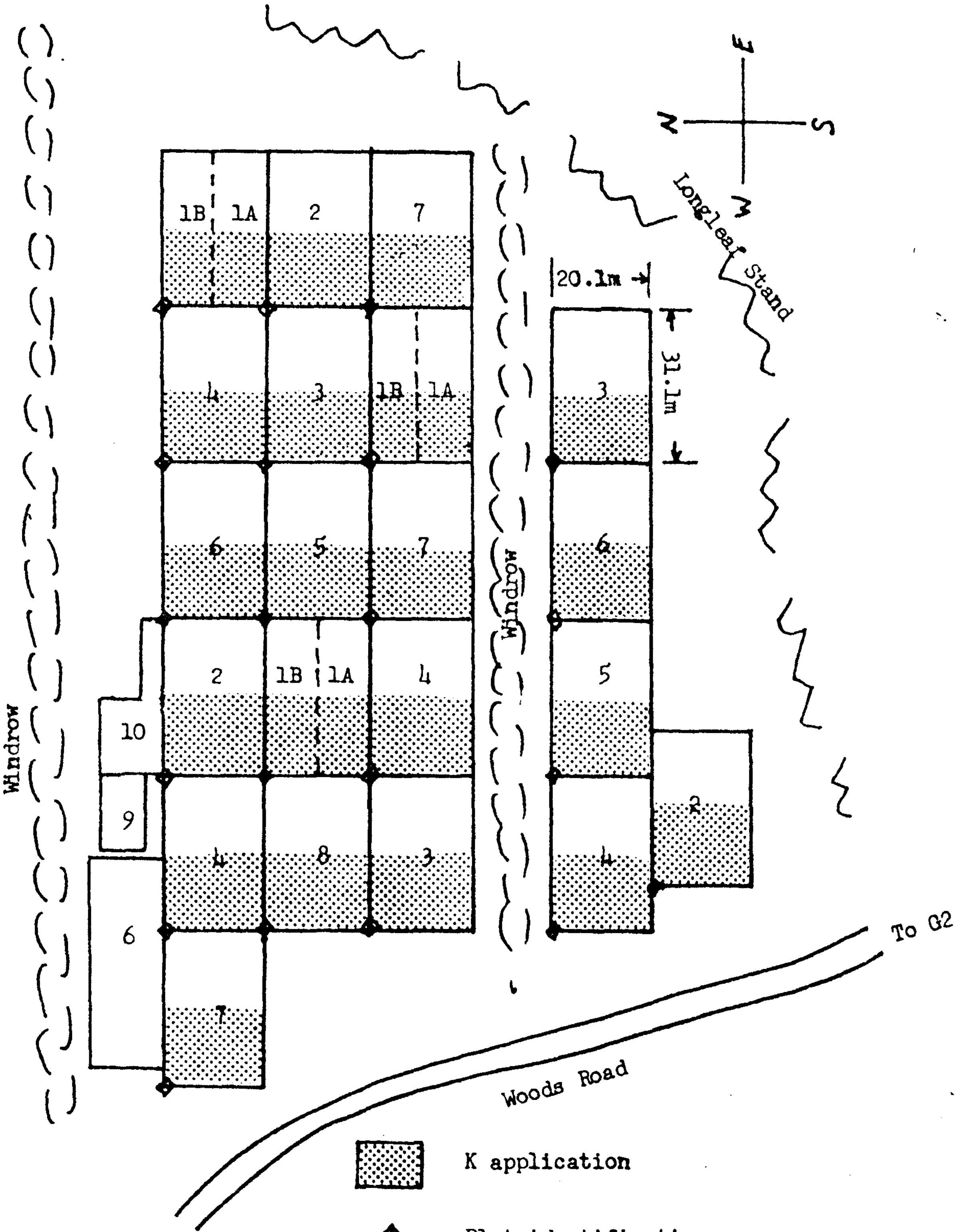

Figure 3. Experimental layout on deep sand area.

Treatment descriptions, deep sand area.

Treatment	Description
1A.	Sand pine, P on plot, K on half plot, uncoated bicolor lespedeza.
1B.	Sand pine, P on plot, K on half plot, coated bicolor lespedeza.
2.	Sand pine, P on plot, K on half plot, virgata lespedeza.
3.	Loblolly pine, P on plot, K on half plot, sericea lespedeza.
4.	Sand pine, P on plot, K on half plot, no legume.
5.	Loblolly pine, P on plot, K on half plot, no legume.
6.	Sand pine, no P, K on half plot, no legume.
7.	Sand pine, P on plot, K on half plot, sericea lespedeza.
8.	Loblolly pine, no P, K on half plot, no legume.
9.	Sand pine, no P, no K, sericea lespedeza.
10.	Sand pine, no P, no K, virgata lespedeza.

Fig. 4. Stand of bicolor lespedeza established in April 1980, on the deep sand site. July 28, 1980

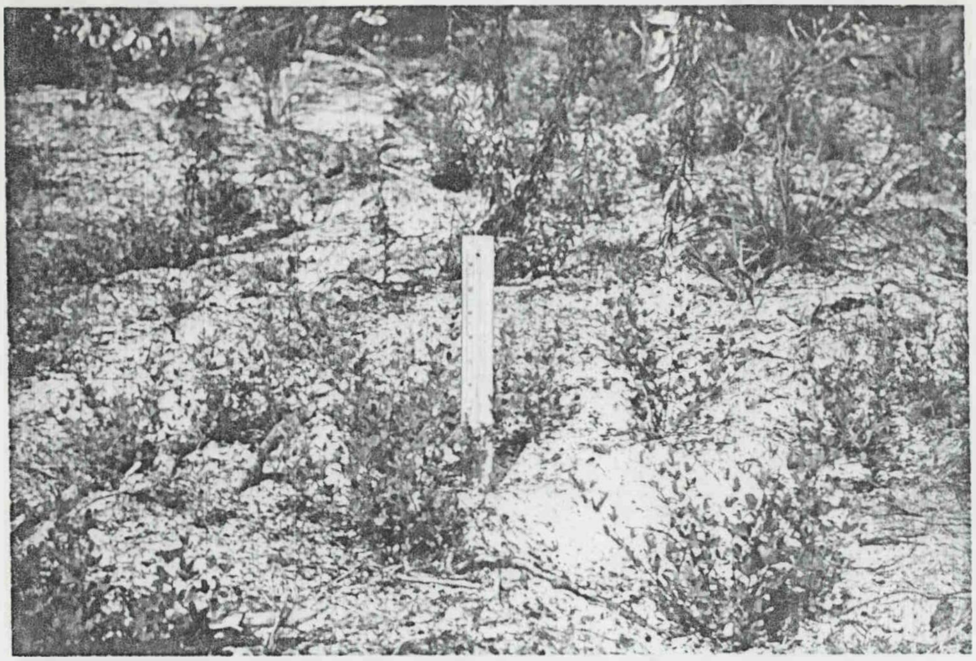

Fig. 5. Stand of virgata lespedeza established in April 1980, on the deep sand site. July 28, 1980

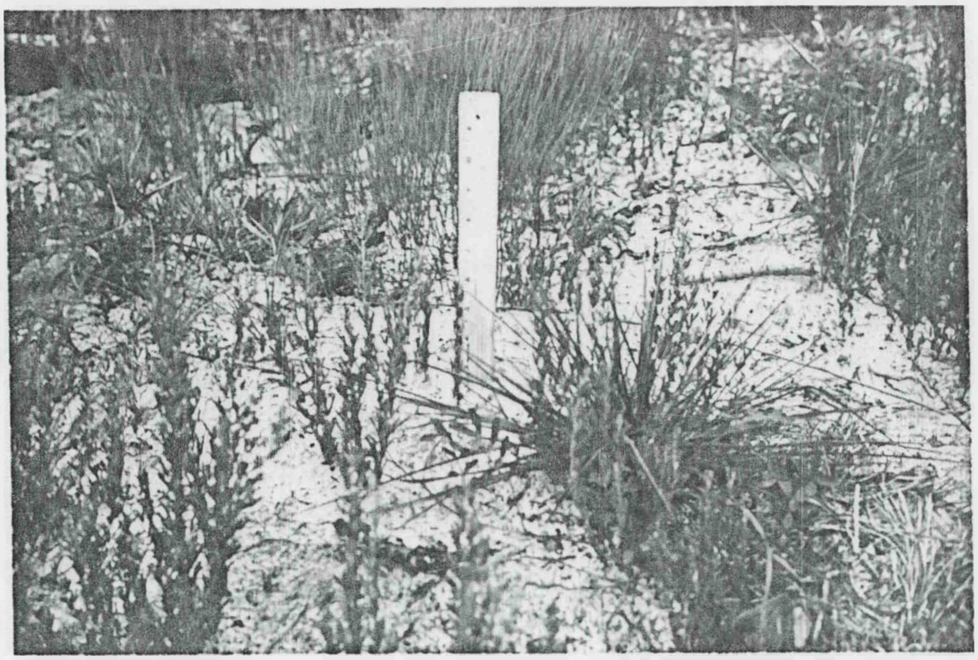

Fig. 6. Stand of sericea lespedeza established in April 1980, on the deep sand site. July 28, 1980

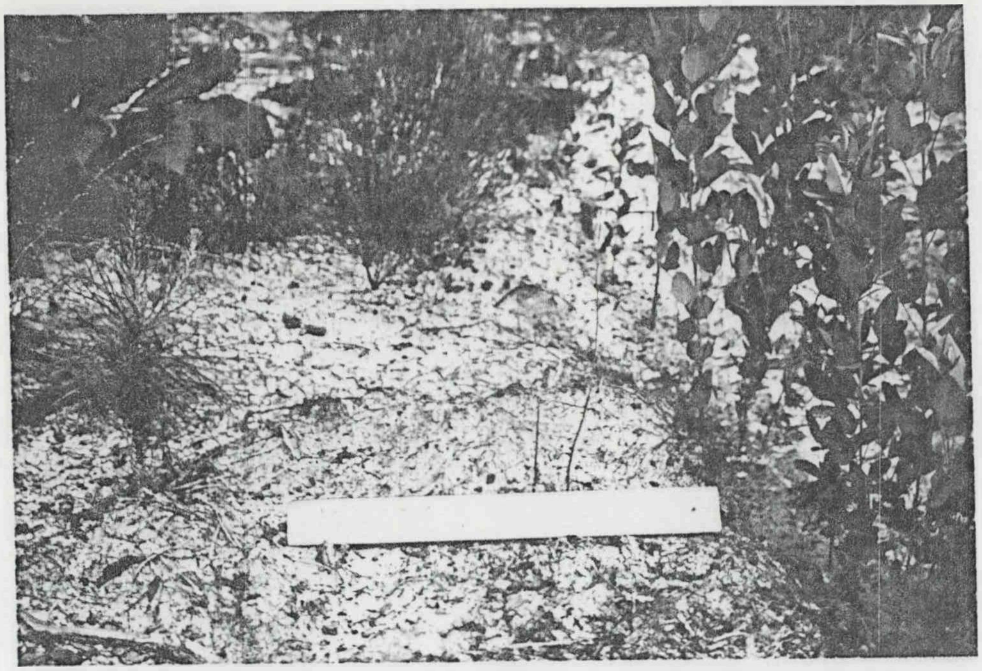

Fig. 7. Undisked tree row area without legumes and bicolor lespedeza in adjacent disked strip on the deep sand site. Note line of bicolor plants resulting from broadcast sown seed caught in disk furrough, and general lack of legumes outside the disked area. July 28, 1980

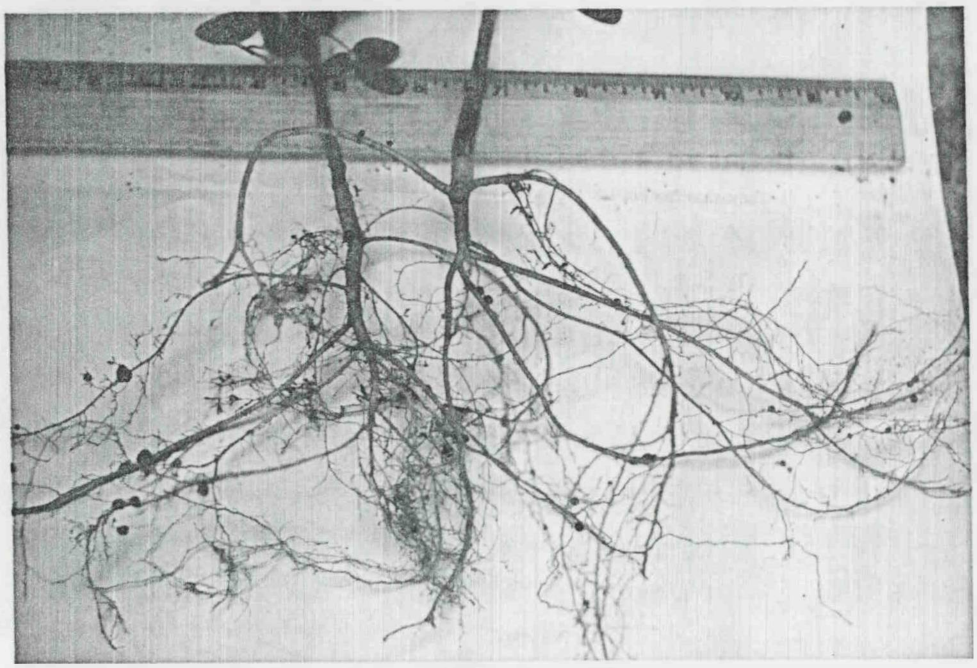

Fig. 8. Root system and nodules of bicolor lespedeza from deep sand site. July 28, 1980

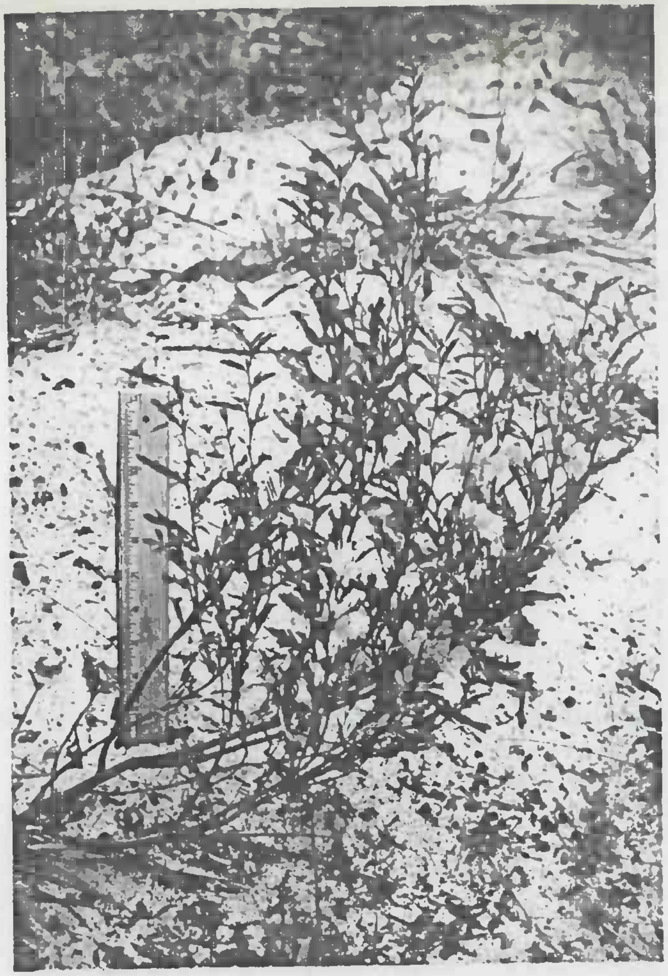

Fig. 9. The deep sand site showing typical vegetative regrowth a year after site preparation. The yellow-flowering partridge pea are the most conspicuous annuals. July 28, 1980

Fig. 10. Native volunteer partridge pea from the deep sand site. These plants provide nutritious forage and seed and are capable of improving the site by fixing nitrogen. July 28, 1980.