GRASS AND PINE CONVERSION
WITH HERBICIDES

By

JERALD KEITH NICKELS

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Oklahoma State University

Stillwater, Oklahoma

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Scope and Method of Study: A study was initiated in the Ouachita Highland Resource Area of Oklahoma in the spring of 1977 to evaluate tall fescue and shortleaf pine conversion systems with two soil applied herbicides, hexazinone and tebuthiuron, in comparison to 2,4-D tree injected. Experimental design was a randomized complete block with eight replications. First year defoliation and second year control (based on crown reduction, stem kill, and basal sprouting) were evaluated for blackjack oak, post oak, winged elm, hickory, and shortleaf pine. The number of stems and total basal area per plot prior to treatment and at the termination of the study were also compared to determine stems remaining and total basal area reduction. The study was burned after defoliation to provide a seedbed for tall fescue. Forage production was determined for tall fescue, native grasses, miscellaneous grasses, sedges, and forbs the fall of 1978 and spring 1979. Shortleaf pine growth response was determined by measuring radial xylem-growth of randomly selected pole and sapling size pine in the hexazinone, 2,4-D injected, and untreated area.

Findings and Conclusions: All treatments adequately controlled the hardwood species with the exception of the more tolerant hickory. However, crown reduction was satisfactory on all hardwoods. Tebuthiuron was also active on pine, killing 88% of the trees. Hexazinone was selective on pine and only slight visual injury was noted the first year at the 2.2 kg/ha rate. Forage yield was influenced by both hardwood and pine control, with the greatest forage yields occurring on the tebuthiuron plots. Tall fescue was the principle forage from these plots. The reduction in hardwood competition with both 2,4-D injected and hexazinone caused a substantial increase in radial xylem-growth of pole and sapling pine by the third growing season. Both forage yield and pine growth were increased when competition was reduced. However, this reduction was more critical for forage yield than for pine release. Control of only hardwoods was not adequate to get major forage response. On the other hand, control of large hardwoods with 1.1 kg/ha of hexazinone was adequate to release the pine. The pine then dominated the site.

ADVISER'S APPROVAL Jimmy F. Stritzke

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Thesis Approved:

Jimmy T. Stritzke
Thesis Adviser

Charles G. Tauer

Fenton Gray

Norman N. Durham
Dean of the Graduate College

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INTRODUCTION

Commercial forest areas of eastern Oklahoma consist of 4.3 million acres located in the 17 eastern counties. Only 30% of these lands are being commercially used for timber production (52). The other 70% of these lands are privately owned and contribute very little towards the needed increase in wood products.

Murphy (32) reported that 1.8 million acres of Oklahoma forestlands are dominated by hardwoods, and 1.7 million acres need treatment to improve pine production. Industry has already intensified their management program on their lands and are operating close to maximum. However, the non-commercial, private landowners have been more interested in short-term investments, and the amount of commercial forestlands has been declining for the past 20 years. The expanding cattle industry in Oklahoma has caused most of this land loss, with lands being converted into pasture systems. These owners are clearing off a few acres, putting in some cattle, and calling it a woodland grazing system. Management is then aimed at grass or cattle production, or in many cases, there is no management.

Herbicides are available to control undesirable hardwoods, and many of these areas have native stands of shortleaf pine (*Pinus echinata*) on them for potential wood product production. The evaluation of these chemicals for grass production and pine release could therefore lead to efficient utilization of these areas for either beef production, wood production, or both.

The objectives of this study are as follows: 1) to compare the effectiveness of hexazinone and tebuthiuron with 2,4-D tree injected for control of hardwood trees; 2) to determine pine tolerance to herbicide treatments; 3) to evaluate forage yield from various treatments after burning and seeding to tall fescue; and 4) to compare growth response of shortleaf pine to hardwood control as a result of 2,4-D tree injected and hexazinone treatments.

CHAPTER II

LITERATURE REVIEW

Foliar Applied Herbicides

Early attempts to control undesirable hardwoods were with fire and selective girdling of individual stems by axe. When herbicides became available, they were tested for brush control on individual large cull hardwood stems (26). The advent of 2,4,5-T (common and chemical names of all herbicides reviewed are listed in Table 1) had a significant impact on the forest industry. For the first time a broadcast foliar herbicide could be used to control large and small hardwoods with little damage to the existing pine trees.

Numerous studies have been conducted with phenoxy herbicides for hardwood control. Darrow and Silker (11) compared different phenoxy compounds and application methods for loblolly and shortleaf pine release (common and scientific names of all plant species reviewed are listed in Table 2). They found that effective top kill on hardwoods was best obtained with a minimum rate of 1.7 kg/ha 2,4,5-T or 2,4,5-TP esters and that helicopter applications were better than fixed wing. Peevy and Brady (41) compared tractor mounted mist-blowers and high volume ground sprayers with fixed-winged application of 2,4,5-T in central Louisiana and found all three methods to be effective at a 2.2 kg/ha rate. Also spring treatments were more effective than August

Table 1. Common and chemical names of herbicides.

Common name	Chemical name
2,4-D	(2,4-dichlorophenoxy) acetic acid
2,4,5-T	(2,4,5-trichlorophenoxy) acetic acid
2,4,5-TP	2-(2,4,5-trichlorophenoxy) propionic acid
Dicamba	3,6-dichloro-o-anisic acid
Fenuron	1,1-dimethyl-3-phenylurea
Hexazinone	[3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4,(1*H*,3*H*)-dione]
Monuron	3-(*p*-chlorophenyl)-1,1-dimethylurea
Picloram	4-amino-3,5,6-trichloropicolinic acid
Tebuthiuron	*N*[5-(1,1-dimethylethyl)-1,3,4-thia-diazol-2-yl]-*N*,*N*'-dimethylurea

Table 2. Common and scientific names of plants.

Common name	Scientific name
Big bluestem	*Andropogon gerardii* Vitman.
Blackjack oak	*Quercus marilandica* Muenchh.
Broomsedge	*Andropogon virginicus* L.
Fescue	*Festuca* spp.
Fireweed	*Epilobium angustifolium* L.
Hickory	*Carya* spp.
Horseweed	*Conyza canadensis* (L.) Cronq.
Indiangrass	*Sorghastrum nutans* (L.) Nash.
Little bluestem	*Schizachyrium scoprium* (Michx.), Nash.
Loblolly pine	*Pinus taeda* Laws.
Longleaf pine	*Pinus palustris* Mill.
Oak	*Quercus* spp.
Pine	*Pinus* spp.
Ponderosa pine	*Pinus ponderosa* Laws.
Post oak	*Quercus stellata* Wangenh.
Shortleaf pine	*Pinus echinata* Mill.
Slash pine	*Pinus elliottii* Engelm.
Spruce	*Picea* spp.
Tall fescue	*Festuca arundinacea* Schreb.
Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees.
Winged elm	*Ulmus alata* Michx.

treatments. Malac (28) conducted a similar study in Georgia and obtained 71% hardwood kill with the mist-blower, 68% kill with the helicopter, and 53% kill with the ground sprayer at a 1.7 kg/ha rate of 2,4,5-T.

Stritzke (48) evaluated several herbicide combinations with 2,4,5-T for broader spectrum of hardwood species control in Oklahoma. Winged elm, a more tolerant species to 2,4,5-T, was effectively controlled with the addition of 0.6 kg/ha picloram to 2.2 kg/ha 2,4,5-T. This treatment resulted in a 100% winged elm top kill without sprout activity. Brady (4) experimented with different formulations of 2,4,5-T using dicamba and picloram. Some of these combinations had better control on all hardwood species than did the 2,4,5-T control. However, he also reported that damage to loblolly pine occurred with the addition of these herbicides to 2,4,5-T. It has been reported 2,4,5-T alone has an effect on shortleaf pine (14). Elwell (14) found that 0.6 kg/ha 2,4,5-T caused reddish coloring on needles of different size shortleaf pine. However, this coloration was lost after 3-4 weeks. Gratkowski (19) reported ponderosa pine resistance to phenoxy herbicides with late summer applications safely releasing pine from shrub competition in Oregon. Nelson et al. (33) found that an excess of 1.7 kg/ha 2,4,5-T for controlling dense mixed brush in loblolly plantations is likely to be toxic to pine without improving the level of brush control.

A disadvantage of chemically thinning was discussed by Bergmann (2). He explained that chemical thinning, where the dead trees remain on the site, would provide breeding places for insect pests and should be taken under consideration.

Soil Applied Herbicides

Pelleted herbicide formulations have the advantage of reduced drift, better target deposition, and less sprouting. The pellet formulation is not a new concept in hardwood control. Hinton (23) and Darrow et al. (10) applied fenuron pellets to reduce hardwood competition and found them effective on light soils. Elwell et al. (16) reported on the use of soil applied substituted ureas (fenuron and monuron) as early as 1954. Effective kill of oak was obtained at a 13.4 kg/ha rate within 30 months after treatment.

More recently, pelleted formulations of tebuthiuron and hexazinone have shown promise for effective hardwood control throughout the South. Eaton (13) described tebuthiuron as a non-selective pre- and post-emergence herbicide. The phytotoxic symtoms suggest that control is obtained by inhibition of photosynthesis with a half life of 12-15 months. The pellet is broadcast on the soil surface and activated by rainfall. McNeill et al. (30) reported that the stability of the pellet will allow it to remain on the soil surface a considerable time without loss of activity before an activating rainfall. The herbicide is absorbed through the plant root system and translocated upward causing leaf senescence and subsequent defoliation. Persistence and resistance to leaching allows the herbicide to maintain long-term activity in the root zone. Several defoliations following each of several major rainfalls cause the plant to eventually die.

Hexazinone activity is very similar to that of tebuthiuron. Rohrbough (42) reported that hexazinone is a broad spectrum herbicide with pre- and postemergence activity. The mode of action is not clear but like tebuthiuron appears to be a photosynthetic inhibitor. Root uptake, translocation, and defoliation cycles are all similar to tebuthiuron activity. The half life of hexazinone is shorter than tebuthiuron, ranging from 1-6 months depending on soil and climatic conditions. Best results have been obtained when plants are in an active growing state.

Shroyer et al. (46) indicated tebuthiuron to be more effective than 2,4,5-T in reducing the total nonstructual carbohydrate content in roots of blackjack oak and winged elm. This resulted in better tree kill with no sprouting evident after two years. Scrifes and Mutz (43) and Peevy (40) noted adequate control over a broad range of hardwood species using tebuthiuron. Nickels and Stritzke (36) found effective hardwood tree kill with 2.2 and 4.5 kg/ha rates of hexazinone and tebuthiuron on post oak, blackjack oak, winged elm, and hickory. Hickory tree kill was satisfactory at a 2.2 kg/ha rate of hexazinone. It was also noted that tebuthiuron caused high mortality among short-leaf pine, while hexazinone caused no apparent pine damage. Hexazinone has also provided a wide range of hardwood species control as evidenced by the work of Scrifres and Mutz (44) and Hamilton (22).

Fitzgerald et al. (18) using several rates of hexazinone as a foliar spray found loblolly pine seedlings resistant at rates of 3.0 kg/ha or less. O'Loughlin et al. (38) reported that damage to loblolly pine in plantations was limited to very light needle burning from foliar spray at rates not to exceed 1.1-2.2 kg/ha. Fitzgerald and Fortson (17) obtained similar results, reporting pine seedling tolerant to 2.0 kg/ha hexazinone, but noted that the addition of surfactants resulted in 10% mortality. Voller and Murphy (51) and Peevy (40) evaluated tebuthiuron for hardwood control in loblolly pine plantations. Both used a large pellet formulation and found that when used properly, the herbicide provided both hardwood control and increased pine survival.

Soil type appears to be very important in influencing the effectiveness of urea type herbicides, since absorption and desorption were influenced by organic matter and clay content (5). Rates have to be increased on clay soils to obtain desirable tree kill (1, 17, 22, 39).

Grass Release

Management skills in grazing and the control of undesirable plants, such as woody brush species, can contribute to an economic gain. Davis (12) reported that proper formulations and applications of herbicides for brush control can result in forage production improvements. He relates that this is due to the increased availability of sunlight, moisture, and space. However, he found that a minimum of 70% tree kill was necessary to obtain good grass production.

A major concern in grass response is time and type of grass produced. Crawford (7), working with aerial application of 2,4,5-T in the Ozark mountains of Arkansas, noted that increases in grass production occurred both the first year and second year after application. The amount of forbs was reduced the first year but increased greatly by the second year. This increase was due mainly to undesirable fireweed and horseweed forb species. He did, however, question the cost in relation to the grazing potential. Plant succession after herbicide treatment has been reported as a very slow process (9). Dalrymple et al. (9) found that with 92% tree kill of oak and winged elm, grass production increased two to three times the first year and seven times by the second year. However, much of this increase was attributed to production of less desirable grass and forb species. Davis (12) reported that the major grass that invaded an area of treatment was broomsedge; and, with the use of moderate grazing, little bluestem became dominant after five years in the Ozark highlands of Arkansas. Elwell (15) found that native grass production in mixed hardwood areas of Oklahoma doubled when hardwoods were controlled. He also noted that grass production did not increase when hardwoods were controlled in areas having heavy stands of pine. The seeding of warm season grasses has been evaluated as a method to speed up the natural process of grass conversion toward desirable grasses. Senter (45) concluded that establishment by seeding was risky on these droughty sites.

It now appears that tebuthiuron and hexazinone can be used as selective herbicides for brush control and grass release. Wilson et al. (53) conducted greenhouse studies to evaluate soil incorporated and surface preemergence activity of tebuthiuron on 28 forage species. These studies indicated a wide range of species tolerance. The most tolerant species were big bluestem, indiangrass, and weeping lovegrass. Twenty-two of the 28 species evaluated were more tolerant on silty loam than sandy loam soils. Scrifres and Mutz (43) reported no undesirable effects on desirable range grasses and range conditions improved by the second year following treatment with 2.24 kg/ha of tebuthiuron. Forb production was reduced 90% after the second year. Scrifres and Mutz (44) found a first year increase in grass production from 9.8 kg/ha on untreated plots to 2,200 kg/ha on plots receiving a 2 to 4 kg/ha rate of hexazinone. Forb production was quite variable but was generally reduced on plots treated with 2 kg/ha of hexazinone.

Pine Growth Response

Pines appear to respond with increased growth when competition from hardwoods or herbaceous vegetation is decreased. As early as 1961, Malac (28) conducted a long-term study in the lower coastal plains of Georgia and South Carolina to determine growth response of slash pine after controlling hardwoods with 2,4,5-T. He reported a 43% height growth increase and 60% diameter growth increase on pines in the treated areas. This compared to an increase of 31% in height and 27% in diameter growth of pine trees in the untreated areas. Diameter growth has been shown to be more responsive to release through hardwood control than height growth (15).

Nickels and Stritzke (37) reported that radial xylem-growth of shortleaf pine increased from 1.9 mm/yr before treatment to 4.5 mm/yr after hardwoods were controlled with hexazinone at a 2.2 kg/ha rate. No increase in xylem-growth of pines was noted in untreated areas.

Nelson et al. (34) found that total biomass of loblolly pine seedlings increased as much as 13 times when weeds were controlled. Huss and Wachendorf (25) conducted studies in the North Rhine-Westphalia area of West Germany and concluded that weed control for spruce was not likely to promote young spruce growth or benefit in survival rate but that the pine was more responsive to control measures and could benefit from herbicide treatment.

Fire and Herbicide Combinations

Fire has also been used as a management tool for both grass and pine production, and its use is still being evaluated for many management practices. The multitude of alternative uses make it very attractive in terms of low cost and time involvement. However, numerous controversies have resulted from its use due to the variability that fire itself creates.

One potential of the use of fire is forage production and establishment of forage grasses. Increases in forage yields have resulted in forests dominated by shortleaf and loblolly pine when prescribed burning was used, as reported by Blair (3) and Halls and Alcaniz (21). Grelen and Enghardt (20) evaluated burning practices in conjunction with thinning in longleaf pine plantations. They found increases in forage yields each year from pine stands 30 to 34 years old. This increase resulted in 1,336.2 kg/ha of forage at age 34, and increase of 165%. It was concluded that with burning and thinning at regular intervals, forage production could be maintained for a number of years. Valamis et al. (50) reported that the use of fire increased the nitrogen content of two ponderosa pine soils of California the first year after burn. This increase was not noted the second year.

Crawford and Bjugsted (8) suggested an alternative to the slow process of plant succession following hardwood control by going to improved pasture systems in the Missouri Ozarks. This consisted of a June foliar spraying for hardwood control and control burning in September followed by aerial seeding of tall fescue. Effective results were obtained; however, tall fescue is drought sensitive and caution against mismanagement was advised. Similar results were reported on the Ouachita Highland Resource Area of Oklahoma (49).

Loveland (27) evaluated the necessity of hardwood leaf litter removal for grass establishment in Oklahoma. He found that establishment success was very poor on areas that were unburned and contained dense litter. McConnell and Smith (29) studied the effects of pine needle litter on survival of fescue grass seedlings. Best survival occurred when the original litter was removed prior to grass seeding and the new litter was allowed to accumulate. The poorest survival occurred where seeds were sown on original litter and the new litter was allowed to accumulate.

Pine growth evaluations have also been conducted following use of fire as a tool for thinning and used in conjunction with herbicides to reduce competition. Morris and Mowatt (31) used fire as a thinning tool but found it was lacking in thinning uniformity throughout a ponderosa pine site. They also found an increase in pine growth using fire as a burning tool; however, they concluded that any competition within 10 feet affected diameter growth but not height growth. Woolridge and Weaver (54) conducted studies in the same area. Their conclusions conflicted with the earlier study on pine growth response. They reported that burning caused a reduction in the rate of ponderosa pine growth. It was not determined if the difference between the previous study by Morris and Mowatt (31) was between sites or that of competition, but burning did cause poor distribution of stocking by overthinning as a result of different fuel amounts. Prescribed burning did not reduce yields from an oak-pine forest in southern New Jersey (47). Somes and Morehead (47) found that periodic uses of winter fires did offer an economical way to convert to or maintain an existing subclimax pine stand without reducing growth rate.

The use of herbicides in conjunction with fire has been studied as a method to prolong brush control. Holt and Nation (24) evaluated the effects of using both high and low rates of 2,4-D plus picloram in conjunction with fire for site preparation intended for loblolly pine plantings. It was found that with higher rates brush was controlled for four years after treatment. The lower rate was only effective when the area was burned the fall of treatment. Burning the year after treatment caused an increase in brush stems. Burning had no effect on brush control with the high rate of herbicide. Chen et al. (6) indicated that, from a wildlife standpoint, herbicide effects when separated from effect by fire can be a disappointment. Herbicides caused an increase in grass production as a result of reduced woody competition but had a reverse effect on legume species, while burning caused an increase in legumes which provided succulent browse for deer. It was suggested that herbicides may be used where hardwood understory is a problem and fire be incorporated to increase wildlife foods.

The current status of vegetation control in pine management was summed up very well by Newbold (35) when he stated,

> Weed control in southern pine management can be carried out in several ways, each best suited to specific conditions. Mechanical and chemical methods and/or prescribed burning may all be integrated in the variable southern ecosystems to provide good weed control at an economical cost if the treatment(s) fits the situation (p. 181).

CHAPTER III

METHODS AND MATERIALS

An experiment was conducted to determine the effects of three herbicides on hardwood control and subsequent forage production and shortleaf pine growth after the entire area was burned. The Ouachita Highland Resource Area of southeastern Oklahoma was selected. This region consisted of native shortleaf pines of various size ranges and mixed hardwoods. The hardwoods accounted for 62% of the total woody species basal area. Common and scientific names of all woody species evaluated in the experimental area are listed in Table 3.

Soils of three different classifications occupy the study area and are listed as follows: 1) fine-loamy, siliceous, thermic Typic Fragiudalfs; 2) clayey, mixed thermic Typic Hapludults; 3) loamy-skeletal, siliceous thermic Lithic Dystrochrepts. Pedons typifying these soils are given in Table 4. All three soils are moderate to well drained with a south slope of 2-15%. Permeability is slow on the Typic Fragiudalfs, moderately slow on the Typic Hapludults, and moderately rapid on the Lithic Dystrochrepts.

The experiment consisted of four herbicide treatments. Each treatment was replicated eight times and plots were arranged in a randomized complete block design. Plots were compass surveyed for 45.7 X 45.7 m size. Three treatments were soil applied and are as follows: 1) tebuthiuron (20% ai. of 3.2 mm dia. pellet) was broadcast over the treatment

Table 3. Common and scientific names of woody species evaluated.

Common name	Scientific name
Hardwood species	
Blackjack oak	*Quercus marilandica* Muenchh.
Hickory	*Carya* spp.
Post oak	*Quercus stellata* Wangenh.
Winged elm	*Ulmus alata* Michx.
Softwood species	
Shortleaf pine	*Pinus echinata* Mill.

Table 4. Morphology of three typifying pedons of soil series in the study.

Horizon	Depth (cm)	Color (moist)	Texture[1/]	Structure[1/]	Consistence[1/]	Boundary[1/]
		Shermore - Typic Fragiudalf; fine-loamy, siliceous, thermic				
A1	0-10	10YR 4/3	fsl	1mgr	mfr	c
A2	10-30	10YR 5/4	fsl	1mgr	mfr	c
B21t	30-39	7.5YR 5/6	scl	2msbk	mfi	g
B22t	39-54	10YR 5/4	scl	2msbk	mfi	g
B23t	54-74	10YR 5/4	scl	2msbk	mfi	g
Bx	74-160	10YR 5/1	scl	2cpr	---	-
Parent Material - Colluvial material underlain with interbedded sandstone and shales.						
		Carnasaw - Typic Hapludult; clayey, mixed thermic				
A1	0-7	10YR 3/2	1	2fgr	mvfr	c
A2	7-22	10YR 5/4	1	1fgr	mvfr	c
B21t	22-37	5YR 5/8	sicl	3fsbk	mfr	g
B22t	37-91	5YR 4/8	sic	3fsbk	mfi	g
B3	91-103	5YR 4/8	gsic	3fbk	mfr	c
C	103-128	-------	----	-----	---	-
Parent Material - Interbedded sandstone and shale tilted 20^{o} to 40^{o}.						
		Clebit - Lithic Dystrochrept; loamy-skeletal, siliceous, thermic (Hector on tilted beds)				
A1	0-12	10YR 3/2	gsl	2fgr	mvfr	c
B2	12-29	10YR 4/3	gsl	2fgr	mvfr	c
R	29-37	--------		----	---	-
Parent Material - Hard sandstone, massive, fractured and tilted 15^{o} to 20^{o}.						

1/ Soil survey abbreviations commonly used.

area with a cyclone hand seeder at a 2.2 kg/ha rate; 2) hexazinone (15% ai. of 1 cm dia. grid ball) was hand placed on a grid pattern of 1.8 X 1.8 m for a 1.1 kg/ha rate; 3) hexazinone (15% ai. of 1 cm dia. grid ball) was hand placed on a grid pattern of 1.3 X 1.3 m for a 2.2 kg/ha rate. Soil active herbicides were applied May 18, 1977. Time in man-hours per hectare (mh/ha) was recorded for the application of each soil applied treatment and were as follows: 1) 1.5 mh/ha for tebuthiuron; 2) 2.5 mh/ha for 1.1 kg/ha hexazinone; 3) 3.2 mh/ha for 2.2 kg/ha hexazinone. Three days after application sufficient rain fell to activate the herbicides (Table 5). The fourth treatment was an injection of hardwoods with 2,4-D. Hardwood trees over 2.5 cm in diameter were basal injected with undiluted 2,4-D amine (1 ml/2.5 cm of stem diameter). Hardwood trees were injected January 4-5, 1978. It required the equivalent of 14.3 manhours per hectare to apply the 2,4-D injected treatment, and it took 4.7 l/ha of undiluted 2,4-D. A listing of treatment dates and parameters evaluated is given in Table 6.

Hardwood Control and Pine Tolerance

Hardwood defoliation and pine injury ratings were taken on the soil applied treatment plots on September 15, 1977. Defoliation estimates were made on all trees over 10 cm in diameter. These trees were selected within a 15 m radius at the center of each plot. An average percent defoliation and needle brownout was then obtained for each species in each plot.

Control ratings of the hardwood species were taken for all treatments on October 17, 1978. All tree species were visually rated on basis of percent crown reduction, dead trees or stem kill, and basal

Table 5. The rainfall data from April 4, 1977 through October 29, 1977.

Date	Centimeters	Date	Centimeters
April 4	.43	July 27	.25
April 16	.33	July 30	2.20
April 17	2.29	Aug. 1	2.29
April 18	1.19	Aug. 11	1.65
April 20	.76	Aug. 12	.64
April 30	2.29	Aug. 14	3.81
May 2	.76	Aug. 16	1.27
May 5	.13	Aug. 17	1.78
May 7	.05	Aug. 20	.43
May 9	.64	Aug. 23	.68
May 21	2.67	Aug. 29	4.52
May 22	2.29	Sept. 6	.46
May 23	.05	Sept. 13	7.11
May 29	.18	Sept. 15	.89
June 13[1/]	.02	Sept. 28	.33
June 25	6.50	Oct. 6	.33
June 26	.46	Oct. 8	2.16
June 27	.58	Oct. 23	.38
June 29	.53	Oct. 24	2.11
July 21	4.83	Oct. 28	.15
July 22	.13	Oct. 29	.05
July 26	4.47		

[1/] Rainfall for the month of June was taken from the next closest station.

Table 6. Parameters and dates of the experimental research.

Parameters	Date
Soil Herbicide Application	May 18, 1977
Initial Brush Counts	September 8, 1977
Defoliation Ratings	September 15, 1977
Control Burn	September 15, 1977
Aerial Seeding Tall Fescue	September 30, 1977
Basal Tree Injection (2,4-D amine)	January 4-5, 1978
Woody Plant Control Ratings	October 17, 1978
Fall Forage Production	October 19, 1978
Spring Forage Production	May 30, 1979
Final Brush Counts	August 21, 1979
Pine Growth Measurements	December 8, 1979

sprouting. Ratings were conducted on the same size trees that were selected for the defoliation estimates. Crown reduction was based on the percentage of dead branches within the crown canopy of each individual species. A tree was rated dead if the entire crown was defoliated and no sprouting was evident.

Brush counts and basal area measurements were conducted at the initiation and at the termination of the study. These counts were taken from a 3.1 X 30.5 m sampling transect permanently established in each plot. Basal stem diameter of each stem was measured with calipers to the nearest millimeter. The difference in stem number and basal area of each species at the initiation and termination was then used to compute percent of each remaining at termination of study.

Grass Response

Ground litter on the study area was burned in the fall after defoliation ratings were taken to provide a seedbed for a 16.8 kg/ha aerial seeding of tall fescue. Forage yields were taken during the fall of 1978 and spring of 1979. Yields were determined by clipping four 45 X 120 cm (5,400 cm^2) subsamples per plot. Subsamples were taken at random within the transect used for stem counts. These forage samples were separated into five groups: 1) tall fescue; 2) native grasses (big bluestem, little bluestem, and indiangrass); 3) miscellaneous grasses (Panicum spp. and nimblewill); 4) forbs (ragweed, croton, goldenrod, and fireweed); and 5) sedges. Common and scientific names of herbaceous plants evaluated are listed in Table 7.

One subsample selected at random from each plot was used to calculate moisture content of the forage. Samples were then heated at

Table 7. Common and scientific names of herbaceous plants evaluated.

Common name	Scientific name
Improved grasses	
Tall fescue	*Festuca arundinacea* Schreb.
Native grasses	
Big bluestem	*Andropogon gerardii* Vitman.
Indiangrass	*Sorghastrum nutans* (L.) Nash.
Little bluestem	*Schizachyrium scoparium* (Michx.), Nash.
Miscellaneous grasses	
Nimblewill	*Muhlenbergia schreberi* J.F. Gmel.
Panicum	*Panicum* spp.
Forbs	
Croton	*Croton* spp.
Fireweed	*Epilobium angustifolium* L.
Goldenrod	*Solidago* spp.
Ragweed	*Ambrosia* spp.
Sedges	
Sedge	*Carex* spp.

65 C for one week to obtain an adjustment factor to convert forage yields to kg/ha of dry matter. Dry matter forage production by vegetative types was statistically analyzed. Least Significant Difference (LSD) at .05 was used to determine significant differences.

Pine Response

Two different size classes of shortleaf pine were selected to evaluate pine growth response to release. Shortleaf pine 1.3 m in height to 10 cm in diameter at 1.4 m above ground level (dbh) were classified as large sapling pine. Those pines 10-20 cm in diameter at 1.4 m above ground level were classified as small pole pine. Five trees of each size class were randomly selected from each of the hexazinone plots and the 2,4-D injected plot in four of the replications of the study area. There were not enough pines of these size classes in the other four replications to justify sampling. Trees of each size class were also selected on an adjacent site that had not been treated. These trees were used to give baseline data but were not used in the statistical comparison of treatments.

Height of the tree was recorded in meters, and tree diameter at 1.4 m above ground level was recorded in centimeters. Increment cores were extracted from the base (15 cm above ground level) of each tree. The age of each tree was determined by counting annual growth rings. The yearly growth after treatment (1977, 1978, and 1979) was recorded in millimeters. The average yearly xylem-growth, prior to treatment, was calculated by measuring the increment growth before treatment and dividing the number of increment rings represented. Pine response data was statistically analyzed, and the Least Significant Difference (LSD) test at .05 was used to determine significant differences.

CHAPTER IV

RESULTS AND DISCUSSION

Hardwood Control and Pine Tolerance

Evaluation of initial activity from the soil applied herbicides (hexazinone and tebuthiuron) was based on the visual defoliation ratings of five major tree species and is presented in Table 8. Defoliation of hardwoods was adequate with all three soil applied treatments. However, percent of defoliation obtained with the 1.1 kg/ha rate of hexazinone was consistently less than with the 2.2 kg/ha rate of hexazinone and with tebuthiuron.

Tebuthiuron was very phytotoxic to pine with an average browning of needles of 85%. Shortleaf pine appeared to be tolerant to the hexazinone treatments. Damage was only 9% at the 2.2 kg/ha rate of hexazinone. This damage was noted primarily on small pines, which could have resulted from heavy concentration of herbicide in close contact to their root systems.

The entire study was burned after defoliation ratings were taken. Fire then became a major component of each treatment. There was a difference in leaf litter accumulation at the time of burning. Only residual leaf litter was present in those plots that were to be injected. Whereas, a significant leaf drop occurred on plots that had been treated with the soil applied herbicides.

Table 8. Visual defoliation ratings of five tree species with hexazinone and tebuthiuron.[1/]

Treatment[2/]	Rate	Tree Species: Blackjack oak	Post oak	Winged elm	Hickory	Shortleaf pine
	(kg/ha)	(%)				
Hexazinone	1.1	93	90	92	87	1
Hexazinone	2.2	95	95	97	96	9
Tebuthiuron	2.2	94	95	97	93	85
$LSD_{0.05}$	---	NS	NS	NS	6.1	6.5

1/ Visual ratings were taken on September 15, 1977. An average percent defoliation and needle brownout was obtained for each species in each plot.

2/ Soil applied treatments were conducted May 18, 1977.

Crown reduction of blackjack oak, post oak, and winged elm was excellent by the second year with all treatments (Table 9). The only significant difference in crown reduction among treatments was with hickory. The 62% crown reduction with 2,4-D injected was significantly less than that obtained with the 2.2 kg/ha rate of hexazinone and tebuthiuron. There was also a significant sprouting problem with hickory. There was also a significant difference in the amount of tree kill for blackjack oak and post oak. Tree kill of these oaks was less with the 1.1 kg/ha rate of hexazinone and the 2,4-D injected.

There was essentially no injury to shortleaf pine with hexazinone treatments the second year. However, 88% of the pine trees were killed on the tebuthiuron plots.

Control evaluation for woody species was also observed in terms of stem number and basal area reduction (Table 10). The percentage of stems remaining at the termination of the study varied with treatment. Tebuthiuron was the only herbicide which reduced stem numbers of all species. Hickory was the most tolerant of tebuthiuron, with 51% of the stems remaining. There was an increase in the number of hardwood stems with 2,4-D injected and 1.1 kg/ha hexazinone. This increase was observed to be due to new sprouts from oaks and hickory and new seedlings of winged elm. The 2.2 kg/ha rate of hexazinone reduced the stem number of post oak and winged elm but not stem number of blackjack oak and hickory.

Shortleaf pine numbers were reduced by all treatments ranging from only 4% remaining in the tebuthiuron plots to 50% remaining in the 2,4-D injected plots. Much of this reduction was attributed to fire damage to small trees since basal area of pine was reduced only in the tebuthiuron plots.

Table 9. Response of four hardwood tree species and shortleaf pine to 2,4-D injected and hexazinone and tebuthiuron soil applied.

Response Indicators	Treatment[1/]	Rate	Tree Species: Blackjack oak	Post oak	Winged elm	Hickory	Shortleaf pine
		(kg/ha)	(%)				
Crown Reduction[2/]	Hexazinone	1.1	96	98	100	74	0
	Hexazinone	2.2	97	99	99	86	1
	Tebuthiuron	2.2	98	100	100	98	88
	2,4-D Inject.	---	94	97	99	62	-
LSD 0.05			NS	NS	NS	13.7	7.0
Tree Kill[3/]	Hexazinone	1.1	64	86	91	27	0
	Hexazinone	2.2	78	92	96	53	1
	Tebuthiuron	2.2	86	97	98	78	88
	2,4-D Inject.	---	60	89	94	41	-
LSD 0.05			17.3	8.9	NS	20.6	7.5
Basal Sprouts[4/]	Hexazinone	1.1	18	6	8	34	0
	Hexazinone	2.2	16	2	3	22	0
	Tebuthiuron	2.2	6	2	1	16	0
	2,4-D Inject.	---	22	4	4	4	-
LSD 0.05			NS	NS	NS	12.8	NS

1/ Hexazinone and tebuthiuron treatments were conducted May 18, 1977, and the 2,4-D injected treatment was conducted January 4-5, 1978.

2/ Each tree crown was evaluated by percent of crown area reduced and averaged.

3/ Number of trees actually killed divided by number of trees evaluated.

4/ Number of trees that basal sprouted divided by number of trees evaluated.

Table 10. Effect of hexazinone, tebuthiuron, and 2,4-D injected treatments on stem numbers and basal area of five tree species.

Response Indicators	Treatment	Rate	Tree Species				
			Blackjack oak	Post oak	Winged elm	Hickory	Shortleaf pine
		(kg/ha)	(%)				
Tree Stems Remaining (8/21/79)[1/]							
	Hexazinone	1.1	118	94	98	161	33
	Hexazinone	2.2	128	52	61	99	28
	Tebuthiuron	2.2	33	14	13	51	4
	2,4-D Inject.	---	111	102	88	115	50
Probability of difference at .05			.78	.99	.97	.98	.14
Basal Area Remaining (8/21/79)[2/]							
	Hexazinone	1.1	5	3	4	40	100
	Hexazinone	2.2	2	1	1	14	92
	Tebuthiuron	2.2	3	1	1	1	5
	2,4-D Inject.	---	20	33	12	67	103
Probability of difference at .05			.48	.40	.47	.44	.99

1/ Difference in stem number at the initiation and termination of the study was used to compute the percent remaining.

2/ Difference in basal area at the initiation and termination of the study was used to compute the percent remaining.

Hardwood control, based on percent basal area remaining, appeared much better than tree stems remaining (Table 10). Over 95% of the basal area of blackjack oak, post oak, and winged elm was reduced by hexazinone and tebuthiuron treatments. Basal area reduction of hickory with tebuthiuron and hexazinone treatments varied from 99% reduction with tebuthiuron to 60% reduction with 1.1 kg/ha rate of hexazinone. Results with 2,4-D injected were not quite as dramatic. Basal area reduction with the 2,4-D injected treatment varied from 88% reduction of winged elm to only 33% reduction of hickory. These results are essentially the same as the crown reduction estimates taken on the larger trees (Table 9).

The increase observed in hardwood stem numbers with the decrease in their basal area indicates an increase of small stems collectively having a reduced basal area. This would be due to the reduction of larger stems as related to the increase in new sprouts and seedlings.

Grass Response

Forage yields taken in the fall of 1978 and following spring are listed in Table 11. The forage groups were evaluated as a percentage of the total production. Tall fescue was the principle forage produced on the tebuthiuron and hexazinone plots. Big bluestem and forbs were the principle forages produced in the 2,4-D injected plots. Forage yield from the hexazinone and tebuthiuron plots was significantly higher during both seasons than forage yield from the 2,4-D injected plots. However, no significant differences in total yield existed between the two seasons.

Table 11. Forage yield from brush control with hexazinone, tebuthiuron, and 2,4-D tree injected in 1978 and 1979.[1/]

Year	Treatment	Rate	Total Forage	Forage Groups				
				Tall Fescue	Native Grasses	Miscellaneous Grasses	Sedges	Forbs
		(kg/ha)	(kg/ha)	(%)				
Fall (1978)	Hexazinone	1.1	304	50	46	0	0	4
	Hexazinone	2.2	459	62	29	2	0	7
	Tebuthiuron	2.2	1188	73	25	2	0	0
	2,4-D Inject.	---	76	18	56	2	4	20
$LSD_{0.05}$			113.1					
Spring (1979)	Hexazinone	1.1	401	52	18	22	2	6
	Hexazinone	2.2	362	70	12	10	0	8
	Tebuthiuron	2.2	1258	86	10	3	1	0
	2,4-D Inject.	---	138	10	37	21	9	23
$LSD_{0.05}$			99.7					

1/ Forage yields were taken October 19, 1978 and May 30, 1979.

The main difference between total yields with hexazinone and tebuthiuron treatments was the amount of tall fescue produced. The percent of tall fescue in tebuthiuron plots was 73 and 86 respectively for the fall and spring dates. At the 1.1 kg/ha rate of hexazinone, the tall fescue yield was 50% to 52% of the total yield, while at the 2.2 kg/ha rate, yield was 62% to 70% of the total.

Part of these forage yield differences can be attributed to the establishment of tall fescue. Tall fescue seedbed preparation, through burning ground litter, provided a sufficient access of seed to mineral soil over the entire study. Emergence of tall fescue was also noted over the entire study, but seedlings failed to establish satisfactorily on the plots where the hardwoods were to be controlled by injection with 2,4-D. Part of this failure in establishment could be due to the hardwoods and pine still growing that fall, but much of it was due to the competition from the small untreated hardwoods and pine trees still growing in the area. Establishment was not the only factor limiting forage yields. This was supported by results taken from the soil applied treatments. There was adequate hardwood control and seedling establishment with the 2.2 kg/ha rate of hexazinone, yet production of tall fescue was less than one-third of the tall fescue produced on the tebuthiuron plots where both hardwoods and pine were controlled.

The soils of the study are shallow and sandy textured soils located on a south aspect. Therefore, competition for moisture is likely to be the primary factor in terms of competition.

Pine Response

Yearly radial xylem-growth for pole size pine, ten years prior to treatment and three years after, is shown in Figure 1. The ten-year growth pattern of the pole size pine was plotted with the rainfall pattern. Growth response was very closely related to the rainfall pattern. The growth patterns for all treatments, including the untreated control, had very similar trends until the time treatments were applied. Radial xylem-growth of pine trees on hexazinone and 2,4-D injected plots increased dramatically in 1979. This growth was greater than the peak growth year of 1973.

A more detailed comparison of growth response of shortleaf pine is given in Table 12. There were no significant differences among treatments in height, dbh, age, or in average yearly growth before treatment on pole and sapling size pine. Pole size pine had an average height of 8.5 m, dbh of 10.9 cm, age of 19 years, and the average yearly growth prior to treatment of 2.3 mm/yr. Sapling pine had an average height of 5.2 m, dbh of 5.4 cm, age of 15 years, and the average yearly growth prior to treatment of 1.5 mm/yr.

The year of treatment (1977) and one year after treatment (1978), the growth response of both pine classes was below the before treatment average. This may be attributed to the low moisture conditions during these two dry years (Figure 1). It was not until 1979 that a response to treatment was noted. The radial xylem-growth more than doubled for both hexazinone treatments when compared to the average growth prior to treatment. Pole size pine increased from 2.3 mm/yr to 5.5 mm in 1979 in the 2.2 kg/ha plots while sapling pines increased from 1.3 mm/yr to

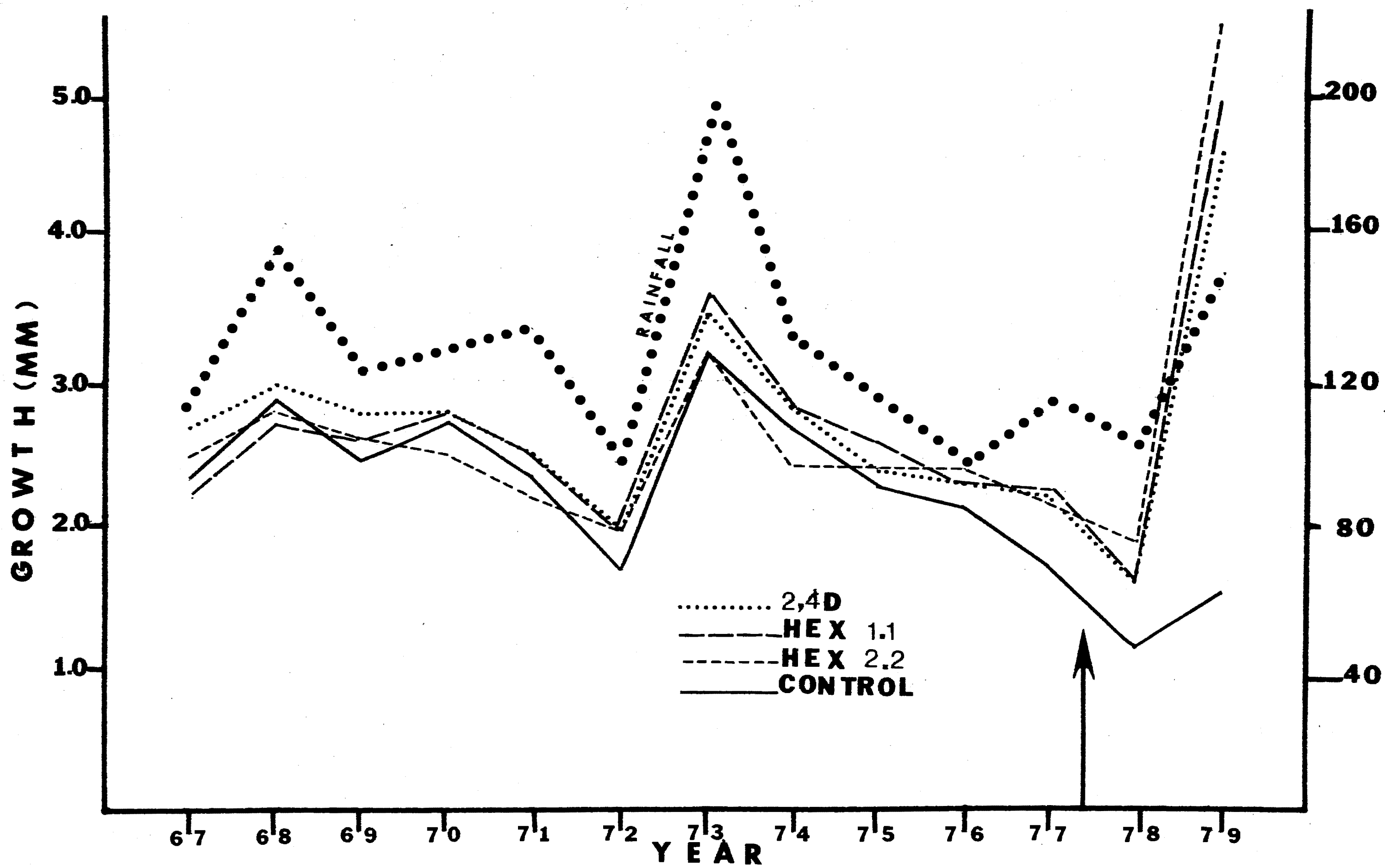

Figure 1. Radial xylem-growth of pole size pine, from ten years prior to treatment and three years after, correlated to yearly rainfall amounts.

Table 12. Growth response of two size classes of shortleaf pine to hexazinone and 2,4-D injected treatments.

						Average Xylem-Growth			
Tree Class	Treatment	Rate	Height	D.B.H.	Age	Before Trt.	1977	1978	1979
		(kg/ha)	(m)	(cm)		(mm)			
Pole Size	Hexazinone	1.1	8.4	10.8	18	2.3	2.2	1.6	4.9
	Hexazinone	2.2	8.7	10.8	18	2.3	2.2	1.9	5.5
	2,4-D Injected	---	8.5	11.2	20	2.4	2.2	1.6	4.5
LSD 0.05			NS	NS	NS	NS	NS	NS	NS
	Untreated Area[1/]	---	9.1	11.0	18	2.3	1.8	1.1	1.5
Sapling Size	Hexazinone	1.1	5.6	5.4	15	1.4	1.3	1.2	3.1
	Hexazinone	2.2	4.8	5.1	15	1.3	1.2	1.2	4.9
	2,4-D Injected	---	5.3	5.6	15	1.7	1.3	1.1	4.0
LSD 0.05			NS	NS	NS	NS	NS	NS	1.5
	Untreated Area[1/]		5.8	5.6	16	1.6	1.1	0.7	1.0

[1/] Not to be included when making L.S.D. comparisons--this is not part of treatment.

4.9 mm. Pines growing in the 1.1 kg/ha rate increased in xylem-growth from 2.3 mm/yr to 4.9 mm on pole size pine and from 1.4 mm/yr to 3.1 mm on sapling pine. Pole and sapling size pines growing on the injection plots increased in xylem-growth from 2.4 mm/yr and 1.7 mm/yr to 4.5 mm and 4.0 mm respectively. There was a decrease in xylem-growth on both pine classes on untreated areas. This decrease on pole and sapling size pine was from 2.3 mm/yr and 1.6 mm/yr to 1.5 mm and 1.0 mm respectively.

The only difference among herbicide treatments on pine growth was with xylem-growth of sapling size trees. Here the xylem-growth of 2,4-D injected and 2.2 kg/ha of hexazinone treatments was significantly better than with the 1.1 kg/ha rate of hexazinone. This may be attributed to a greater reduction of hickory stems in the higher rate of hexazinone and 2,4-D injected plots (Table 10). These remaining hardwoods would be more in direct competition with the sapling size pine than with the pole size pine. Moisture availability could well be the competition factor for this size class.

CHAPTER V

SUMMARY

A research field study was conducted to determine effects of herbicide hardwood control on forage yield and shortleaf pine growth. Two soil applied herbicides, hexazinone at 1.1 kg/ha and 2.2 kg/ha and tebuthiuron at 2.2 kg/ha, were compared with tree injection of a dimethylamine salt formulation of 2,4-D. Hardwood tree kill and basal area reduction of post oak and winged elm were excellent with all treatments. Hickory and blackjack oak were more tolerant to treatment. All treatments adequately controlled blackjack oak, but the low rate of hexazinone and the 2,4-D injected treatments resulted in poor tree kill of hickory. However, canopy reduction was satisfactory with these two treatments.

Forage yield was influenced by hardwood and pine reduction. When hardwoods were reduced, an adequate leaf drop resulted, and this provided enough fuel to obtain a sufficient burn to provide a seedbed for tall fescue. The highest forage yields were on the tebuthiuron plots where both hardwoods and pines were controlled. Most of this forage yield was tall fescue. Hexazinone treatments were intermediate in both total forage yield and tall fescue yield. Very little forage was produced on the 2,4-D injected plots due to pine and hardwood competition.

Radial xylem-growth of pole and sapling size pine increased substantially by the third growing season after release from hardwood competition. Response was similar with 2,4-D injected and hexazinone treatments. Total vegetative control may neither be expected nor desired for pine release. Sufficient reduction to allow for pine dominance of the site may be all that is necessary, provided the site is suited for pine growth. This did not appear to be the case for adequate forage yield. With all treatments except tebuthiuron, the pine still occupied a major portion of the site and substantially reduced establishment and forage yield of tall fescue.

Future research will be needed to determine if forage and pine can be effectively and economically produced on the same area. Additional data will need to be taken on these plots to determine long-term effects. In addition, other studies need to be established to compare different age classes of pines and compare various sites.

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VITA[2]

Jerald Keith Nickels

Candidate for the Degree of

Master of Science

Thesis: GRASS AND PINE CONVERSION WITH HERBICIDES

Major Field: Agronomy

Biographical:

Personal Data: Born in Stillwater, Oklahoma, September 1, 1942, the son of Mack and Lodiene Nickels.

Education: Graduated from Stillwater High School, Stillwater, Oklahoma, in May 1961; received Bachelor of Science degree from Oklahoma State University, Stillwater, Oklahoma, with a major in Forestry in May, 1965; completed the requirements for Master of Science degree at Oklahoma State University in May, 1980, with a major in Agronomy.

Experience: Worked part-time in sorghum research at Oklahoma State University, worked part-time for U.S. Forest Service as a forestry aid, served in armed forces with U.S. Navy, worked full-time as a Forester in Wallace, Idaho, worked full-time as research technician at Oklahoma State University.

Member of: Southern Weed Science Society of America and CAST.