SEASONAL FERTILIZATION AND TOP REMOVAL OF AMERICAN ELM AFFECTS HERBAGE AND SPROUT PRODUCTION AND BROWSING

By

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SEASONAL FERTILIZATION AND TOP REMOVAL OF

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AND SPROUT PRODUCTION

AND BROWSING

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PREFACE

This study is concerned with the management of a floodplain area with overstory of American elm for use as both wildlife habitat and livestock grazing. The primary objectives were to determine sprout and herbage responses to removal of the overstory canopy at three phenological stages, with and without fertilization, and to determine sprout usage by cattle and wildlife.

I wish to extend my sincere appreciation to my major adviser, Dr. Jeff Powell, for his patient guidance and assistance throughout this study. Thanks are also expressed to the other committee members, Dr. Jim F. Stritzke and Dr. Jerry J. Crockett, for their suggestions. Thanks are also due Dr. Robert Morrison for his assistance in the statistical analysis.

A well-earned acknowledgment is due the field crew for their assistance in collecting data, and particularly for their assistance in clearing the plots.

My parents are due special recognition for their tireless encouragement and support.

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CHAPTER I

INTRODUCTION

Rice (1965) reported that research on bottomland woodlands in Oklahoma had been neglected. This omission has prevented the formulation of alternatives for the land manager who would like to manage lowland hardwoods.

The very sites occupied by American elm (Ulmus americana L.)[1] and other lowland hardwoods make them attractive as wildlife habitat. These areas along creeks and rivers offer recreational possibilities that mean extra profits to landowners. However, in most cases these sites must be manipulated to make them more attractive to wildlife and people.

Many studies have shown that removal of overstory tree canopy results in increased production of palatable forage for both wildlife and livestock. The livestock operator who possesses areas of lowland hardwoods needs various alternatives which will allow him to more effectively increase production of red meat. This study was designed to give land managers more viable alternatives for the management of lowland hardwoods.

Objectives

Although American elm is considered to be primarily a lowland

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[1]Names of forbs and woody plants are from Subcommittee on Standardization of Common and Botanical Names of Weeds (1971).

species, it is not confined to such sites and is commonly found on upland plains adjacent to floodplains (Fowells, 1965). Rice and Penfound (1959) reported that wooded areas in Oklahoma are expanding due to the invasion of trees from ravines into surrounding grasslands. This study was undertaken to determine if the forage producing capability, as well as wildlife habitat value, of an area invaded by American elm could be increased by overstory removal and fertilization. The objectives of the study were to determine the: (1) effect of top removal at different phenological stages on production of elm sprouts; (2) degree of browsing of elm sprouts by deer and rodents, and by cattle in conjunction with deer and rodents; (3) nutritive value of elm sprouts throughout the growing season; (4) effects of fertilization on production, nutritive value, and degree of browsing of elm sprouts; (5) response of herbage to canopy removal; and (6) effects of fertilization on production and nutritive value of herbage.

Literature Review

American Elm Description and Distribution

American elm is one of the six species of *Ulmus* native to the United States. American elm is deciduous and capable of attaining great size, with large spreading crowns. Heights to 38 meters are reached on favorable sites. Flowering occurs in early spring before the leaves appear. The single seed is borne in a flat, rounded samara (Fowells, 1965).

American elm is found throughout the eastern half of the United States as a member of the mixed-hardwood forest. West of the Missouri River, elm is found only in the more mesic sites, such as stream bottoms and flood plains. American elm extends its range westward as a member of the post-climax communities of floodplains (Buck, 1964; Oosting, 1956; Peattie, 1950). Elm advances into the true prairie by way of the many small streams and ravines which dissect grasslands (Albertson and Weaver, 1945; Bragg and Smith, 1943; Elwell et al., 1974). Carpenter (1937) classified the elm stage of ravine succession as an edaphic subclimax, which could be invaded by prairie species during times of low soil water if the overhead canopy was not closed.

Parker (1967) divided the forests of Payne County, Oklahoma, into four units based on edaphic and topographic factors: (1) postoak - blackjack type, (2) American elm - hackberry type, (3) American elm - eastern cottonwood type, (4) American elm type. American elm was the dominant tree species on four of the five sites sampled on alluvial soils. In a survey of 10 northcentral Oklahoma counties, including Payne, Rice (1965) divided the bottomland forests into 10 types. American elm was the dominant tree species in 38 of the 47 stands sampled within these 10 types.

School lands in Payne County totaling 9,990 hectares have been mapped as to cover type (Frye, 1972). Almost 10% of this area includes cover types in which elm is commonly found.

Reduction of Elm Overstory

Little work has been done in Oklahoma concerning the manipulation of lowland hardwoods. Areas treated mechanically, especially bottomlands, have usually been placed into intensive cultivation or permanent pastures (personal observation). No literature was found dealing with mechanical removal of American elm.

The primary emphasis to date has been chemical treatment of upland woody species (Elwell, 1953; Ray, 1958). Efforts to control elm with foliar sprays of phenoxy herbicides have given variable results, but have generally been unsuccessful (Elwell et al., 1974). Kirby (1965) obtained greater percent kill with a diamine formulation of 2,4,5-T than with a low volatile ester formulation. The 2,4,5-T ester gave excellent control after treating two successive years by completely wetting leaves and twigs. Picloram has shown promise for winged elm (*Ulmus alata*) control when used in a mixture with 2,4,5-T or silvex (Elwell et al., 1974). Injection treatments are more effective than basal or soil herbicide treatments, but vary widely with different combinations of season of treatment, type of carrier, and type and concentration of herbicide (Stryker, 1966).

Browsing of Woody Plants

Although various species of elm occur over the eastern half of the United States, little emphasis is placed on their importance as browse species. Those studies considering elm as browse placed it low on the list of species preferred by both wildlife and cattle (Hosley, 1956; Petrides, 1941). Pogge (1967), however, working with elm in Pennsylvania found that more than 90% of the stump and stem sprouts of felled elm trees were browsed by deer in the first growing season. Cattle graze American elm in Oklahoma, often keeping individual trees hedged to a shrub-like condition (Dwyer, 1961).

Winged elm is also heavily browsed by cattle in Oklahoma (Dalrymple et al., 1965). Halls et al. (1970) reported that winged elm ranked first in number of twigs browsed among 16 species studied in the east

Texas pine-hardwood forests during the spring months. Browsing of winged elm decreased considerably from spring to fall even though the relative abundance of unbrowsed twigs remained high. In the Missouri Ozarks less than half the shrubs and trees browsed during spring were browsed later during the summer (Dunkeson, 1955).

Browsing of woody plants is directly correlated with plant moisture content (Alkon, 1961). In a southern Appalachian cove hardwood, seedlings were almost four times as numerous as sprouts three years after a commercial cut, but utilization of seedlings by deer was only one fourth that of sprouts (Moore and Johnson, 1967). Preference seemed more closely related to growth rate or succulence than to plant species. Deer in Pennsylvania were observed feeding extensively on normally unpalatable beech (<u>Fagus grandifolia</u>) sprouts during spring when the shoots were succulent (Shafer, 1965). Also showing that even the most unpalatable species may not always be rejected, Swank (1956) found that Turbinella oak in Arizona, usually an unbrowsed species, was heavily browsed during periods of high moisture content.

<u>Effects of Overstory Removal</u>

That disturbed, hardwood sites produce more herbage than undisturbed stands is well documented (Della-Bianca and Johnson, 1965; Elwell, 1960; Elwell, 1964; Martin et al., 1955; Read, 1951; Vogel and Peters, 1961).

Most of the present deer habitat was created or improved through the formation of secondary stages of succession by logging, grazing, and burning (Leopold, 1950). Disturbed woodlands have a characteristically high production of palatable browse and herbage.

In the Ouachita National Forest of Oklahoma, browse yields varied from 85 lb/acre in an undisturbed oak-pine timber type to 182 lb/acre in an oak-pine type disturbed by timberstand improvement and harvest cutting (Segelquist and Pennington, 1968). A 5-year study involving strips of girdled and ungirdled trees in a postoak - blackjack oak forest in the Missouri Ozarks showed an increase of palatable browse and grasses of 30% and 72%, respectively (Baskett et al., 1957). Ehrenreich and Crosby (1960), also working in the Missouri Ozarks, reported that areas with 80% or more crown cover produced only 250 lb/acre herbage while cleared areas produced over 1700 lb/acre.

Browse production in an uncut mixed oak - pine forest was 10 lb/acre, but after 80% of the tree basal area was removed, the browse increased to 246 lb/acre by the fourth year before starting to decline after the fifth year (Patton and McGinnes, 1964). Blair (1971) observed that after removal of hardwoods, browse increased for 6 to 8 years but returned to pretreatment levels within 10 years.

Dramatic increases in twig growth and fruit yields of browse plants occurred in openings as compared to the same species growing underneath a moderate stand of shortleaf (*Pinus echinata*) and loblolly pines (*P. taeda*) (Halls and Alcaniz, 1968). Working with this same vegetative type, Schuster (1967) found that browse yields as well as herbage production increased as tree overstory was reduced. Herbage production in the Coastal Plain pine - hardwood forests exhibited a curvilinear relationship with tree overstory (Halls and Schuster, 1965).

The quality of herbage is also influenced by the amount of canopy present. In an early study, Welton and Morris (1928) found woodland forage to be less palatable to cattle than forage in open areas.

Browse plants growing in openings usually contained more crude protein and phosphorus, but less crude fiber and calcium than plants growing underneath a canopy of pines (Halls and Epps, 1969). In the Black Hills, levels of calcium and crude fiber were higher underneath an overstory of ponderosa pine (Pinus ponderosa) while nitrogen-free extract was highest on open sites (McEwen and Dietz, 1965). The lignin content of bermudagrass (Cynodon dactylon)[2] increased and available carbohydrates decreased with decreasing light intensity in Georgia (Burton et al., 1959).

Fertilization

The application of fertilizers to woody plants has been used almost exclusively as a growth stimulant for valuable lumber producing species, especially conifers. However, some interesting results have been observed due to the fertilization of woodlands. These include: increased production of higher quality herbage (Duval and Grelen, 1967; Hughes et al., 1971; Longhurst et al., 1968); higher digestibility of herbage (Heineman and Evans, 1966); improved wildlife habitat (Ward and Bowersox, 1970); and increased palatability of relatively unpalatable species (Gibbens and Pieper, 1962).

Frequency of browsing of dogwoods (Cornus spp.) on plots fertilized with varying amounts and types of fertilizers ranged from 4% on control plots to 81% on plots fertilized with 280 lb. nitrogen/acre (Mitchell and Hosley, 1936). Ward and Bowersox (1970) found the degree of browsing of upland oaks increased as applied nitrogen was increased

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[2]Names of grasses are from Gould (1968).

from 0 to 180 lb/acre. No change in utilization could be attributed to either calcium or phosphate fertilizers.

The use of fertilizers to increase utilization of unpalatable browse species has received relatively little attention. Fertilized plants of Mariposa manzanita (Arctostaphylos mariposa), an unpalatable species in California, were browsed much heavier than unfertilized plants (Gibbens and Pieper, 1962). The addition of nitrogen fertilizer produced the only measurable increase in utilization of Douglas fir (Pseudotsuga menziesii) by deer (Longhurst et al., 1968).

Fertilization of conifers causes some problems with damage by browsing. The terminal shoots and buds of Pacific silver fir (Abies amabilis) trees fertilized with nitrogen were significantly more damaged by rodents than adjacent unfertilized trees (Gessel and Orians, 1967). On plots fertilized with 100 lb nitrogen/acre, deer browsed 90-100% of the new shoots of Douglas fir the first growing season and 50-75% during the second growing season. Control plots had 0-10% and 0-5% utilization the first and second growing seasons, respectively (Oh et al., 1970).

Grazing animals are apparently able to seek out forage of higher quality. Observations of deer indicated they could differentiate Douglas fir fertilized with nitrogen and preferred them over unfertilized trees (Longhurst et al., 1968). Experiments on the Scottish moor showed hares and rabbits selected heather with a high content of both nitrogen and phosphorus during the winter and selected for nitrogen only during the summer (Miller, 1968). Swift (1948) found deer consistently grazed young wheat plants and clover which grew in a certain portion of a field. The deer chose forage which gave them 12% more ether extract, 38% more calcium, and 34% more phosphorus than ungrazed plants.

Variability of Sprout Data

Some researchers have reported problems in sampling browse populations. In a test of different sampling intensities of browse production, Blair (1958) found that an excessive number of plots is necessary to obtain reliable measurements. Sampling errors ranged from 26 to 44%. A range in the standard error of the mean from 24 to 44% was not thought to be excessive in a Michigan study (Gysel and Stearns, 1968). Lindsey (1955) considered a sampling error no larger than 20% to be an acceptable sampling intensity for species in forest ecology. Lyon (1968) compared several density sampling methods in a shrub population with known parameters and reported that all methods tested gave such poor results that no technique could be considered desirable. He further stated that high variability was inherent with density sampling, and the standard deviation of any density sampling technique would be nearly as large as the mean.

Description of Area

General Area

Payne County lies in the northcentral portion of Oklahoma. The climate is continental, with hot summers and variable winters. The average annual temperature, measured from 1951 to 1960, was 16^{o} C. Temperatures may exceed 37^{o} C in the summer, with a record low of -28^{o} C. The last killing spring frost usually occurs in April and the first killing frost of fall is generally in October. The average number of frost-free days is 211 (U. S. Dept. of Commerce, 1965).

Average yearly precipitation is 817 mm, with approximately 50% occurring from June through October (Appendix A). Precipitation is frequently unevenly distributed through the year, with long dry periods, which is characteristic of the Great Plains region.

The vegetation, as described by Bruner (1931), is characteristic of the tall grass prairie of the redbed plains. Topography is undulating, sloping slightly to the south. Elevation is approximately 270 meters.

Study Area

The study area is located on land bordering Stillwater Creek approximately 14 miles west of Stillwater, Oklahoma (Figure 1). The study area lies within a transition zone between the floodplain of Stillwater Creek and the surrounding upland prairie. The area had been under cultivation in the past, probably settled near the turn of the century under the Homestead Act, and farmed until 35-40 years ago. The land has since been invaded by American elm, which is the dominant plant. Soils are alluvial, grading into a Port clay loam near the upland. This site is representative of areas contiguous to the many streams and drainageways in central Oklahoma (Parker, 1967).

The vegetation consists of an overstory of the dominant American elm, with green ash (*Fraxinus pennsylvanica*), black locust (*Robinia pseudoacacia*), hackberry (*Celtis occidentalis*), postoak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and walnut (*Juglans nigra*) interspersed throughout the study area.

Figure 1. View of Study Area Looking from Upland Prairie Toward Floodplain

The understory cover ranges from litter accumulations to tall grasses, depending upon the amount of overhead canopy present. Common grasses and grass-like plants are little bluestem (Schizachyrium scoparium), broomsedge bluestem (Andropogon virginicus), purpletop (Tridens flavus), Scribner's panicum (Panicum scribnerarianum), Japanese brome (Bromus japonicus), Virginia wildrye (Elymus virginicus), and sedges (Carex spp.). Common forbs include western ironweed (Vernonia baldwinii), wild carrot (Daucus carota), tick clover (Desmodium sessilifolium), and goldenrod (Solidago, spp.). Buckbrush (Symphoricarpos orbiculatus) and smooth sumac (Rhus glabra) are frequently found shrubs.

Wildlife found on the study area is typical of that found throughout central Oklahoma. Whitetail deer (Odocoileus virginianus), bob-white quail (Colinus virginianus), turkey (Meleagris gallopavo), squirrels (Sciurus spp.), and cottontail rabbits (Sylvilagus floridanus) are found on the study area.[3]

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[3]Wildlife names are from Martin et al. (1951).

CHAPTER II

PROCEDURES

The study area consisted of two adjacent areas. One was ungrazed by domestic livestock and will be henceforth known as the deer-only area. Separated from the deer-only area by a barbed wire fence was the deer and cattle area. This area was grazed by steers during 1973, with free access by deer.

Deer-Only Area

A randomized block experimental design was employed, with three replications of three cutting dates and two fertilizer treatments. One control plot per replication was left uncleared and unfertilized. Each plot measured 15 meters by 30 meters.

The three cutting dates were selected to coincide with elm phenological stages of mature leaf stage, bud stage, and half-leaf, rapid growth stage. These cutting dates were August 15, 1972, March 1, 1973, and May 15, 1973. These cutting dates and phenological stages occur within the summer, winter, and spring seasons. Henceforth the plots will be known as summer-cut, winter-cut, and spring-cut plots, respectively.

On each cutting date all trees on plots randomly selected to be cleared that date were cut at approximately two to four inches above ground level with gasoline-powered chain saws. Suitable trees were cut into firewood lengths and tops were stacked around plot borders. Plots chosen for fertilization were fertilized immediately after clearing with a formulation equal to 74 kg/hectare of nitrogen and phosphate each. Fertilizer was applied manually using crank-type mechanical spreaders.

Sprout Response

At the end of the 1972 growing season, sprout production was determined on summer-cut plots using 2 belt transects per plot, each measuring 5 meters by 30 meters. Four sampling points were located equidistant from each other the length of each transect. Stumps that lay within each belt transect were counted and identified as either elm or other species and classified as sprouting or non-sprouting. Sprouts from the sprouting elm nearest each sampling point were clipped and bagged. Before drying, the total number of basal sprouts and average sprout length were determined. All clipped samples were weighed before and after drying at 45^{o} C for 36-48 hours to determine percent sprout dry matter. Dried samples were ground to pass through a 40-mesh screen for crude protein determination.

At the end of the 1973 growing season, sprout data were taken from all cleared plots, using 3 belt transects per plot, each measuring 3 meters by 24 meters. Three sampling points were located equidistant from each other the length of each transect. The sprouting elm stump nearest each sampling point was sampled for basal stump diameter, number of basal sprouts, number of twig tips, and average sprout length. One of these stump subplots per transect was chosen at random, clipped, and treated as in 1972.

Degree of Browsing

The degree of browsing of elm sprouts by deer and rodents on the deer-only area was determined monthly from May to September in 1973. During the first week of each of these months, three sprouting elm stumps were chosen at random in each plot. The total number of twig tips and number of those twigs recently browsed were recorded for each of the selected stumps. One of these stumps was chosen at random, clipped, and treated as were all other clipped samples.

The term "degree of browsing," as used here, is the number of browsed twigs divided by the total number of twigs, expressed as a percentage. Stoddart (1935) used this method of counting grazed and ungrazed grass stalks to determine utilization for formulating a guide to proper range use. Degree of browsing was used by Aldous (1944) as a method of rapidly conducting deer browse surveys. Regressions of reduction in total twig length on percentage of twig numbers browsed gave correlations of 0.78 and 0.89 for Prunus virginiana and Amelanchier alnifolia, respectively. The study showed this method sensitive for utilization levels to 60% for Amelanchier alnifolia and 55% for Prunus virginiana (Stickney, 1966). Mitchell and Hosley (1936) felt that frequency of browsing of dogwood (percentage of number of dogwoods browsed) was a better index to preference of dogwood than weight of foliage consumed.

I felt that a larger percentage of the elm population could be sampled using degree of browsing as an index of browse utilization rather than weight or length of foliage removed. The time required to determine weight of foliage removed or to mark and measure twigs for obtaining length removed by browsing would have made it impossible to sample at the desired intensity.

Herbage Response

Herbage data were obtained at each sampling point on all transects using a one-half square meter quadrat. Species composition by weight and dry herbage production in kg/hectare were determined by the double-sampling method, as developed by Wilm et al. (1944). A predetermined number of quadrats per plot were clipped and bagged for use in the double-sampling procedure, and for crude protein determination. All clipped herbage samples were treated the same as sprout samples.

Soil Water

At each sampling date for sprout and herbage data, 3 soil samples to a depth of 30 cm were taken on each plot using a split-tube. These samples were combined to form one sample per plot. Percent soil water was determined by the gravimetric method (N.R.C., 1962).

Deer and Cattle Area

During 1973, the area adjacent to the deer-only area was grazed at a moderate stocking rate with 9 steers, averaging 245 kg, from May to October. A randomized block experimental design was used with 4 replications of the same 2 fertilizer treatments as on the deer-only area, 0 and 74 kg/hectare each of nitrogen and phosphate. The single cutting date, May 15, 1973, was identical to the spring cutting date on the deer-only area. One plot per replication was left uncleared as a control. All plots measured 5 meters by 7 meters.

Sprout Response

The tree stand in this area was very uniform, with approximately 25 live elm trees in each plot at time of cutting. At the end of the 1973 growing season six sprouting elms in each plot were selected at random. From these, basal diameter, number of basal sprouts, number of twig tips, and average sprout length were determined. No clipped samples were taken because intense utilization by cattle left most sprouts literally browsed as close to the stump as possible.

Herbage Response

Herbage data were taken at the end of the 1973 growing season in the same manner as on plots in the deer-only area. Three one-half square meter, circular quadrats were sampled in each plot, with one quadrat clipped at random for use in the double-sampling procedure. No clipped samples were kept for crude protein determination because of the lack of vegetation on cleared plots and heavy grazing pressure by cattle.

Crude Protein Determination

All clipped herbage and sprout samples were analyzed for crude protein. The crude protein determinations were obtained by the Kjeldahl method, as described in Official Methods of Analysis (A.O.A.C., 1970).

Data Analysis

All data were keypunched onto computer cards and statistically analyzed using the Statistical Analysis System and Oklahoma State

University's IBM 360 computer. Field data collected in 1973 were recorded directly onto keypunch sheets (Appendix B). Computer cards were keypunched directly from the field data sheets to minimize possible errors in the transfer of data from one sheet to another. Differences among treatments were determined by analysis of variance. Differences within treatments were determined by least significant differences (Steel and Torrie, 1960).

CHAPTER III

RESULTS AND DISCUSSION

Sprout Response in Deer-Only Area

The plots were located in a fairly uniform stand of different-age trees, 97% of which were American elm. The remaining three percent consisted of ash, hackberry, locust, and oaks. Average number of trees per hectare was 2500, with the differences among treatments or replications not different at the 20% level. Mean basal diameter per sprouting elm stump was 10.1 cm, also not different among treatments or replications. Twelve percent of the total elm stumps did not sprout after top removal. The number of sprouting elms on fertilized plots was slightly less than on unfertilized plots, although the difference was not significant at the 20% level. This difference between fertilizer treatments may have been due to the difficulty in locating stumps on fertilized plots with large amounts of herbage.

The sprout characteristics studied include average sprout length, total sprout length per stump, number of basal sprouts, number of twig tips, dry sprout weight per stump, and basal diameter. These were considered to be the most important characteristics relevant to sprout growth.

Schuster (1965) found that twig length and twig numbers when used in combination was the best indicator of browse yields. For most species, total twig length was the single variable most closely related to shoot and twig weight. The longevity of desirable overstory removal effects is closely related to sprout length. Browse yields decline when sprouts grow beyond the reach of browsing animals (Gysel and Stearns, 1968; Patton and McGinnes, 1964).

Number of twig tips has been shown to be related to intensity of browsing (Shafer, 1965). Repeated browsing of twigs may cause the sprouting clump to become bushy, or hedged.

Some species show definite relationships between stump basal diameter and sprout production (MacKinney and Korstian, 1932).

Average Sprout Length

Trees cut in the summer of 1972 showed little sprout elongation from time of cutting until the end of the 1972 growing season. Fertilized sprouts (5.7 cm) were shorter than unfertilized sprouts (9.5 cm), but the difference was not significant at the 20% level. At the end of the 1973 growing season, average sprout length on trees cut in the summer of 1972 was 36.4 cm on unfertilized plots and 44.3 cm on fertilized plots. This difference between fertilizer treatments was significant at the 10% level. Figure 2 represents average sprout length of all cleared plots at the end of the 1973 growing season. A positive response was attributed to fertilizer for all seasons of cutting ($P < .10$).

Average sprout length of trees cut in the summer of 1972 and late winter of 1973 exhibited similar growth responses. Average sprout length of spring-cut trees was significantly ($P < .01$) less than that on summer- and winter-cut trees, although sprout initiation began on the spring-cut trees less than a month later than on the summer- and

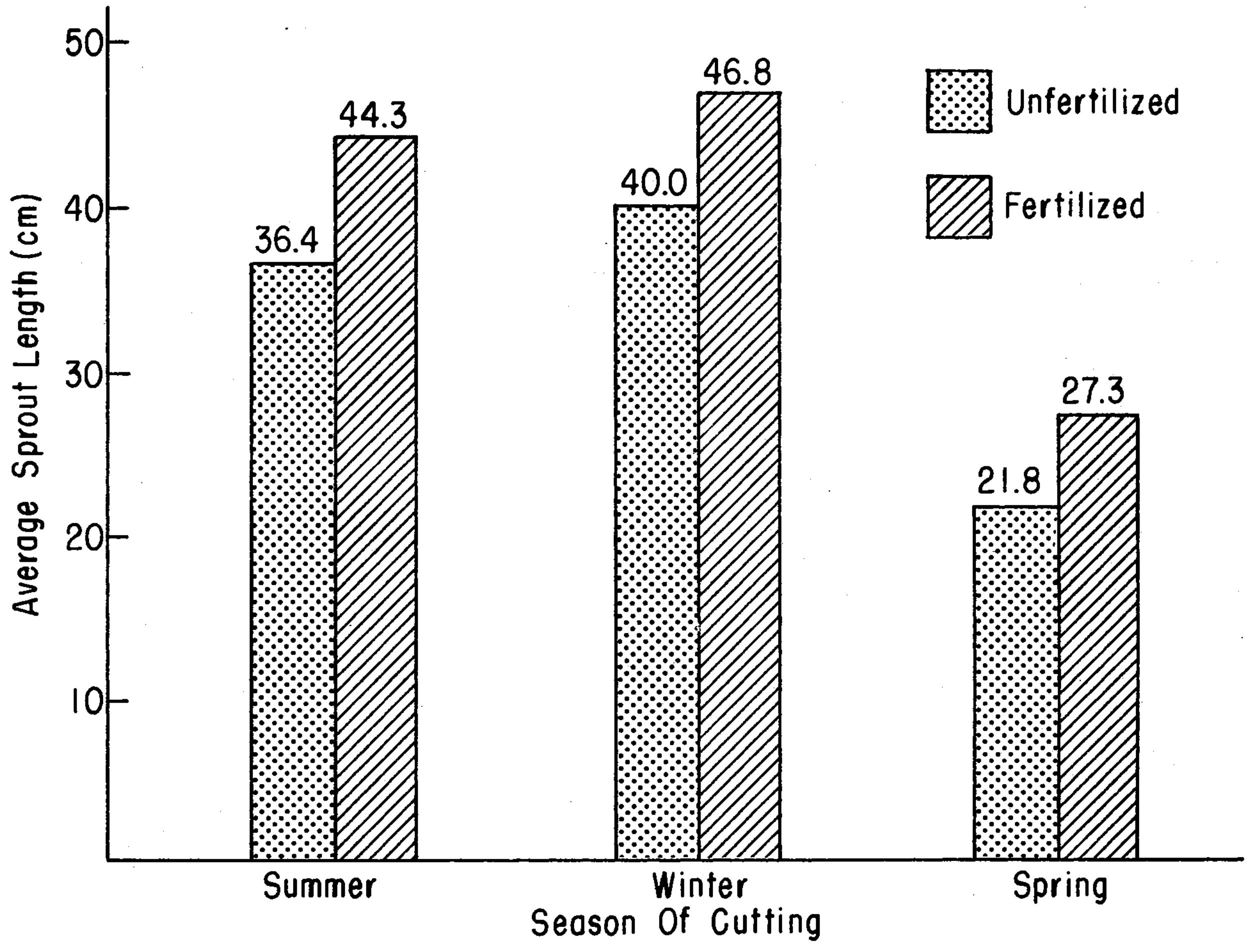

Figure 2. Average Length of Elm Sprouts for Each Season of Cutting at End of 1973 Growing Season

winter-cut trees in 1973. This difference is probably due to the fact that the summer- and winter-cut trees used stored carbohydrates primarily for sprout production, while trees on spring-cut plots had already depleted some food reserves for leaf development at time of cutting. These results agree with findings by researchers working with other woody species. Stoeckler (1947) reported that aspen (Populus tremuloides) sprouted with maximum vigor if cut during winter dormancy, but cutting after rapid leaf development had depleted food reserves gave maximum reduction in vigor and size of sprouts. In Arkansas, highest mortality and greatest sprout inhibition of oaks occurred when cut in the interval during which the leaves emerged and reached full size and the following two months (Grano, 1955).

Basal Sprouts

The number of basal sprouts varied among seasons of cutting, but was significant at only the 20% level. There was no difference due to fertilizer treatments.

Some interesting points may be made from the basal sprout data (Figure 3). The number of basal sprouts on the summer-cut trees at the end of the 1972 growing season was about the same as the number of basal sprouts on the spring-cut trees at the end of the 1973 growing season. This is particularly noteworthy because the spring-cut trees had a six-month growing season in a year of above-average rainfall (1973), as compared to the summer-cut trees which had a three-month growing season before frost in 1972, a year of below-average rainfall. This seems to indicate that a cutting date associated with the half-leaf phenological stage in elm retards the formation of basal sprouts within a single

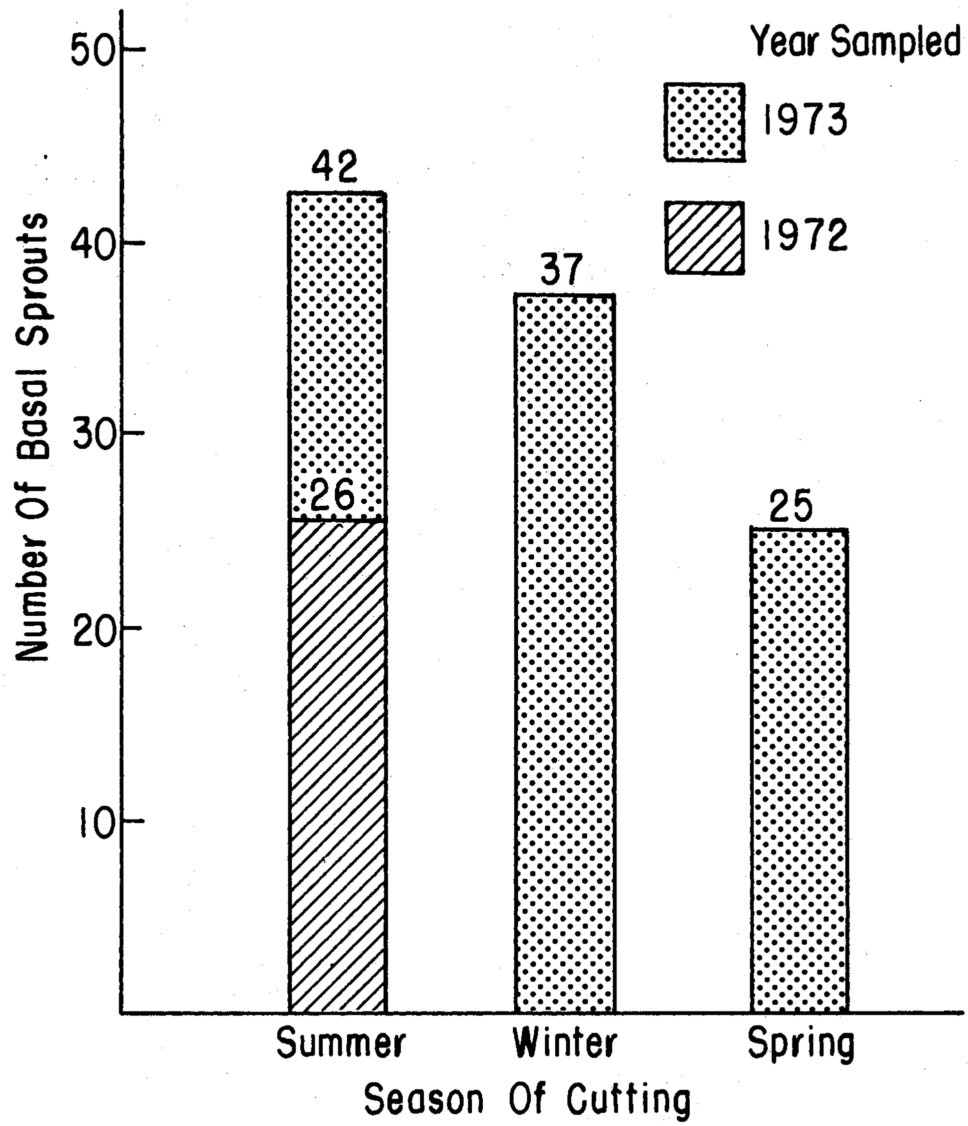

Figure 3. Number of Basal Sprouts Averaged over Fertilizer Treatments for Each Season of Cutting

growing season. The winter-cut trees cleared in the bud stage had almost as many basal sprouts (37) at the end of the 1973 growing season as the summer-cut trees (42) cut in the full-leaf stage in 1972. Stumps on the summer-cut plots showed additivity in number of basal sprouts in two consecutive growing seasons, from 1972 (26) to 1973 (42).

Total Sprout Length per Stump

The total sprout length per sprouting elm stump was obtained by multiplying the average sprout length by the total number of basal sprouts per stump. Total sprout length was not different at the 20% level between fertilizer treatments, so total sprout length per stump was averaged over fertilizer treatments (Figure 4). Total sprout length of the spring-cut trees was significantly ($P < .05$) less than both summer and winter-cut trees, which were not different at the 20% level. Total sprout length per stump was more highly correlated with number of basal sprouts ($r = .93$) ($P < .001$) than average sprout length ($r = .41$ ($P < .001$). Therefore a cutting date that hinders formation of basal sprouts should also cause a lowered production of total sprout length per stump.

Number of Twig Tips

The average number of twig tips per sprouting stump followed the same general pattern as number of basal sprouts and total sprout length per stump. Spring-cut trees had significantly ($P < .05$) fewer twig tips (65) than either summer- (160) or winter-cut trees (135) (Figure 5). The difference in number of twig tips on unfertilized (110) and fertilized (127) stumps was not statistically significant at the

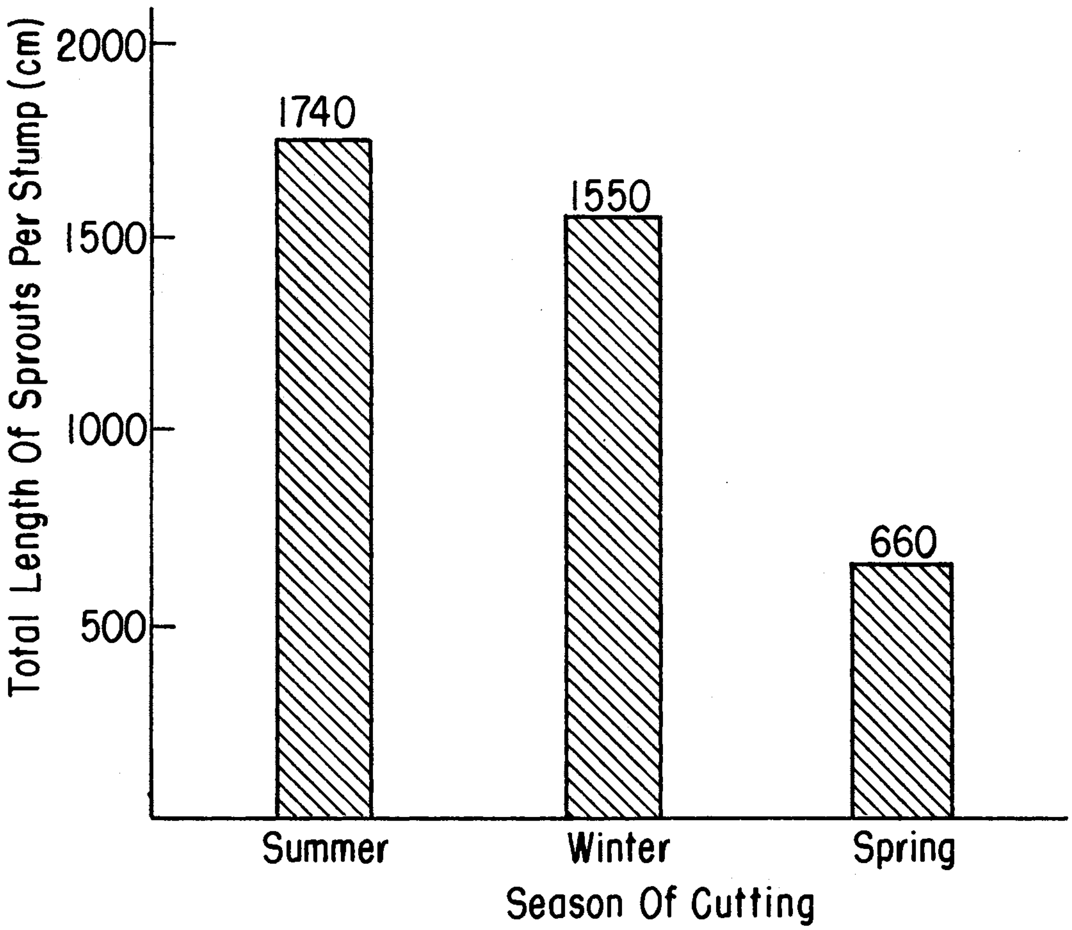

Figure 4. Total Length of Sprouts per Stump Averaged over Fertilizer Treatments for Each Season of Cutting

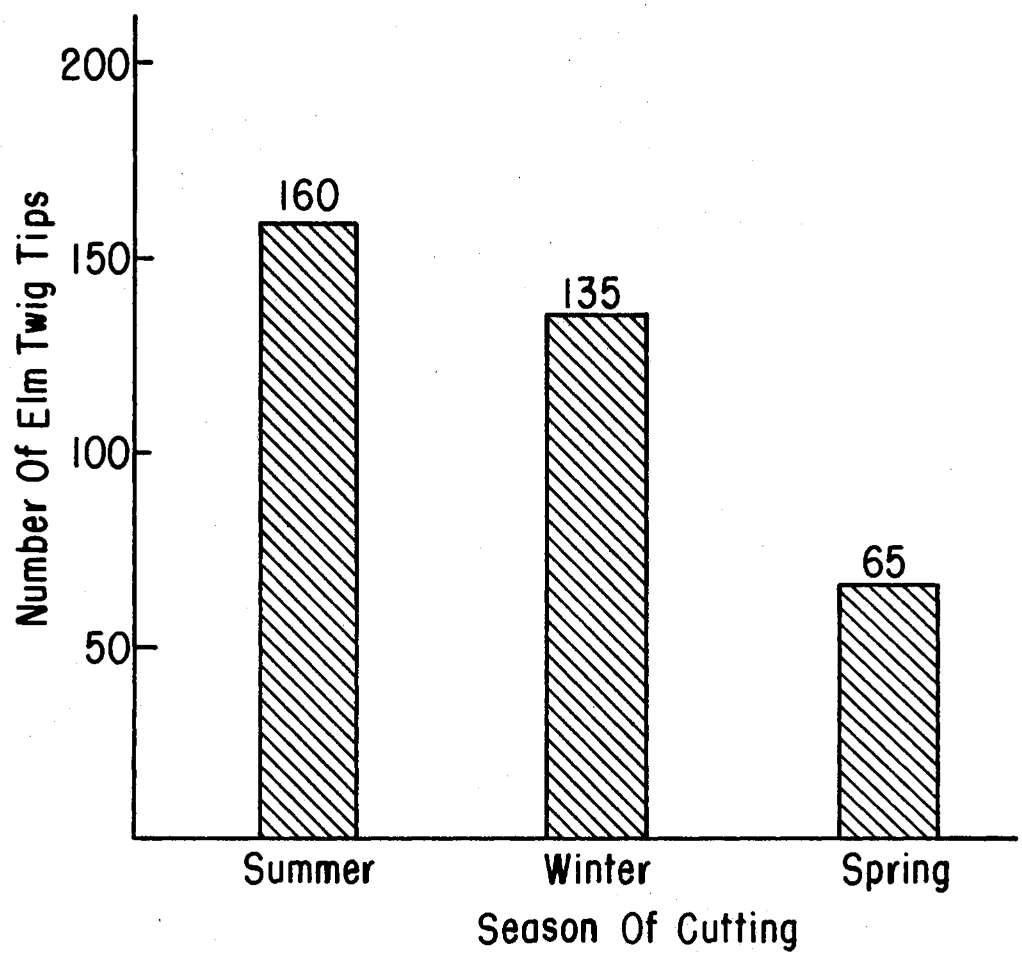

Figure 5. Number of Elm Twig Tips Averaged over Fertilizer Treatments for Each Season of Cutting

20% level of probability. Twig tips showed a strong relationship ($r = .76$) ($P < .001$) with number of basal sprouts.

Sprout Dry Weight

Sprout dry weights, from samples clipped at the end of the 1973 growing season, were significantly ($P < .05$) greater from fertilized summer- and winter-cut trees than from spring-cut trees or from unfertilized trees (Figure 6). Average sprout weight per stump ranged from 42 gms per stump on unfertilized, spring-cut plots to 205 gms per stump on fertilized, summer-cut plots (Figures 7A and 7B).

Weight per sprout was significantly ($P < .05$) different between fertilizer treatments. Weight per sprout of unfertilized trees was 3.0 gms and that of fertilized trees was 5.3 gms.

Basal Diameter

Contrary to the results obtained for other species by other workers (Longhurst, 1956; MacKinney and Korstian, 1932; Wenger, 1953), in this study American elm showed no strong relationship between sprout production and stump basal diameter. The highest correlation coefficient between basal diameter and all sprout production factors was with basal sprout numbers ($r = .52$) ($P < .001$).

Sprout Dry Matter Content

The percent dry matter content of elm sprouts was determined from clipped samples taken each month during the growing season. Because of differences in sprout dry matter content between spring-cut plots and summer- and winter-cut plots, they will be discussed separately.

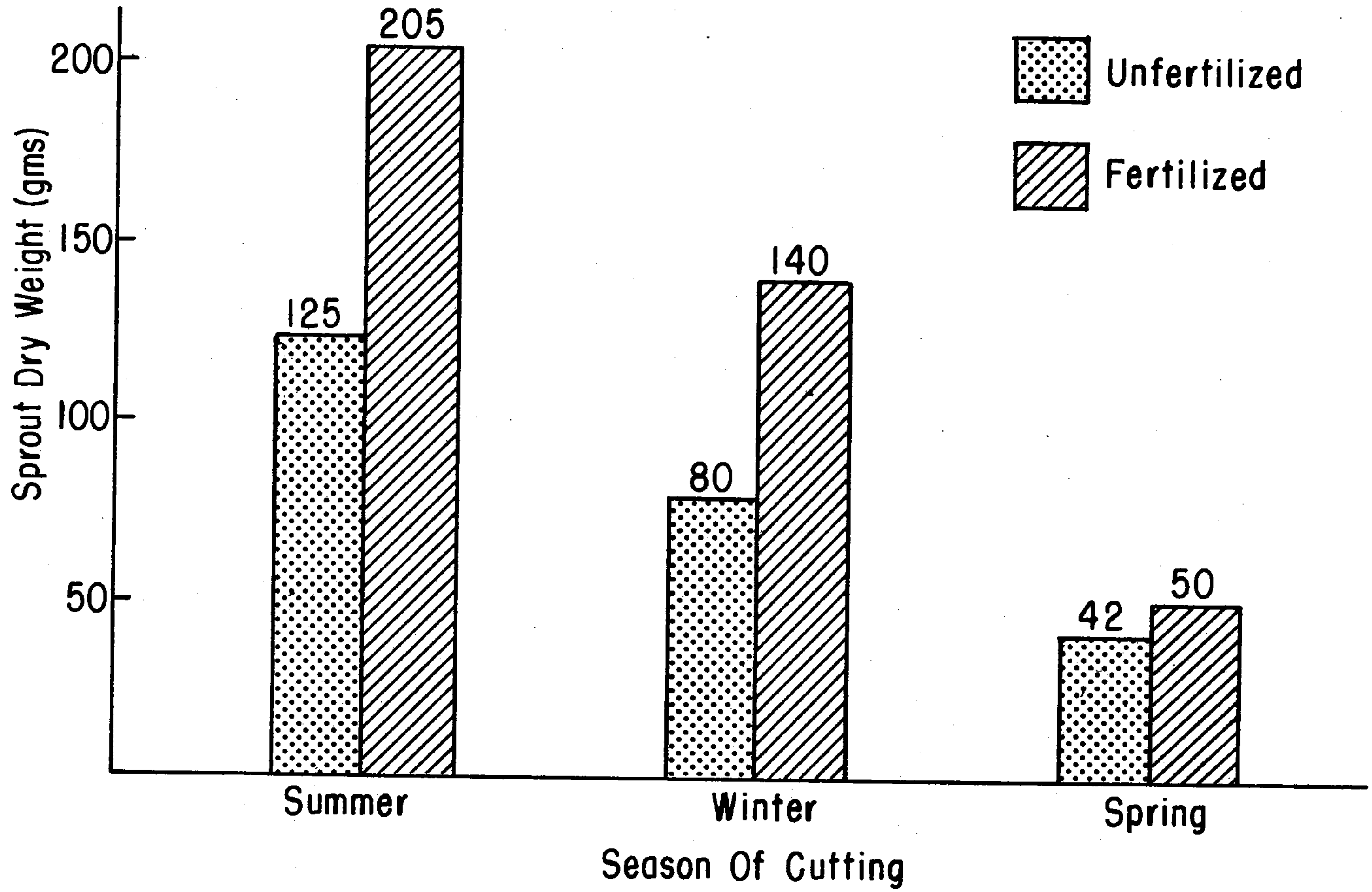

Figure 6. Average Sprout Dry Weight (gms) per Stump on Unfertilized and Fertilized Plots for Each Season of Cutting

Figure 7A. Growth Response of Elm Sprouts on Unfertilized, Spring-Cut Plot in August, 1973

Figure 7B. Growth Response of Elm Sprouts on Fertilized, Spring-Cut Plot in August, 1973

Summer- and Winter-Cut Plots. Sprout dry matter content on fertilized plots (36.4%) was slightly lower than that on unfertilized plots (38.3%), the difference being significant at the 15% level. Differences in sprout dry matter content due to sampling date were very highly significant ($P < .001$). This was due to the fact that the sprout dry matter content increased as sprout growth matured.

Sprout dry matter content on summer- and winter-cut plots averaged together increased steadily from a low of 26% in May to a high of 45% in August and remained at about that level in September before increasing to 48% in October (Figure 8). The differences in sprout dry matter content between May to June, June to July, July to August, and September to October were all significant at the 5% level. Dry matter content decreased slightly between August and September and any real decrease in percent dry matter was probably due to increased rainfall which resulted in a significant ($P < .01$) increase in percent soil water from August (8.2%) to September (18.4%).

Others working with browse plants have found that dry matter content generally increases throughout the growing season as twigs become more fibrous (Short and Harrell, 1969). Moisture content of three shrub species in Arizona decreased from May to the following February, but increased during heavy August rains (Reynolds, 1967).

Spring-Cut Plots. The dry matter content of sprouts on the spring-cut plots was lower than that on the other plots at all sampling dates, although significant at only the 15% level. Percent dry matter rose from 35% in July to 40% in August, decreased to 32% in September, and increased to 52% in October. The spring-cut plots were expected to have a lower content of dry matter than plots cleared earlier because

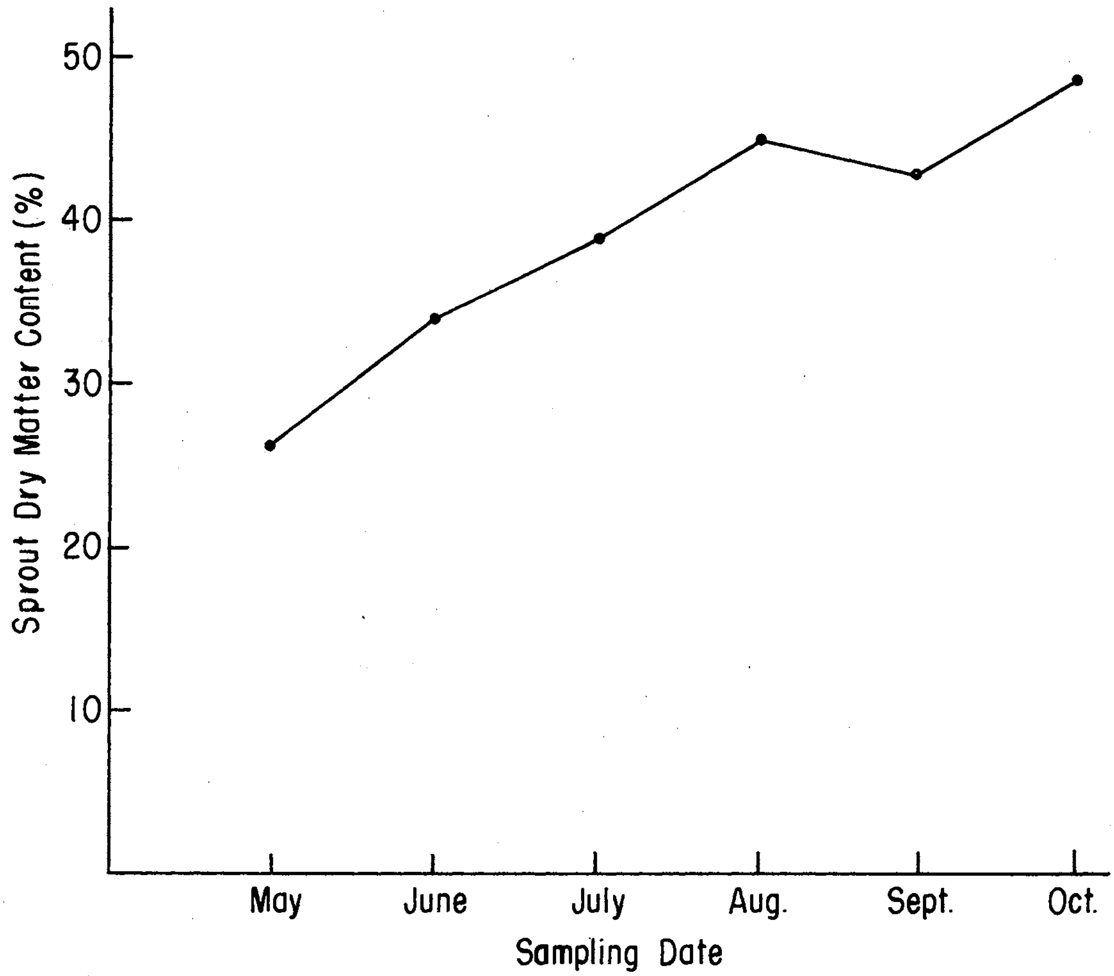

Figure 8. Percent Sprout Dry Matter on Summer- and Winter-Cut Plots Averaged over Fertilizer Treatments on Each Sampling Date

sprouts on the spring-cut plots were in a less mature stage. Dry matter content is lowest during periods of rapid growth (Blair and Epps, 1969). The increased content of sprout dry matter in October may have been partially due to the fact that the leaves were less succulent immediately before leaf-drop (Blair and Epps, 1969).

On the October, 1973, sampling date, leaves and stems on the spring-cut plots were separated when clipped. Percent dry matter was determined for leaves and stems. Both leaves and stems showed no differences in dry matter content due to fertilizer treatment at the 20% level. However, dry matter content of stems (49%) was significantly ($P < .05$) greater than that of leaves (43%). This difference is to be expected, due to the woody nature of the stems (Blair and Epps, 1967).

Leaf-Stem Ratio

The leaf-stem ratio of the spring-cut plots was higher for sprouts on fertilized plots (.88) than on unfertilized plots (.72). This difference was significant at the 20% level.

The leaf-stem ratio of all spring-cut plots (.80) was significantly ($P < .05$) greater than that of summer-cut plots (.43) and winter-cut plots (.33). This high ratio of leaves to stems was probably instrumental in the low dry matter content, as well as the slightly higher crude protein content of sprouts from spring-cut plots than sprouts from summer- and winter-cut plots.

Sprout Crude Protein Content

Sprout crude protein content was determined from clipped samples collected monthly from May to October, 1973. Crude protein level of sprouts from fertilized plots (9.1%) was significantly ($P < .10$) higher than those from unfertilized plots (8.4%), when averaged over all sampling dates. This difference in protein content was accompanied by a color difference, with fertilized sprouts being darker green in color. Figure 9 denotes sprout crude protein averaged over all fertilizer and cutting treatments at each sampling date. The protein level at each sampling date was significantly ($P < .05$) different from the sampling dates immediately preceding and following that date.

Sprout crude protein content averaged 12% in May when sprouts were most succulent (dry matter content = 26%). Crude protein content decreased throughout the growing season to a low level of 6% in October (dry matter content = 51%). This decrease in crude protein content as the growing season progressed is also shown by a negative relationship between crude protein content and sampling date ($r = -.65$) ($P < .001$). A significant ($P < .05$) sampling date and season of cutting interaction occurred when the protein content in sprouts from the winter-cut trees decreased from 12% in May to 7% in June, and then increased to 10% in July while protein content in sprouts from summer-cut trees steadily declined. Sprout crude protein content was negatively correlated to dry matter content ($r = -.55$) ($P < .001$), but percent sprout dry matter of the sprouts from the winter-cut trees did not deviate from the summer-cut values at any time during this period. Percent soil water decreased from 20% in May to 7% in July, but was not different between summer- and winter-cut plots.

Twigs and leaves of winged elm clipped from May to September (Dalrymple et al., 1965) contained about the same percent crude protein as did samples collected at comparable dates in my study. The

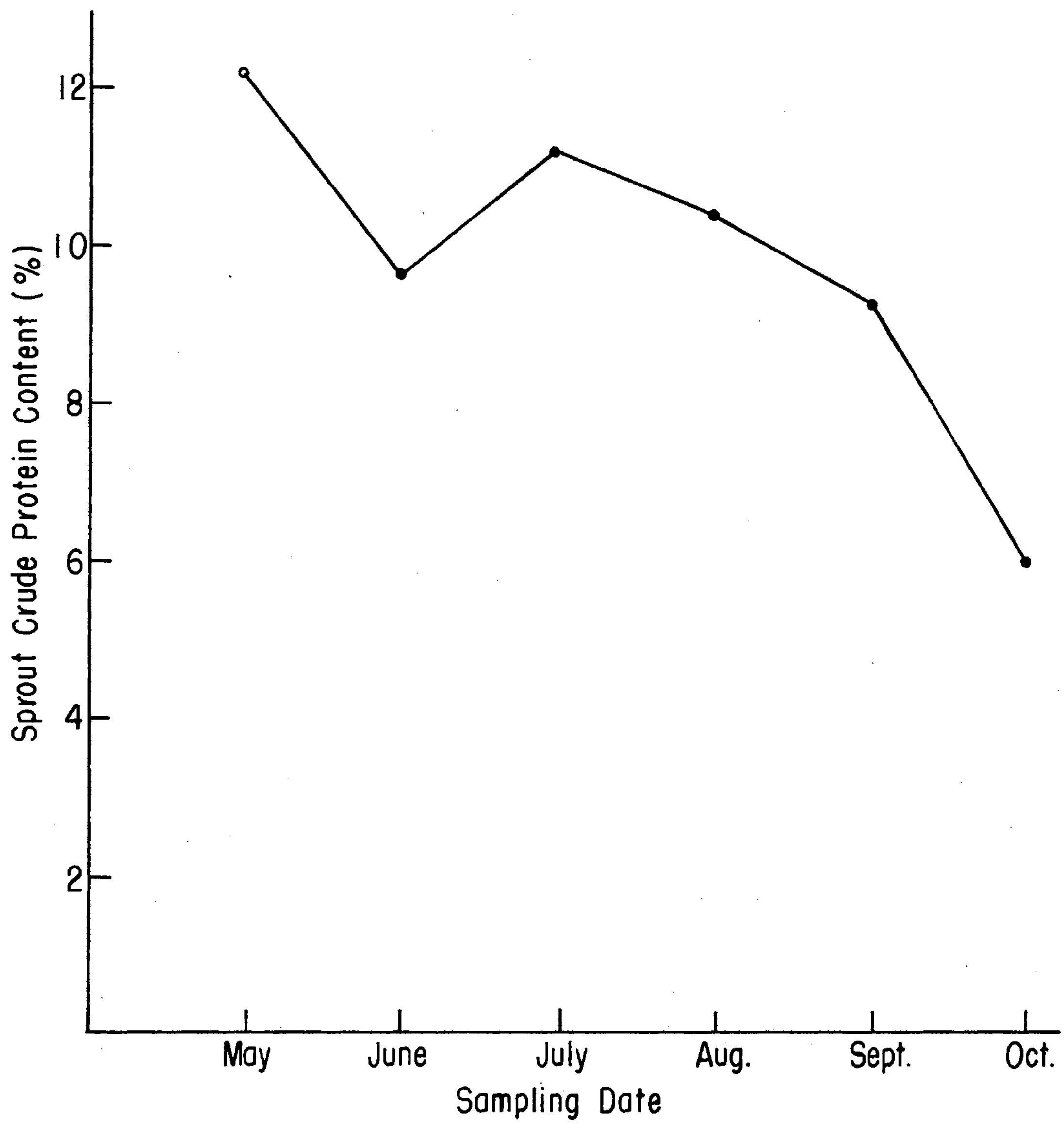

Figure 9. Sprout Crude Protein Content Averaged over All Treatments on Each Sampling Date

findings of Blair and Epps (1969) and Reynolds and Sampson (1943) agree with the results of this study that crude protein content of browse plants decreases throughout the growing season.

Clipped sprout samples on spring-cut plots were separated into leaf and stem fractions when sampled at the end of the 1973 growing season. Crude protein content of fertilized leaves (9.8%) and stems (4.0%) was significantly ($P < .05$) higher than that of unfertilized leaves (8.3%) and stems (3.5%).

Crude protein content of leaves (9.0%) was significantly ($P < .01$) greater than that of stems (3.7%) when averaged over fertilizer treatments. This is in agreement with Blair and Epps (1969) who reported higher levels of crude protein in leaves than twigs in five of seven browse species studied.

Variability of Sprout Data

Literature previously cited indicates that all known procedures of sampling populations of browse plants are inadequate in that reliable measurements are unattainable unless an inordinate number of samples are obtained.

The unfertilized, summer-cut sprout data from the October sampling date were analyzed separately to remove confounding effects of fertilizer, season of cutting, and sampling date. Variation in total elms per transect, as measured by coefficient of variation was rather high (56%). However, sampling error ($\frac{S_{\bar{x}}}{\bar{X}}$) was a reasonable 18%, which is below the 20% limit set by Lindsey (1955) as being acceptable in forest sampling. Thus, the sampling intensity of elm density used in this study seems acceptable. Simple descriptive statistics for various sprout factors sampled at the end of the 1973 growing season are presented in Table I.

Sprout Response in Deer and Cattle Area

Average Sprout Length

Steers grazing the deer and cattle area browsed elm sprouts very close, with sprout length averaging only 5.1 cm. Sprout length on the spring-cut plots in the deer-only area averaged 24.5 cm (Figure 10). This difference was very highly significant ($P < .001$). Comparing average sprout length in the deer and cattle area with sprout length in the deer-only area, I found the fertilized sprouts were utilized to a greater extent than unfertilized sprouts. Unfertilized sprouts in the deer and cattle area were 25% as long as those in the unfertilized, deer-only area, while sprout length in the fertilized, deer and cattle area was only 18% of the fertilized, deer-only sprout length. This agrees with the degree of browsing data obtained from the deer-only area which showed fertilized sprouts were browsed more heavily than unfertilized sprouts.

Total Sprout Length Per Stump

The total length of sprouts per stump was obtained as in the deer-only area by multiplying average sprout length by number of basal sprouts. Basal sprout numbers showed little difference between fertilized and unfertilized plots. The number of basal sprouts in the deer and cattle area (19) was slightly lower than the spring-cut trees in the deer-only area (25).

TABLE I

SIMPLE DESCRIPTIVE STATISTICS OF VARIOUS SPROUT FACTORS FROM UNFERTILIZED, SUMMER-CUT PLOTS

Factor	N	Units	Mean ± 90% Confidence Limit	Range	C.V. (%)	$s_{\bar{x}}$
Total Elms per Transect	9	--	23 ± 7	9 - 43	56	4
Sprouting Elms per Transect	9	--	21 ± 9	4 - 42	70	5
Non-sprouting Elms	9	%	18 ± 1	0 - 56	129	8
Dry Sprout Weight	9	gm	127 ± 69	22 - 349	88	37
Sprout Dry Matter Content	9	%	58 ± 6	49 - 79	15	3
Elm Twig Tips	27	--	140 ± 32	32 - 410	71	19
Average Sprout Length	27	cm	36 ± 3	15 - 53	23	2
Total Sprout Length per Stump	27	cm	1420 ± 348	182 - 4663	75	204
Stump Basal Diameter	27	cm	11 ± 2	4 - 32	57	1
Number Basal Sprouts	27	--	38 ± 8	7 - 102	64	5
Leaf-Stem Ratio	9	--	0.4 ± 0.1	0.1 - 0.5	32	<0.1

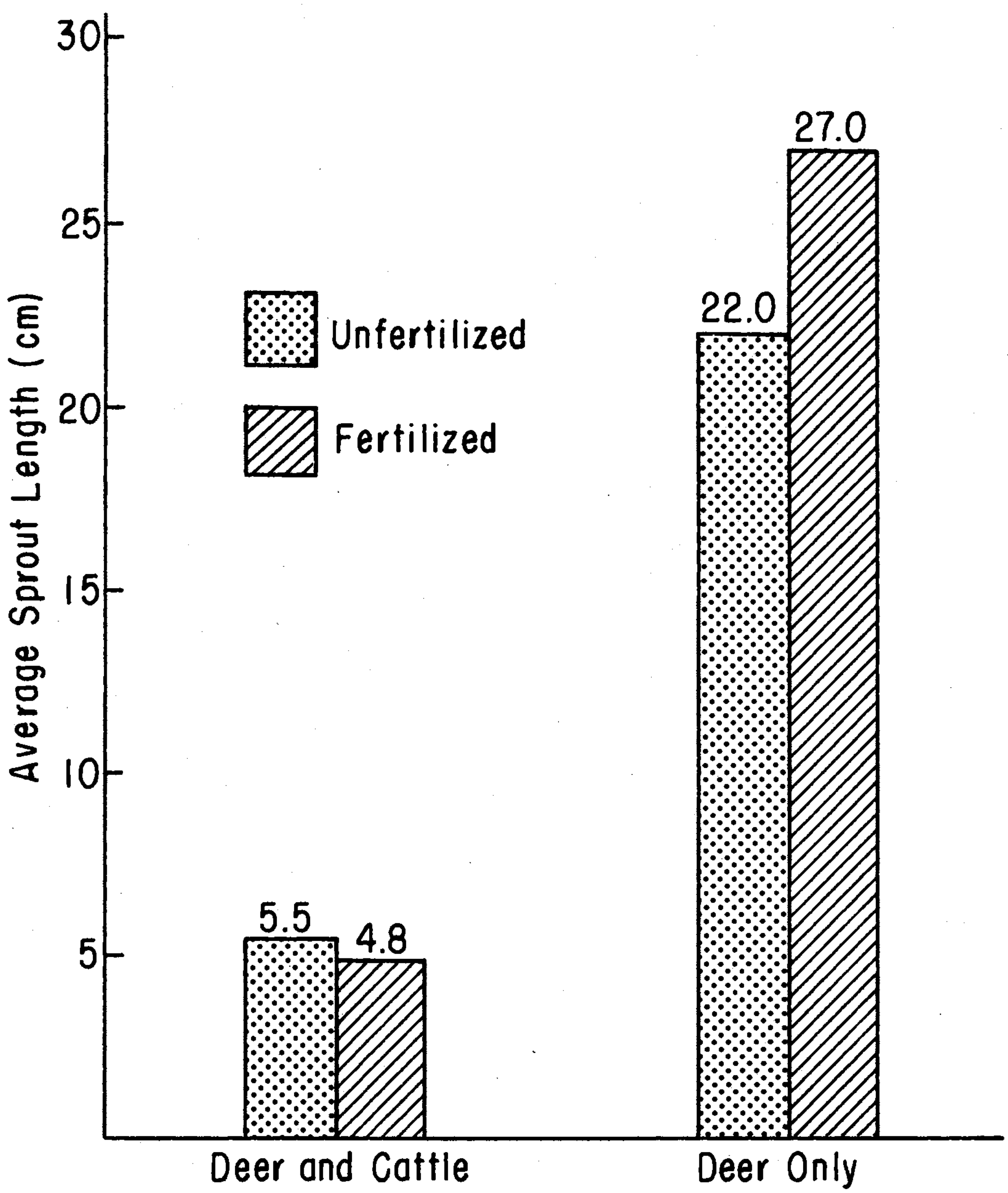

Figure 10. Average Sprout Length at End of 1973 Growing Season on Spring-Cut Plots in Both Deer and Cattle Area and Deer-Only Area

The total sprout length per stump data for the deer and cattle area is predictably similar to the average sprout length data, with the total sprout length per stump in the deer and cattle area significantly ($P < .001$) less than that in the deer-only area (Figure 11).

Number of Twig Tips

The average number of twig tips per sprouting stump in the deer and cattle area was significantly ($P < .01$) less than in the deer-only area (Figure 12). Twig tip numbers were the same for both fertilizer treatments in the deer and cattle area, which when compared to the spring-cut plots in the deer-only area, could represent a higher degree of utilization of fertilized over unfertilized sprouts. Twig tip numbers were highly correlated with basal sprout numbers ($r = .90$) ($P < .001$).

Sprout Dry Weight

Because of extremely heavy grazing pressure on sprouting elms, sprouts remaining on the stumps were too short to obtain a sample for weight determination from individual stumps.

Management Implications

Literature cited earlier in this paper has shown that elm and other species have been kept in a shrub-like state by heavy browsing. Other studies have indicated that continued removal of leaves and stems may lead to death of the plant. It is not known how the heavy browsing of American elm by cattle, in this study, will affect physiology of the cut elms. When sprouting is completed in 1974, the percent nonsprouting

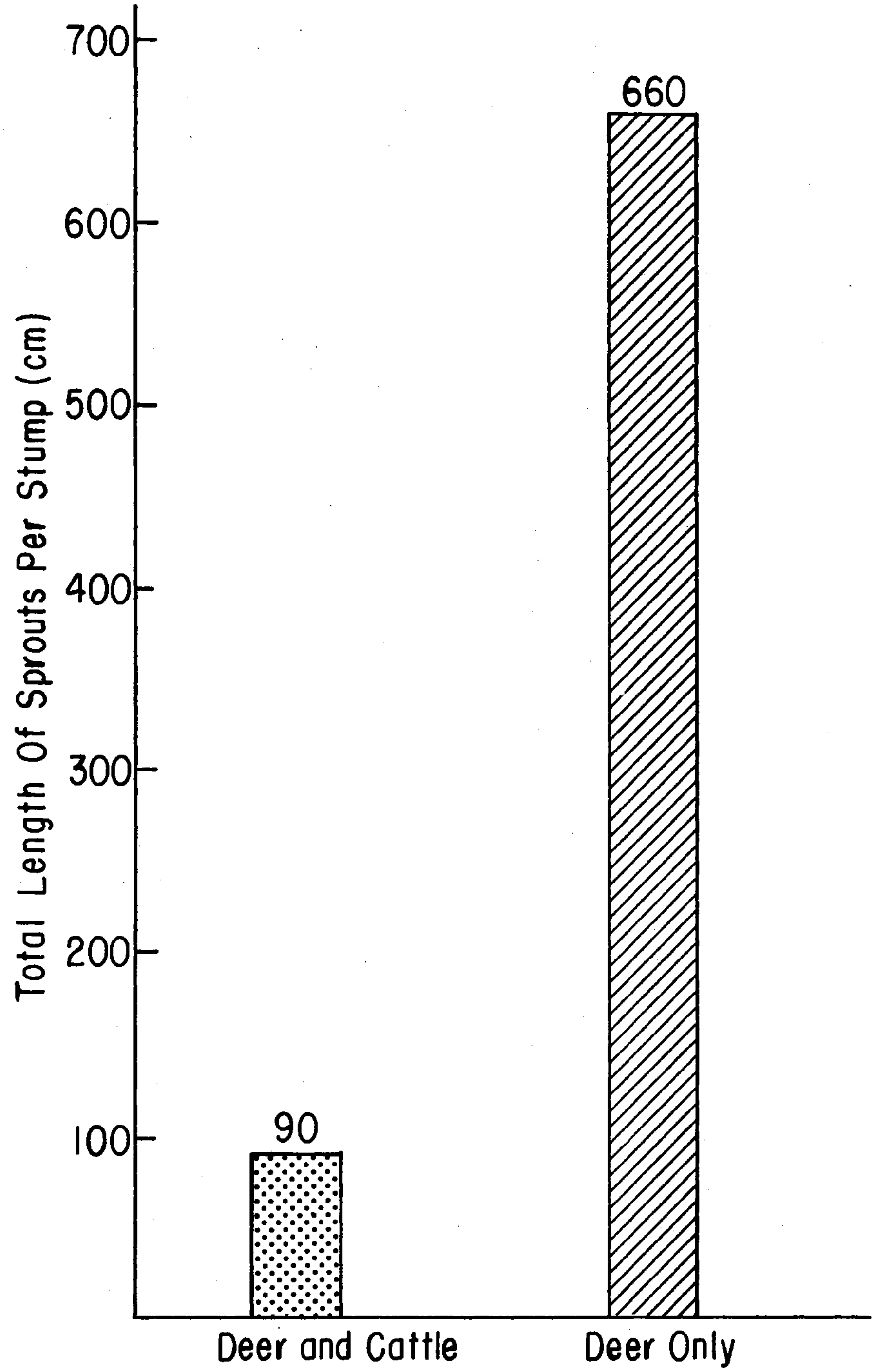

Figure 11. Total Length of Sprouts per Stump Averaged over Fertilizer Treatments for Spring-Cut Plots in Both Deer and Cattle Area and Deer-Only Area

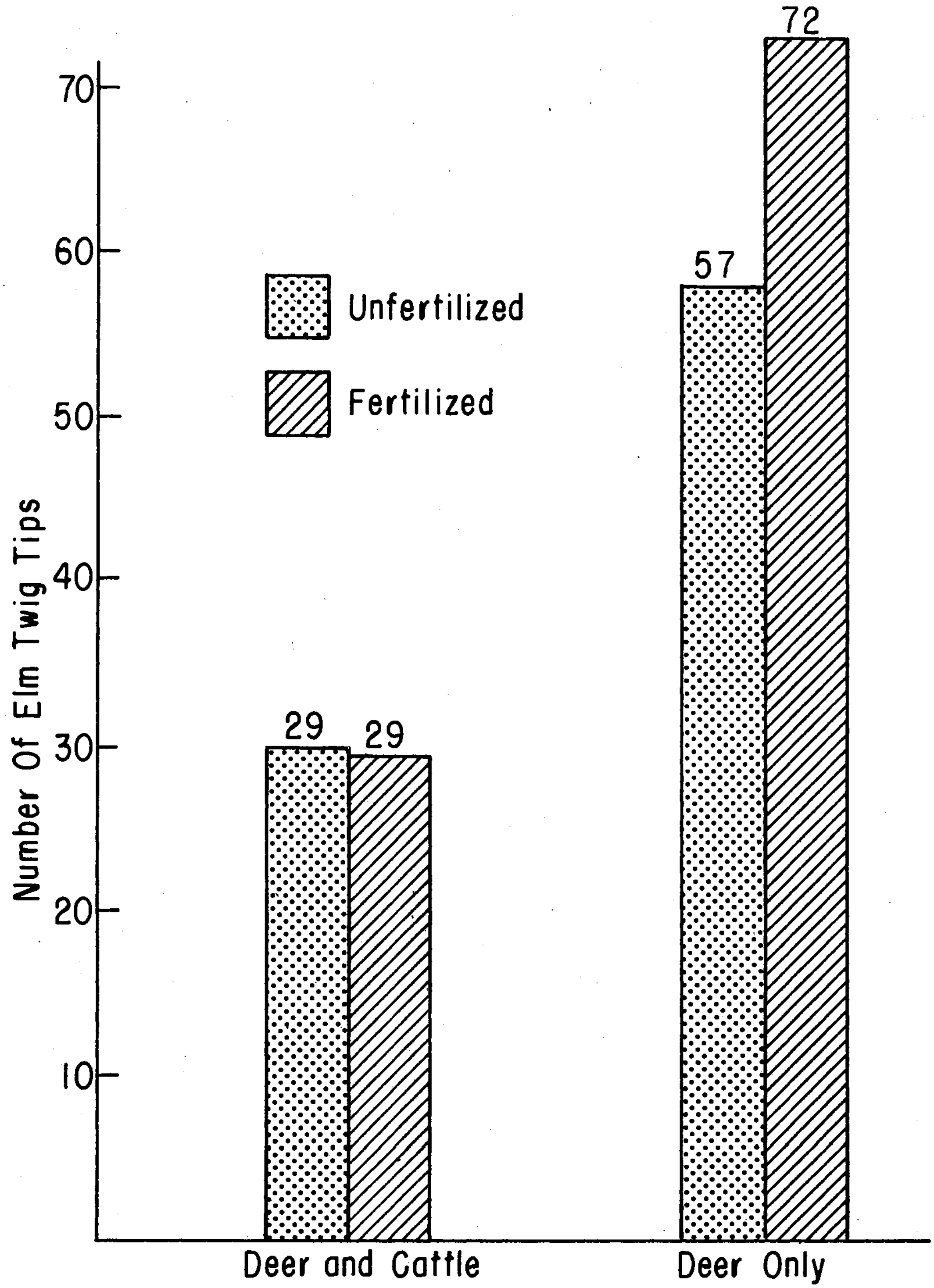

Figure 12. Number of Elm Twig Tips on Spring-Cut Plots in Both Deer and Cattle Area and Deer-Only Area

stumps will be determined in the deer and cattle area. Future research should involve determining the critical amount of sprout removal, above which would cause death of the tree and below which would allow continued sprout production. The desired amount of sprout removal could be accomplished by either biological or mechanical means.

Small cleared areas could be used in a management program of mechanical-biological control of elm. If continued sprout production was preferred, larger cleared areas would reduce heavy browsing by precluding heavy concentrations of browsers on a small area.

Degree of Browsing of Sprouts in Deer-Only Area

It became evident soon after the trees cut in the summer of 1972 began sprouting that the sprouts were being browsed by wildlife. Plans were therefore made to quantify this browsing throughout the 1973 growing season.

Season of Cutting x Sampling Date Relationships

Summer- and winter-cut plots were sampled for degree of browsing monthly from May to September. Spring-cut plots were sampled only from July to September because of the time lag between time of cutting and sufficient sprout growth for sampling.

Degree of browsing for each season of cutting averaged over fertilizer treatments on each sampling date shows browsing of sprouts on the summer- and winter-cut plots to be quite similar through the season (Figure 13). Browsing of sprouts on the spring-cut plots, however, was significantly ($P < .05$) different from that on both summer- and winter-cut plots at each common sampling date.

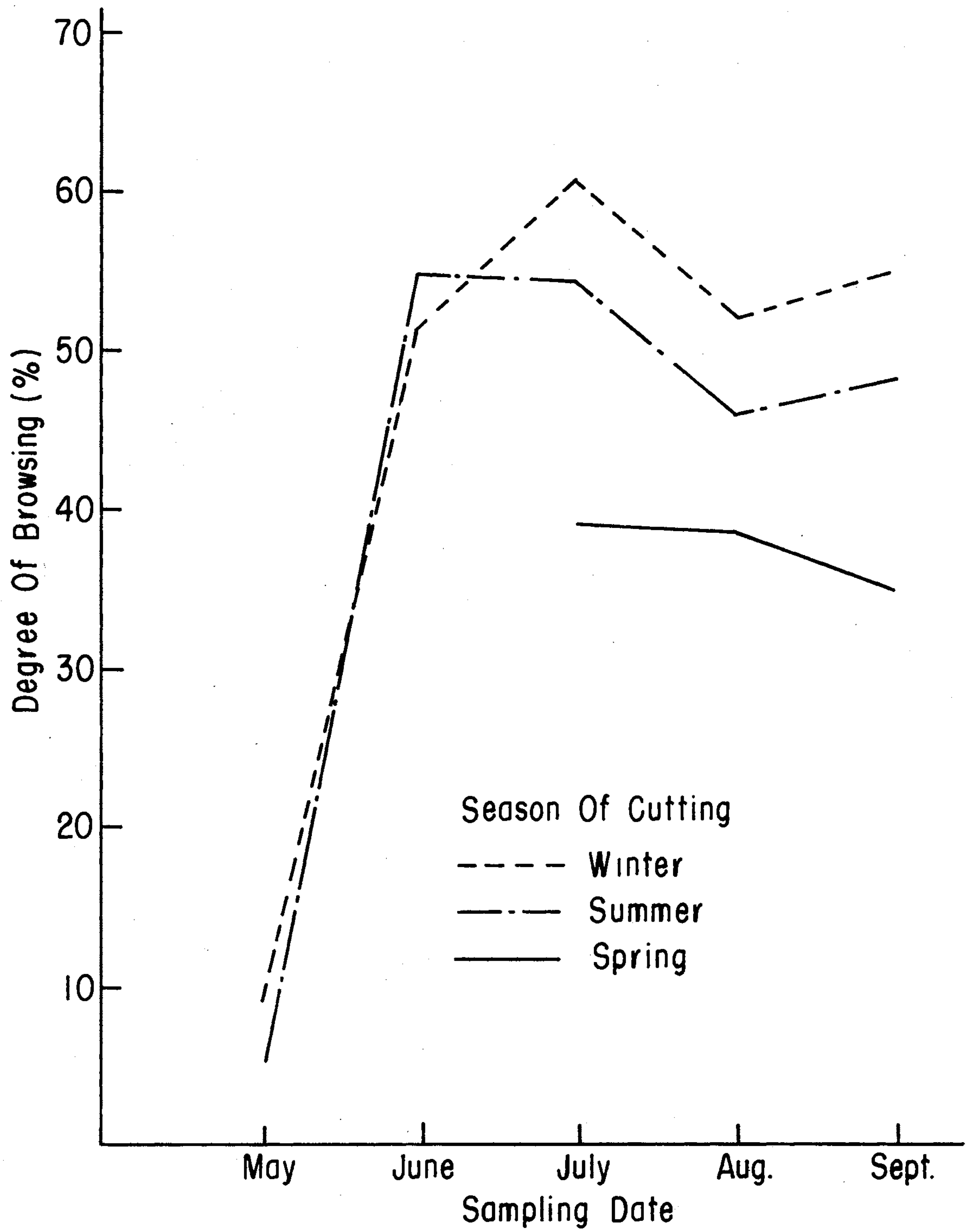

Figure 13. Degree of Browsing Relationships Between Season of Cutting and Sampling Date. All Values Averaged over Fertilizer Treatments

Analysis of variance of all plots over all sampling dates indicated a highly significant ($P < .01$) interaction between season of cutting and sampling date. The level of significance of the interaction was effectively reduced to greater than 20% when summer- and winter-cut plots were analyzed separately from spring-cut plots. Browsing on summer-cut and winter-cut plots will be discussed as one situation, while browsing on spring-cut plots will be discussed as a separate situation.

Summer- and Winter-Cut Plots

As stated earlier, differences in browsing on summer- and winter-cut plots was not significant at the 20% level when analyzed over all sampling dates. This was the basis for combining the two seasons of cutting. However, the degree of browsing on unfertilized plots (38%) was significantly ($P < .05$) less than that on fertilized plots (50%) when averaged over all sampling dates. This difference, in addition to a significant ($P < .05$) fertilizer treatment and sampling date interaction, made it implausible to average degree of browsing over fertilizer treatments. In all discussions concerning degree of browsing on summer- and winter-cut plots, the effect of fertilizer treatments will be discussed separately.

On the May sampling date, the degree of browsing was very similar on fertilized and unfertilized plots (Figure 14). However, by June the degree of browsing increased significantly ($P < .01$) for both unfertilized and fertilized plots, with the degree of browsing significantly ($P < .01$) greater on the fertilized plots. This marked increase in degree of browsing from May to June cannot be explained. Soil water

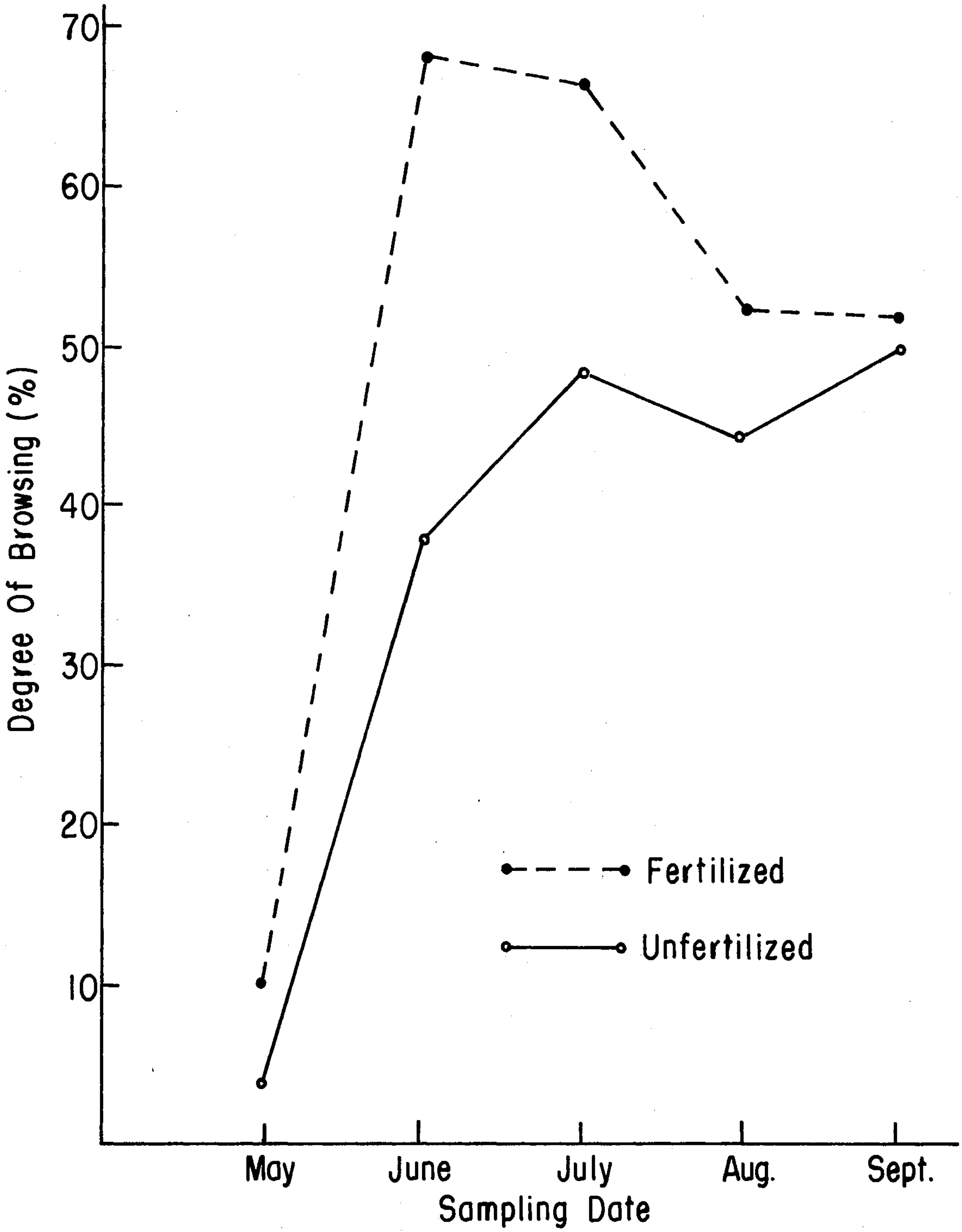

Figure 14. Degree of Browsing on Fertilizer Treatments on Each Sampling Date for Summer- and Winter-Cut Plots Averaged Together

content remained constant at 19% and sprout dry matter content increased from 26% to 34% in this period. Crude protein content of sprouts also decreased from 12% to less than 8% from May to June. The fact that the sprouts were small and few in number may have made them difficult to find in some of the plots which had substantial amounts of herbage present.

From June to July the degree of browsing on unfertilized plots increased significantly ($P < .05$), while browsing on the fertilized plots decreased slightly. Browsing due to fertilizer treatments was also significantly ($P < .05$) different on the July sampling date. Degree of browsing in August and September was very similar for fertilized and unfertilized plots.

From June, when the difference in degree of browsing between fertilizer treatments was greatest, to September, the level of browsing on fertilized and unfertilized plots tended to converge. After the June sampling date, the degree of browsing on fertilized plots decreased throughout the rest of the season, while browsing on unfertilized plots increased from May to September. This trend cannot be explained fully from the data available. Differences in sprout crude protein content, as well as sprout dry matter content, remained about the same between fertilizer treatments on all sampling dates.

Spring-cut Plots

I thought new sprout growth on the spring-cut plots would be utilized heavily because of its being more succulent than the more mature sprouts on other plots. However, this was not the case. As mentioned earlier, the degree of browsing on these plots was significantly lower

($P < .05$) than all other plots at each date sampled. Degree of browsing was significantly different ($P < .05$) between fertilizer treatments only for the August sampling date, when the degree of browsing on the fertilized plots increased from 41% in July to 60% in August. The degree of browsing on unfertilized plots decreased from 37% in July to 19% in August. In September, the degree of browsing decreased to 43% on the fertilized plots and increased to 28% on the plots left unfertilized.

Management Implications

The higher level of browsing of sprouts on fertilized plots has certain management implications that should not be overlooked. Literature already cited has shown that species normally considered unpalatable to various grazing animals may be heavily utilized after application of fertilizers. Although the effect of the observed level of browsing on the physiology of the sprouting elms is not known, continued heavy browsing could presumably kill the trees. However, different species vary widely in their resistance to utilization (Lay, 1965).

The implications of the lesser amount of browsing of sprouts on spring-cut plots are not clear. The lower browsing intensity could allow sufficient photosynthesis to maintain carbohydrate reserves, whereas removal of leaves by browsing could cause depletion of those reserves. The experiment should be continued for several years to allow results not evident in this study to be quantified.

Significant correlations between degree of browsing and the various sprout and herbage factors sampled were not attained. The level of browsing of any one species is no doubt interrelated with many other factors not readily measured, such as seasonal wildlife food preferences, quantity and quality of associated species, distribution of browsing animals over time and space, environmental factors, etc. In general, the degree of browsing showed little relationship with any of the sprout, herbage, or soil factors sampled. In this instance the amount of browsing of elm sprouts may have been related to so many different variables that none was more important when considered separately.

Future studies of this type could perhaps be improved through interdepartmental efforts to more thoroughly investigate all research aspects. For instance, if the numbers of deer and rodents on the study area throughout the year were known, perhaps differences in degree of browsing could be more fully explained. A study in South Texas showed differences in rodent populations on areas treated with various brush control treatments (Powell, 1968). In Nova Scotia, utilization of all types of browse studied was heavier by hares than deer (Telfer, 1972).

Herbage Response in Deer-Only Area

Species Composition

The summer-cut plots, cleared in August, 1972, were the first plots cleared. Therefore, these plots were sampled over a longer period of time than those cut at the later dates. Sampled at time of cutting, the species composition by weight on these plots consisted primarily of cool season grasses, such as japanese brome, sedges, and virginia wildrye (Table II). Next in relative abundance were "desirable" grasses (preferred by cattle) such as Scribner's panicum, purpletop, and little bluestem, which made up nearly 30% of the herbage

TABLE II

SPECIES COMPOSITION FOR ALL SAMPLING DATES IN DEER-ONLY AREA

Sampling Date	Season of Cutting	Fertilizer Treatment	% Cool Season Grasses	% Desirable Grasses	% Less Desirable Grasses	% Total Grasses	% Forbs
August, 1972	Summer	Unfert	39	28	10	77	23
		Fert	45	29	15	89	11
January, 1973	Control		53	14	18	91	9
	Summer	Unfert	73	7	13	93	7
		Fert	70	10	17	96	4
June, 1973	Control		53	7	10	70	30
	Summer	Unfert	46	6	13	66	34
		Fert	55	12	7	74	26
	Winter	Unfert	37	7	13	58	42
		Fert	70	10	5	85	15
	Spring	Unfert	21	32	11	64	36
		Fert	40	30	10	80	20
October, 1973	Control		54	6	20	81	19
	Summer	Unfert	21	21	27	69	31
		Fert	33	27	16	75	25
	Winter	Unfert	24	16	25	65	35
		Fert	45	19	10	74	26
	Spring	Unfert	15	46	17	78	22
		Fert	41	27	17	85	15

present. The remaining 25-30% was divided nearly equally between "less desirable" grasses, particularly annuals, and forbs, such as wild carrot and tickclover.

These plots, together with the control plots, were sampled again in January, 1973. The cool season grasses had increased from 39 and 45% in August to 73 and 70% of the total herbage on the unfertilized and fertilized plots, respectively. The relative abundance of cool season grasses on control plots at this time was 53%. This relative increase in percent cool season grasses on the cleared plots occurred at the expense of desirable grasses primarily, with a concurrent reduction in percent forbs.

By June, trees on all plots selected to be cleared had been cut, and all plots were sampled to quantify the observed response of cool season grasses on some plots. The relative abundance of cool season grasses on control plots remained the same as in January, while forbs increased from 9 to 30%. The percent cool season grasses on summer-cut plots decreased, whereas percent forbs increased between January and June. The relative abundance of cool season grasses on the fertilized, winter-cut plots was significantly ($P < .05$) greater than that on the unfertilized plots. Percent forbs on fertilized plots was significantly ($P < .05$) less than on unfertilized plots.

The June sampling date occurred less than one month after the spring-cut plots were cleared, so the species composition at that sampling date was essentially that which existed at the time of cutting. Spring-cut plots had a higher percentage of desirable grasses at time of cutting than all other plots. These grasses were mainly little bluestem and purpletop.

The last sampling date was in October, at the end of the 1973 growing season. Species composition of the control plots remained relatively constant from June to October, differing only in a slight decrease in percent forbs and a slight increase in less desirable grasses. All plots, with the exception of the control and fertilized, spring-cut plots, showed declines in relative abundance of cool season grasses from June to October.

The percent cool season grasses on the control plots was significantly ($P < .05$) greater than on all unfertilized plots or on fertilized, summer-cut plots. Fertilized winter- and spring-cut plots had significantly ($P < .05$) greater amounts of cool season grasses than unfertilized plots. Fertilizer apparently enhances the environment for cool season grasses after the shade-producing overstory is removed. When the level of added nutrients is reduced through removal by plants, leaching, etc., as on the fertilized, summer-cut plots, the relative amount of cool season grasses tends to decrease.

The relative abundance of forbs present in October exhibited the trend, which first became evident on the June sampling date, of all unfertilized plots having a higher percentage of forbs than fertilized plots. This seems somewhat contrary to the behavior expected when fertilizer, especially a formulation containing phosphate, is applied to an area in a relatively low seral state. The rapid response of cool season grasses may have preempted the forbs for nutrients and soil water.

Herbage Production

At time of cutting, the amount of total herbage on the summer-cut plots was 850-890 kg/hectare (Table III).

The summer-cut plots were sampled again in January, 1973, with the control plots. This sampling date was much later than desired because of inclement weather, therefore herbage production was much lower due to deterioration of standing plants than if sampling had been earlier. Forb and total grass production was lower than at time of cutting, no doubt due to deterioration. Cool season grass production on control and fertilized plots was essentially the same as at time of cutting. Cool season grasses were evidently able to respond to the fertilizer applied in August to allow cool season grass production on the fertilized, cleared plots to remain relatively constant from August to January, while production of cool season grasses decreased considerably during that time on unfertilized plots.

Total herbage production on control plots was greater than both unfertilized and fertilized, cleared plots. The tree stand on the control plots could have protected the herbage from the winter weather to allow less weathering of standing herbage than on cleared plots.

The rapid growth of cool season grasses on fertilized, cleared plots prompted the June sampling date. The amount of herbage production on the control plots was about the same as that on all unfertilized, cleared plots. This relatively high production on control plots was mainly due to the large amount of cool season grasses. Production of cool season grasses was significantly ($P < .05$) greater on the fertilized, winter- and spring-cut plots than on the unfertilized plots. The difference in cool season grass production due to fertilizer on summer-cut plots was significant at the 10% level of probability. All fertilized, cleared plots had greater production of desirable grasses and

TABLE III

HERBAGE PRODUCTION (KG/HECTARE) FOR ALL SAMPLING DATES IN DEER-ONLY AREA

Sampling Date	Season of Cutting	Fertilizer Treatment	Production					
			Cool Season Grasses	Desirable Grasses	Less Desirable Grasses	Total Grasses	Forbs	Total Production
August, 1972	Summer	Unfert	340	250	90	685	200	890
		Fert	380	250	130	760	90	850
January, 1973	Control		330	80	110	565	50	620
	Summer	Unfert	180	30	60	450	30	480
		Fert	350	50	80	480	20	500
June, 1973	Control		910	120	170	1210	520	1730
	Summer	Unfert	860	110	240	1235	640	1870
		Fert	1310	280	160	1770	620	2390
	Winter	Unfert	610	110	210	965	700	1660
		Fert	2730	390	190	3315	580	3900
	Spring	Unfert	360	560	190	1120	630	1750
		Fert	1030	800	260	2070	520	2590
October, 1973	Control		500	50	180	750	170	920
	Summer	Unfert	480	480	620	1585	710	2300
		Fert	860	700	420	1960	650	2610
	Winter	Unfert	450	300	460	1215	650	1870
		Fert	1640	690	360	2705	950	3650
	Spring	Unfert	360	1110	410	1890	530	2420
		Fert	1310	860	540	2725	480	3200

total grasses than control plots.

Forb production was about the same on all plots in June. Although relative abundance of forbs was less on fertilized plots than on unfertilized plots, forb production on fertilized plots was nearly equal to forb production on unfertilized plots. There was also a difference in species response to fertilizer treatments. Principal forbs on the unfertilized plots were wild carrot and tick clover. Fertilized plots, however, contained larger forbs such as marestail (*Erigeron canadensis*) and some annual sunflower (*Helianthus annuus*). The forb species on the fertilized plots should be more beneficial to both wildlife and livestock than those found on the unfertilized plots.

Herbage production was determined at the end of the 1973 growing season, in October, for all plots (Figure 15). Cool season grass production was about the same for the control plots as all unfertilized, cleared plots. The fertilized winter- and spring-cut plots had significantly ($P < .05$) greater production of cool season grasses than control plots. Fertilized, summer-cut plots had only slightly higher production of cool season grasses than control plots.

Production of desirable grasses, less desirable grasses, total grasses, and forbs was greater on all cleared plots than on control plots. Total herbage production on control plots was significantly ($P < .05$) less than on all cleared plots.

The total herbage production on control plots at the end of the 1973 growing season (920 kg/hectare) was only slightly greater than that on the summer-cut plots at the time of cutting (890 kg/hectare), August, 1972. This indicates the greater amount of herbage production on cleared plots was due more to overstory removal than to the above

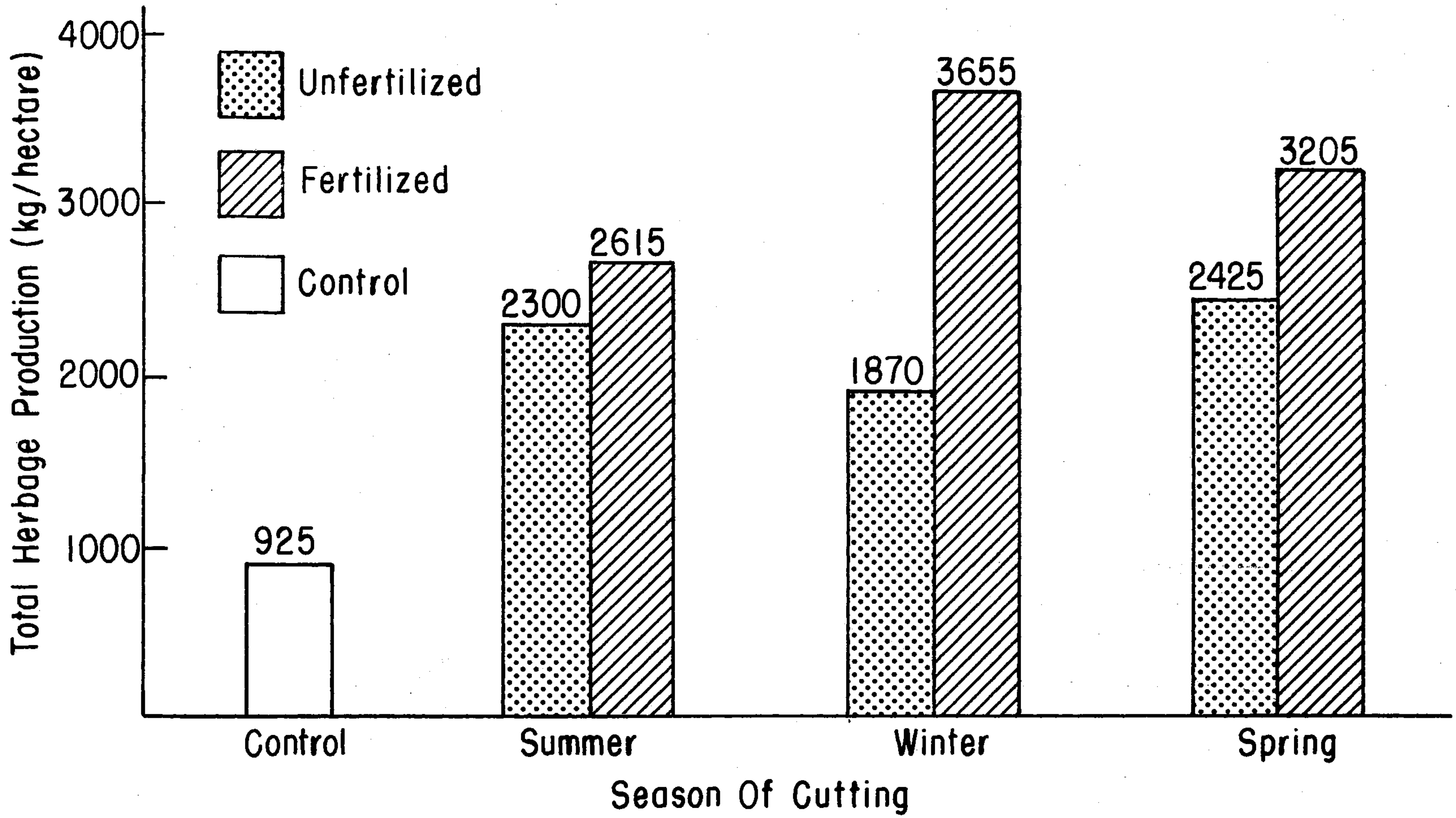

Figure 15. Total Herbage Production on All Plots at End of 1973 Growing Season

average rainfall received during 1973.

Cool season grasses were able to respond to fertilizer on the cleared plots if the fertilizer was available during their active growing period. Overstory removal released desirable and less desirable grasses as well as forbs, although total grass production overshadowed the concurrent increase in forb production. At every sampling date all fertilized plots had more total herbage production than unfertilized plots.

Crude Protein Content of Herbage

The application of fertilizer did not produce the expected increase in crude protein content of the herbage. In January, percent crude protein was at the highest level recorded during the study. The percent crude protein content of the herbage from fertilized plots (12.0%) was significantly higher than that on both control (8.9%) and unfertilized plots (8.2%) (Table IV).

When sampled in June, the difference in crude protein content between fertilizer treatments was significant at only the 20% level. The crude protein content of herbage on cleared plots (7.4%) was higher ($P < .10$) than that on control plots (6.5%). At this sampling date the herbage on spring-cut plots had higher ($P < .05$) crude protein content than the herbage on both control and summer-cut plots. The reason for the higher crude protein content of herbage in June on the unfertilized, spring-cut plots (9.7%) than that on the fertilized, spring-cut plots (7.0%), is not known. The comparatively high percent crude protein in herbage on fertilized, winter-cut plots (8.3%) may have been due largely to the high relative abundance of cool season grasses (70%) on the June

TABLE IV

PERCENT CRUDE PROTEIN CONTENT OF HERBAGE ON PLOTS IN DEER-ONLY AREA ON SAMPLING DATES IN 1973

Sampling Date	Fertilizer Treatment	Season of Cutting				
		Control	Summer	Winter	Spring	Average of All Plots
January	Unfert	1/	8.2	2/	2/	8.2
	Fert	1/	12.0	2/	2/	12.0
	Average	7.7	10.1	2/	2/	8.9
June	Unfert	1/	6.6	6.5	9.7	7.6
	Fert	1/	6.6	8.3	7.0	7.3
	Average	6.5	6.6	7.4	8.3	7.2
October	Unfert	1/	6.4	7.3	5.2	6.3
	Fert	1/	7.1	6.8	7.7	7.2
	Average	8.5	6.8	7.0	6.5	7.2

1/ Control plot values included in only the overall sampling date average.

2/ Not sampled that date.

sampling date. Herbage crude protein content was positively correlated with relative abundance of cool season grasses ($r = .56$) ($P < .001$).

At the end of the 1973 growing season (October), the herbage on control plots was higher in crude protein content than that on all cleared plots. The difference in crude protein content of herbage on cleared plots due to fertilizer was significant at the 15% level.

In general, crude protein content of herbage on cleared plots decreased from January to October. Crude protein content of herbage on summer-cut plots in January (10.1%) was significantly ($P < .05$) greater than that in June (6.6%) and October (6.8%).

On the June and October sampling dates, a trend between time since fertilizer application and crude protein content of the herbage became apparent. In June, crude protein content of herbage on fertilized, summer-cut plots (6.6%) was lower than that from both winter-cut plots (8.3%) and spring-cut plots (7.0%). Much of the fertilizer applied to the summer-cut plots may have been lost to leaching, etc., whereas the herbage on the winter-cut plots was able to use much of the applied fertilizer, and the herbage on the spring-cut plots had not had sufficient time since application of fertilizer to effectively utilize that fertilizer. In October, the crude protein content of herbage on summer-cut plots (7.1%) and winter-cut plots (6.8%) were about the same, while herbage on spring-cut plots (7.7%) was highest in crude protein content. The fertilizer on summer- and winter-cut plots could have been dissipated throughout the growing season, and fertilizer applied to spring-cut plots was probably still being taken up by plants.

Crude Protein Yield

The total yield of crude protein was determined for each of the sampling dates in 1973. Crude protein yield is the total amount of protein in the herbage. This is determined by multiplying percent crude protein by total herbage production in kg/hectare. Crude protein yield is expressed as kg crude protein/hectare.

Crude protein yield averaged over all treatments was significantly ($P < .01$) lower for herbage sampled in January (55 kg/hectare) than in either June (155 kg/hectare) or October (155 kg/hectare) (Table V). Although crude protein content of herbage in January was higher than other sampling dates, the total herbage production was lowest, hence crude protein yield was also low. Crude protein content of herbage in June (7.2%) was the same as in October (7.2%), and total herbage production in October (2420 kg/hectare) was about the same as that in June (2270 kg/hectare). Average crude protein yield was the same in June as in October (155 kg/hectare).

Crude protein yield in herbage on summer-cut plots increased from January to October while percent crude protein content decreased during that time. This increase in crude protein yield in the face of declining crude protein content was due to the fact that the crude protein was being dissipated throughout greater amounts of total herbage.

Soil Chemical Analysis

Soil samples taken at the June sampling date were analyzed for various soil constituents (Table VI). Nitrogen level was less than 5 ppm on all plots. Phosphorus level was higher on fertilized plots

TABLE V

CRUDE PROTEIN YIELD (KG/HECTARE) OF HERBAGE
ON ALL PLOTS SAMPLED IN 1973

Sampling Date	Fertilizer Treatment	Season of Cutting				
		Control	Summer	Winter	Spring	Average
January	Unfert	1/	45	2/	2/	45
	Fert	1/	60	2/	2/	60
	Average	40	55	2/	2/	55
June	Unfert		130	80	215	140
	Fert		150	280	175	200
	Average	100	140	180	195	155
October	Unfert		150	125	130	135
	Fert		200	245	230	225
	Average	70	175	185	180	155

1/Control plot values included in only the overall sampling date average.

2/Not sampled that date.

TABLE VI

SOIL CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN JUNE, 1973

	Plot						
		Summer-Cut		Winter-Cut		Spring-Cut	
Item	Control	Unfert	Fert	Unfert	Fert	Unfert	Fert
N (ppm)	<5	<5	<5	<5	<5	<5	<5
P (ppm)	7	10	15	7	10	5	11
K (ppm)	168	188	158	150	233	153	148
Ca (ppm)	1276	1230	1196	1196	1353	1133	1280
Mg (ppm)	288	300	310	286	328	291	326
Na (ppm)	56	58	62	71	63	68	67
O.M (%)	1.7	1.7	1.6	1.9	2.1	1.5	1.6
pH	6.3	6.4	6.2	6.3	6.2	6.3	6.2

(12 ppm) than on unfertilized plots (7 ppm). The difference was significant at the 10% level. No other soil factors showed any clear trends between treatments.

Grazing Residue in Deer and Cattle Area

Herbage data were collected on the grazing residue remaining in the deer and cattle area at the end of the 1973 growing season. The amount of grazing residue remaining on the control plots was significantly ($P < .05$) greater than on all cleared plots (Table VII). Herbage data from the deer-only area showed that overstory removal greatly increased herbage production. The lower amount of herbage residue remaining on the cleared plots was therefore not due to overstory removal, but to cattle concentrating on the cleared area and neglecting the control plots which had elm overstory (Figures 16A and 16B). Other workers have found that cattle tend to prefer forage from open areas over that from shaded areas (McEwen and Dietz, 1965; Reynolds, 1962; Welton and Morris, 1928).

The relative abundance and amount of residue of cool season grasses was less on the fertilized, cleared plots. In light of the data from the deer-only area, which showed a response of cool season grasses to fertilizer, it is assumed that the utilization of cool season grasses by cattle was greatest on fertilized, cleared plots.

Forb production on cleared plots was less than on control plots. The principal forb present was western ragweed (*Ambrosia psilostachya*), which is generally ungrazed by cattle. Therefore, the combination of clearing and grazing by cattle either did not cause an increase in forb production during 1973 or increased forb utilization by cattle negated any increase due to clearing or fertilization.

TABLE VII

SPECIES COMPOSITION AND GRAZING RESIDUE FOR UNFERTILIZED-CLEARED, FERTILIZED-CLEARED, AND CONTROL PLOTS IN DEER AND CATTLE-GRAZED AREA

Species Composition

Plot	% Cool Season Grasses	% Desirable Grasses	% Total Grasses	% Forbs
Control	33	23	83	17
Cleared-Unfert	41	6	53	47
Cleared-Fert	21	5	37	63

Grazing Residue (Kg/hectare)

Plot	Cool Season Grasses	Desirable Grasses	Total Grasses	Forbs	Total Herbage Production
Control	330	220	790	160	960
Cleared-Unfert	70	10	90	80	170
Cleared-Fert	40	10	70	120	190

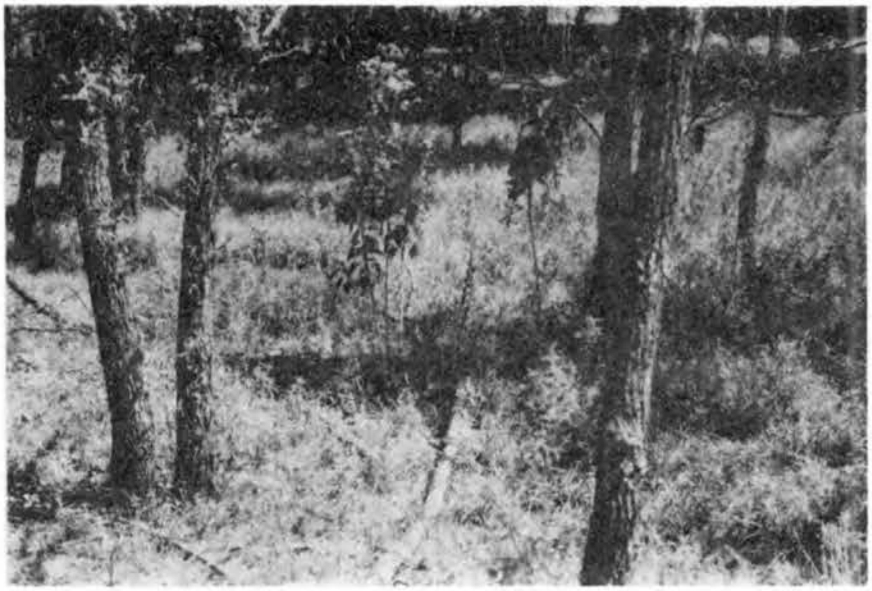

Figure 16A. Control Plot in Deer and Cattle Area in August, 1973

Figure 16B. Cleared Plot in Deer and Cattle Area in August, 1973. Note Length of Elm Sprouts

CHAPTER IV

SUMMARY AND CONCLUSIONS

In 1972 and 1973, plots in a floodplain stand of American elm ungrazed by livestock were cleared in three seasons corresponding to three phenological stages of American elm. These seasons and their analogous phenological stages were: (1) summer: mature-leaf stage; (2) winter: bud stage; and (3) spring: half-leaf, rapid growth stage. Plots were also cut in the spring in an adjacent area grazed by cattle. Two fertilizer treatments were applied at time of cutting: 0 and 74 kg/hectare each of nitrogen and phosphate. All treatments were replicated three times. One control plot per replication was left uncleared and unfertilized.

The objectives of the study were to determine the effects of clearing, with and without fertilizer, on production of elm sprouts; utilization of sprouts by deer, and by deer and cattle; herbage production; and nutritive value of sprouts and herbage.

Sprout production was determined at the end of the 1972 and 1973 growing seasons. Degree of browsing by deer was determined monthly from May to September in 1973. Herbage production was determined in the deer-only area in August, 1972, January, 1973, June, 1973, and October, 1973. All data from the plots grazed by deer and cattle were collected in October, 1973.

American elm made up 97% of the stand, which averaged 2500 trees per hectare. Average basal diameter of cut trees was 10.1 cm. Twelve percent of the trees failed to resprout after top removal, but no statistical difference existed among treatments.

At the end of the 1973 growing season, average sprout length was greater on summer- and winter-cut plots than spring-cut plots and greater on all fertilized plots than unfertilized plots. This difference was significant at the 5% level for the summer- and winter-cut plots.

Number of basal sprouts was not greatly different between cutting dates, or fertilizer treatments. Basal sprout numbers increased with time since cutting date with the trees cut in August, 1972, showing additivity of basal sprout numbers from 1972 (26) to 1973 (42).

Total sprout length per stump was not different between fertilizer treatments, but total sprout length on spring-cut trees (660 cm) was much less than that on summer- and winter-cut trees (1500 cm and 1740 cm). Twig tips per stump followed the same pattern as basal sprouts and total sprout length.

Dry weight of sprouts per stump was greater on fertilized summer- and winter-cut plots than on unfertilized summer- and winter-cut plots as well as all spring-cut plots. No relationships could be drawn between basal diameter and sprout production.

Sprout dry matter content increased throughout the growing season on all treatments. Percent sprout dry matter decreased slightly from August to September when favorable rainfall significantly increased soil water content.

Crude protein content of sprouts decreased throughout the growing season, with an unexplainable dip in June followed by a rise in July.

Cattle grazing the deer and cattle area browsed the elm sprouts very heavily. Average sprout length in the deer and cattle area (5.4 cm) was much less than that in the deer-only area (24.5 cm). Fertilized sprouts were browsed more heavily than unfertilized sprouts. Total sprout length per stump and number of twig tips were both less than in the deer-only area. Too little sprout residue remained to obtain weight samples.

Degree of elm sprout browsing by deer and rodents was determined from May to September 1973. Degree of browsing on spring-cut plots was less than that on summer- and winter-cut plots. Level of browsing on summer- and winter-cut plots was higher on fertilized plots (50%) than on unfertilized plots (38%).

After a dramatic rise in degree of browsing from May to June, the degree of browsing on fertilized plots decreased the remainder of the growing season, while that on unfertilized plots increased throughout the growing season. Browsing of American elm could be included in a management plan for wildlife, livestock, or both.

Herbage production in the deer-only area responded to removal of overstory, and to fertilizer. Species composition of control plots remained relatively constant from January to October. In general, the species composition of cleared plots showed a decrease in cool season grasses on unfertilized plots, while cool season grasses on fertilized, cleared plots increased after fertilization, but decreased as the fertilizer was dissipated.

Relative abundance of forbs was less on all fertilized plots than on unfertilized plots, although actual production of forbs was variable on different fertilizer - season of cutting combinations.

Total herbage production on control plots was less than on all cleared plots at the end of the 1973 growing season. All fertilized plots had higher total herbage production than unfertilized plots on all sampling dates.

Crude protein content of herbage was generally greatest during the period following fertilization until dissipation of fertilizer.

Crude protein yield of herbage increased as production increased, although crude protein content of herbage decreased.

In the area grazed by deer and cattle, grazing residue remaining on control plots at the end of the 1973 growing season was much greater than that on all cleared plots. This was apparently due to the cattle's concentrating on the cleared plots, and neglecting forage on uncleared, control plots.

This study has shown that American elm, common near floodplains in central Oklahoma, may be effectively manipulated to increase the value of that site for wildlife and livestock.

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APPENDIX A

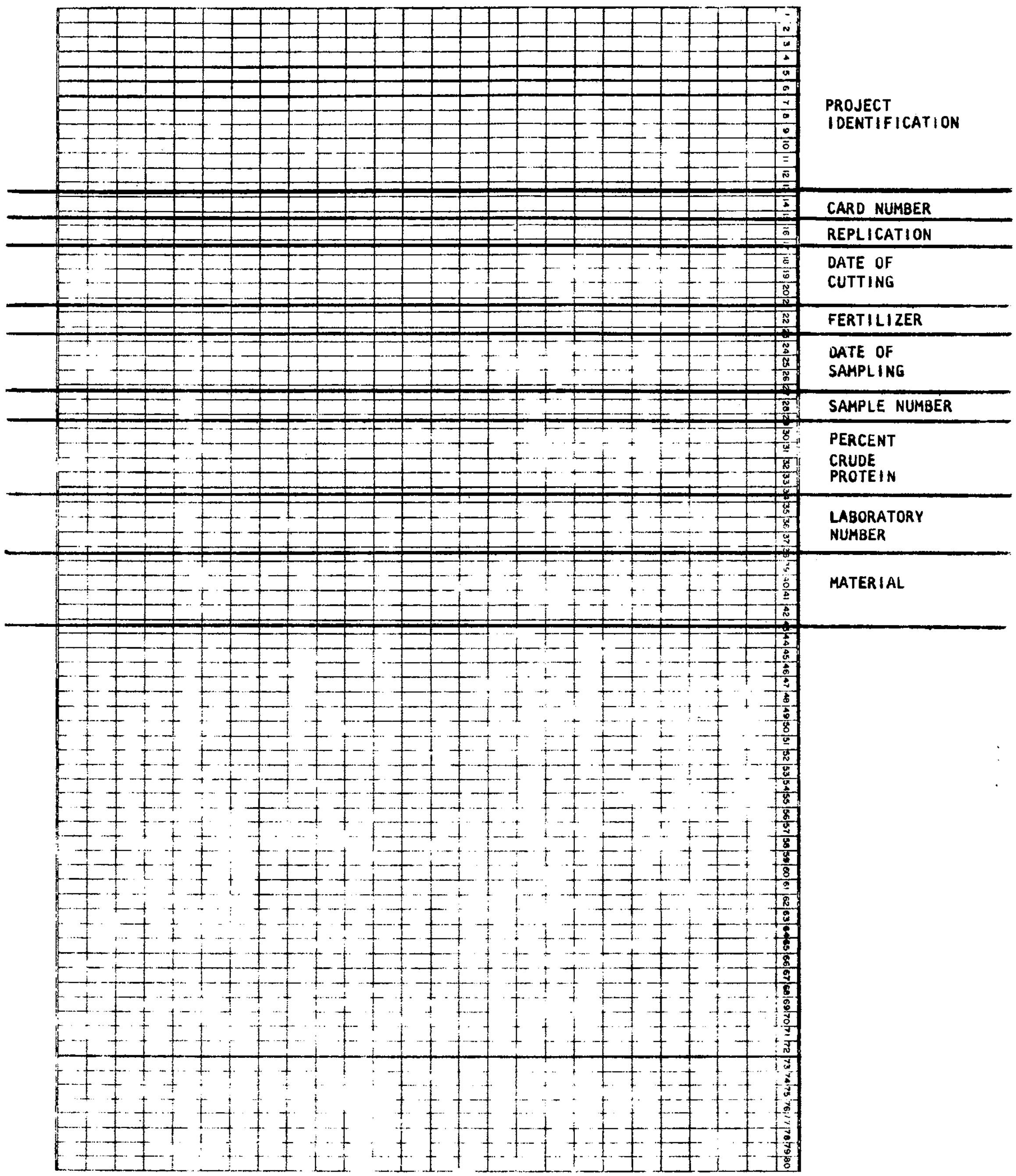
PRECIPITATION RECEIVED AT STILLWATER, OKLAHOMA, IN 1972 AND 1973 WITH 40-YEAR NORM

Month	Precipitation (mm) Received in: 1972	1973	40-yr. Norm	% of Norm 1972	1973
January	2	82	29	7	279
February	4	30	34	10	89
March	37	196	47	56	416
April	59	87	73	81	120
May	64	81	117	55	69
June	90	55	108	84	51
July	73	110	90	81	123
August	75	55	81	92	67
September	64	315	86	74	367
October	125	62	71	177	88
November	96	78	47	204	165
December	39	27	34	115	78
TOTAL	717	1179	817	88	144

APPENDIX B

KEYPUNCH SHEET USED IN FIELD

DATA COLLECTION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CARD NUMBER
REPLICATION
DATE OF CUTTING
FERTILIZER
DATE OF SAMPLING
SAMPLE NUMBER
PERCENT CRUDE PROTEIN
LABORATORY NUMBER
MATERIAL

VITA

James Floyd George

Candidate for the Degree of

Master of Science

Thesis: SEASONAL FERTILIZATION AND TOP REMOVAL OF AMERICAN ELM AFFECTS HERBAGE AND SPROUT PRODUCTION AND BROWSING

Major Field: Agronomy

Biographical:

Personal Data: Born in Jayton, Texas, April 21, 1947, the son of Mr. and Mrs. Carl George.

Education: Graduated from Spur High School, Spur, Texas, in May, 1965; received the Bachelor of Science degree in Range Management from Texas Tech University in 1970; completed requirements for the Master of Science degree at Oklahoma State University in May, 1974.

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