COMPARATIVE ANALYSIS OF LEAF SURFACES AND RELATED FUNCTIONS OF FOUR NATIVE GRASS SPECIES AND BERMUDAGRASS

By

EMMETT WATSON McCORD

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1951

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1959

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of the Oklahoma State University
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Thesis Approved:

J Gardner
Thesis Adviser

J Q Lynd

W E McMurphy

Eddie Basler

D D Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

More than half of the land in Oklahoma is in native grass. Cattlemen for years have depended on native grass for livestock grazing. It is estimated that more than half of the feed-stuff consumed by livestock comes from native grass.

Native grass has some advantages over introduced grass in that it can withstand drouthy, shallow and low fertility soils. Production of native grass is feasible on rough, hilly, and rocky soils, where introduced grasses cannot be planted. However native grass cannot withstand prolonged heavy grazing and excessive trampling which decrease vigor and eventually eliminate many desirable native species from stands.

In addition to large areas of native grass for livestock grazing there are three million acres of introduced grasses utilized by grazing, the most important of which is bermudagrass, Cynodon dactylon. Bermudagrass can withstand heavy grazing pressures, which increases its desirability for pasture. However it must be fertilized especially with nitrogen or grown with adapted legumes in order to express its full potential.

Under high nitrogen fertility, weed control and favorable management practices bermudagrass will out yield native grass. When as much as 100 pounds of nitrogen per acre is applied, about three tons of dry forage can be expected from bermudagrass in eastern Oklahoma. A stand of native grasses can be expected to produce about one ton of dry forage in this area. Bermudagrass grown on similiar soils as native grasses generally will not yield as much as native grasses unless commercial fertilizers are added.

Many researchers have investigated factors that influence the yield of dry matter of forage plants by what has been termed "growth analysis". "Growth analysis" considers yield to be related to leaf area and net assimilation rate as affected by time.

This investigation was designed to employ "growth analysis" on some important native grass species and bermudagrass in hopes of gaining a better understanding of the production disparity between the native grasses and bermudagrass. It was hypothesized that there was no difference in the photosynthetic efficiency, but the yield differences could be explained by differences in leaf surface presented by the two species. The following functions were considered: (1) leaf area, (2) leaf area index (LAI), (3) net assimilation rate (NAR), (4) leaf-stem ratio (L/S), (5) leaf area-plant weight ratio (LA/Pl. wt.) ratio, and (6) relative growth rate (RGR). Leaf area index has been defined as the leaf area per unit area of land. Net assimilation rate is the rate of increase in total plant weight per unit of assimilating materials. Relative growth rate is the product of NAR and the leaf area-plant weight ratio.

CHAPTER II

LITERATURE REVIEW

Growth analysis has been used by many research workers. It is an analytical method by which dry matter accumulation is related quantitatively to certain plant parameters primarily involving photosynthesis. Gregory (20), Blackman, (9) along with Briggs, Kidd and West (11) suggested the growth analysis technique to study growth and yield by the calculation of growth functions of specific physiological significance from simple measurement of dry weight and leaf area, made at time intervals during the growth period. Gregory (20) was one of the first to analyze quantitatively under controlled conditions, the effect of light and temperature on rate of leaf growth. Leaf area and weight of cucumber were determined during the early vegetative stages. Briggs, Kidd and West (11) studied growth curves of corn, and concluded that quantitative growth analysis could be made by considering relative growth rate, leaf area index and certain other factors.

Watson (47) pointed out that growth analysis technique has some limitations: 1) It depends on the excess dry matter gained by photosynthesis over the loss by respiration, the rate of the last process will influence the NAR. 2) Respiration is a process occurring over all the plant so its relations to NAR will be influenced by leaf area increase. 3) Leaf area is the best, but not a perfect measure of the capacity of the system responsible for dry matter accumulation because photosynthesis is not entirely limited to the leaf lamina. 4) Usually the root system is not recovered and consequently, NAR is underestimated when roots increased in weight or is overestimated when root reserves are translocated to the shoot during the experimental period.

Leaf Area

Leaf area is important in the production of dry matter due to its relationship to light absorption and resultant photosynthesis. If, however, LAI is increased above this point dry matter production decreases due to mutual shading of lower leaves possibly making them parasitic. Also optimum LAI varied with various crops. Dry matter production was affected directly by the LAI. In nearly every case reported, after the optimum LAI was reached maximum production was observed but dry matter production per unit of leaf area decreased as LAI increased from a given suboptimum level.

Romshe (36) found a positive correlation between fresh weight of the leaflets of tomatoes and the leaf area. He concluded that the fresh weights of leaves gave an accurate measure of relative leaf area. Blackman and Rutler (8) used the "trace method" to determine leaf area. Subsamples of leaves were placed between two glass sheets and traced on paper and measured by a planimeter. They found also the length of a leaf times the width corrected by a factor peculiar to the species gave a good estimate of leaf area. Leaf area was determined by Davis (15) for field beans using the center leaflet and measuring length times width with a correction factor. Kemp (25) estimated leaf area of ryegrass, orchardgrass, tall fescue, and timothy by obtaining linear measurements of leaves with the breadth at the mid point of the leaf. He derived the equation for leaf area determination, $A = kLB$; where A is area; k is the constant; L is the length and B is the breadth at the mid point. The k value in his equation was determined to be 0.905.

Brougham (13) found a relationship between light interception and leaf area in the regrowth of pure stands of short-rotation ryegrass, perennial ryegrass, timothy, and white clover, and a mixture of ryegrass and white clover. The critical LAI, at which 95% light interception occurred at midday in midsummer, was 7.1, 7.1, 6.5, and 3.5 and 4.5 for these species, respectively. Percent of incident light penetrating through the foliage was highest at noon and lowest 2 to 3 hours before sunset and after sunrise. In pasture swards dry matter production was almost at a constant maximum rate as LAI values went from 5 to 9.

Stern (41) found that the optimum LAI varied with varying radiations. Work with white clover alone and in mixtures confirmed the existence of an optimum LAI. The optimum LAI increased as the level of radiation increased. It was further noted that at a low LAI, low levels of radiation were as effective as high levels of radiation for maximum growth rates. Stern confirmed the view that the optimum LAI in crops and pastures varies considerably between summer and winter and between cloudy temperate zones and high radiation, tropical areas. In certain plant communities growth will be accelerated as either the leaf area or the radiation moves toward an optimum combination. Conversely growth will decline and even become negative if the radiation falls when the LAI is high or if the LAI is reduced when the radiation is high.

Alexander and McCloud (1), using a CO^2 gas analyzer studied the effects of various clipping regimes and the relation between light saturation and net photosynthesis of detached leaves as compared to photosynthesis in the leaf surface of variously managed communities of bermudagrass. They found that the detached leaves reached saturation at about 2500-3000 foot-candles. Bermudagrass swards with 8 to 14 inches of growth before clipping required 4000-5000 f.c. for light saturation. Growth of 20-26" required more than 7000 f.c. They concluded that rate of dry matter accumulation is the summation of the degree to which the total leaf volume is saturated with light during the growth period and can be altered by management practices. They found LAI values as high as 25 in bermudagrass.

Niciporovic (31) in discussing utilization of incident energy of solar radiation by crops of different structure and the concept of an early attainment of LAI of 3.0 to 3.5 or up to 4 in high radiation conditions, followed by stable values and a final decline when mobile substances can be transferred to economically valuable parts. Excessively high values of LAI of 5.6 or even 10, did not contribute to a greater light absorption.

Pearce, Brown and Blaser (35) studying detached leaves of orchardgrass found light saturation was at 3000 foot-candles compared to 4500 foot-candles for uncut orchardgrass stands with LAI's between 3 and 8. In the solid stand a LAI of 5.5 was optimum and the leaf efficiency was about 4.5 mg. $CO_2/dm^2/hr$. Grass stands intercepted 95% of the light at 15 days regrowth and a LAI of about 5.0. Regrowth was linear from 8 to 30 days after cutting. Both regrowth data and net CO^2 uptake supported the conclusion that LAI's between 3.5 and 8 were near optiminal.

Shibles and Weber (39) experimenting with soybeans concluded that the percent solar radiation interception and rate of dry matter production increased with increasing leaf area development; reached a maximum, and then remained constant with further increases in LAI. Dry matter production was linearly related to per cent light interception. It was further concluded that the lower shaded leaves of the soybean canopy were not "parasitic" upon the production portion of the canopy, and did not, therefore, detract from the net production of the photosynthate by the soybean community.

Leaf area is influenced by many factors as has been shown by the previous discussion. Plant population has an influence on leaf area. Many workers have studied various planting regimes and their effect on leaf area index.

Alexander and McCloud (3) in another study investigated various row spacings with various stubble heights with pearlmillet. With widening rows and more severe cutting the stubble LAI's decreased from 48.0 to 1.2. The low LAI of 1.2 produced more regrowth per unit LAI, thus the optimum stubble LAI for highest rate of regrowth in pearlmillet under these conditions was found to be about 3.0. Efficiency in producing regrowth, however, was still increasing with decreasing LAI. In another experiment on pearlmillet they used a CO_2 gas analyzer to measure CO_2 uptake, which is a good measure of growth or yield of forage. They found the net photosynthetic rate rose rapidly as plant density increased from 3/4 to 2 plants per square foot then remain constant with increased density. However at the highest density of 12 plants per square foot net photosynthetic rate fell sharply to less than that for the lowest density. It was postulated that this pronounced drop in net photosynthesis rate resulted from lower effective LAI through the formation of a top canopy.

Kanda and Sato (27) planted rice in zig-zag hill arrangements and in square hill arrangements. The LAI of the densely planted square arrangements was 9 then declined rapidly to 4.5 during the milk ripe stage. The LAI of the zig-zag planted arrangement reached only 5 and remained so until just before ripening.

Davidson and Donald (14) experimented with subterranean clover at different densities with different defoliation regimes at various dates and found that dry matter production increased to a maximum when LAI was 4 to 5. The rate of dry matter production declined by 30% when the LAI reached 8.7. Leaf production was greatest when LAI was 4 to 5 and approached zero when LAI reached 8.7. Irrespective of densities all swards tended to a common ceiling LAI and yield by the end of the growing season. If swards were defoliated when LAI was near ceiling, dry matter and leaf production increased, but if defoliation was below ceiling the LAI, dry matter and leaf production decreased. They concluded that pastures of optimum LAI will give greater production than swards of lower or higher LAI. Defoliation can greatly increase leaf production unless LAI is kept at a suboptimum.

Grof (21) working with rescuegrass and reed canarygrass in association with ladino clover under irrigation found the highest total daily production increments for rescuegrass and ladino clover were 85, 71, and 56 pounds of dry matter per acre for spring, summer and winter, respectively. Ladino clover reached a maximum rate of growth at a relatively low LAI. The rate of dry matter accumulation remained high until the LAI reached 4, approximately 3 weeks after defoliation, and when approximately 1500 pounds dry matter per acre were present. He reasoned that frequent grazing would give the highest yields for most years.

Hammond and Pendleton (23) used leaf defoliation treatments to study the effect of leaf position of yield of corn, kernel weight, kernel number and protein content of the grain. Removal of the upper leaves drastically reduced yields more than removal of the lower leaves. The removal of any leaf area caused a reduction in grain production but caused an increase grain protein.

Fuess and Tesar (19) working with alfalfa measured net production, leaf area, leaf distribution and light interception under four cutting regimes. They found the LAI reached an average of 5.1 during the first cutting. They concluded that LAI was not a good predictor of yield for alfalfa.

Watson and French (46) attempted to increase yield of kale by thinning the plants to maintain an optimum LAI of 3.5, but because of seasonal variation there was too little or too much thinning causing LAI to vary too much from optimum. A 6% increase of dry matter from thinned stands was obtained over unthinned stands, but thinning was laborious, tedious, and of questionable economic value.

Lambert (29) by the application of nitrogen increased LAI of timothy and meadow fescue, but maximum LAI's were not reached due to the cutting treatments imposed. Timothy swards had a higher LAI than did meadow fescue between April and July. Meadow fescue LAI was above timothy from mid July until October. A maximum LAI of 10.6 was obtained for timothy and 8.8 for fescue. Brougham (12) recorded LAI of 11.7 for timothy and 14.7 for ryegrass and ladino clover with nitrogen fertilization.

Seed size has a direct relation to the leaf area seedling plants and consequently to LAI. Several workers have shown the results of various seed sizes and resultant leaf areas (3, 5, 6). Mick (33) found that the large alfalfa seed produced larger leaf areas than did the small seeded alfalfa. Black (6) found that plants from small seed composed 25% of the leaf area at the first sampling in a mixed sward. The plants were so located as to absorb only 10% of the incident light energy. The leaf area declined to 10 to 20 per cent, respectively, on the last sampling dates. The plants from small seed disappeared because of competition.

Net Assimilation Rate

Net assimilation rate (NAR) was first defined by Gregory (20) as the rate of increase in total plant weight per unit of assimilating material, i.e., leaf-area. Williams (51) stated that net assimilation rate has merit for plant growth analysis only during the phases of growth when carbon assimilation accounts for the bulk of the change in dry weight of the plant. Leaf protein proved more adequate than leaf weight as an index of internal factors for growth.

Heath and Gregory (24) concluded that the differences in NAR between different crops and environments are scarcely greater than those due to seasonal effects alone. They further concluded that all plants in their wide range of environments show practically the same mean NAR during the vegetative stage. NAR was affected by the intensity of external factors of light, temperatures, and CO_2 concentration. Applications of nitrogen did not affect NAR, according to them, which is contrary to the findings of Watson (49).

Watson (47) expressed net assimilation rate (NAR) by the following equation:

$$NAR = \frac{W_2-W_1}{t_2-t_1} \times \frac{\log_e L_2-\log_e L_1}{L_2-L_1}$$

Where W_1 and W_2 are total dry weights per sample
L_1 and L_2 are the leaf areas per sample at times t_1 and t_2

He stated that this formula gives an accurate measure of the mean NAR over an interval of time. The mean value of NAR = $\frac{1}{L} \cdot \frac{dw}{dt}$ if the relationship between weight and leaf area is linear. Results of work by Watson did not confirm the findings of Heath and Gregory (24) that there was little variation between species in NAR. His work showed that four species (sugar beets, wheat, barley and potatoes) differed from each other. He found further that fertilizer application, especially nitrogen, consistently increased NAR. In general, however, the major effects of varied nutrient supply on dry matter production were mainly the result of change in leaf area with variations in NAR of secondary importance.

Blackman and Rutler (8) found that shading to as low as 11% daylight caused little variation in the total leaf-weight per plant, but increased the total leaf area progressively. This increase in leaf area is reflected in the leaf/stem ratio. They observed that NAR was directly proportional to the logarithm of light intensity. They too found that NAR was unaffected by the supply of nitrogen, phosphorus and potash. Watson (49) experimented with five varieties of potatoes and three varieties of sugar beets found that nutrient supply had little affect on NAR, contrary to his earlier findings of wheat, barley and mangolds. In general the nutrient effects were greater on leaf area than on net assimilation rate. According to Watson there is evidence that NAR and LAI are inversely correlated in sugar beets and potatoes. Generally the main source of variation in NAR was from external factors such as temperature, light, etc. He demonstrated that NAR decreased in kale with an increase in LAI, but his determinations were not accurate enough to establish the precise form of the relationship of NAR to LAI.

Kushizaki and Imamura (28) studied growth of potatoes in the greenhouse and found the NAR maximum at the flower-bud development stage and LAI to be a maximum of 2.4 by the end of flowering. Wassink (45) sampled potatoes every 3 to 4 weeks during the growing season and found the solar energy conversion was approximately 5% in June and July and 1 to 2% for the whole growing season. During the season the leaf area/dry weight ratio decreased from 120 to 20 cm^2 per gram dry weight. The LAI was 2.5 to 3.5 and the NAR approximately 7×10^{-4} grams of dry matter per day per square centimeter of leaf surface. Thorne (44) concluded that NAR for barley was related to age of the leaf and was independent of different environments.

Grove (22) working with tall fescue used the formula:

$$NAR = \frac{W_2 - W_1}{1/2(L_1 + L_2)}$$

He assumed that the NAR and LAI were linearly related. He measured NAR as grams of dry matter per square decimeter per week. He further concluded, as many workers have, that dry matter accumulation is dependent on LAI.

Relative Growth Rate

In 1919 Blackman (10) developed a procedure for analyzing growth in terms of dry weight change. He likened the dry weight change to the

process of compound interest, the increment produced in any interval adding to the "capital" for growth in subsequent periods. The interest rate can be shown by the following formula: $W_1 = W_o e^{rt}$
Where W_1 = the final weight, W_o = the initial weight, r = the rate of interest, and t = time, e is the base of the natural logrithum. Blackman described r, the rate of interest, as the efficiency index of dry weight production. A large efficiency index plus large seeds are needed for the highest production of vegetative materials by a single plant.

Fisher (18) showed that if W_1 and W_2 are the total dry weights at t_1 and t_2 respectively, the mean value of relative growth rate for the time interval $t_2 - t_1$, is given by $\frac{(\log_e W_2 - \log_e W_1)}{t_2 - t_1}$ whatever the form of growth curve. Briggs, Kidd and West (11) suggested the relative growth rate was the product of the NAR and the ratio of total leaf area to total plant weight at any instant.

Duncan (16) found that relative growth rate could be calculated from the equation: $W = Ke^{(P-R)T}$ where W = dry weight
K = a constant related to seed size
P = the rate of photosynthesis
R = the rate of respiration
e = the base of the natural log.

All of the terms may be evaluated by obtaining the dry weight of the plants at two different times. Photosynthesis less respiration is the relative growth rate. These data were obtained from millet.

Grove (22) used the equation:

$$RGR = \frac{W_2 - W_1}{1/2(W_1 + W_2)}$$

to calculate relative growth rate in tall fescue. Growth efficiency was estimated from the increase in dry weight of the tops and expressed as NAR and RGR. Whitehead and Myerscough (50) investigating several species found that the ratio of mean RGR to mean relative rate of leaf area has merit of biological importance and can be used to make accurate determinations of the mean unit leaf rate, i.e., NAR. Muromato, Hesketh, Sharkwy and Ahmed (34) found that dry matter accumulation varied little among cotton varieties. Differences in vigor or RGR were associated with differences in rate of leaf area development.

Tillering

Tillering in some crops may be an important factor to help increase yield, by increasing the LAI and number of heads on the plant.

Stospopf, Reinbergs and Tanner (42) studying tillering in spring cereals found that tillering rate was influenced by variety, seeding rate, date and fertility. They indicated that tillering may reduce yield due to excessive shading. They agreed that maximum production in spring cereals per acre may involve a controlled population with the optimum LAI coinciding with anthesis. Langer (30) suggested factors that effect tillering are: genotype, temperature, light intensity, and water supply.

Taylor and Templeton (43) found orchardgrass seeded in September developed 3 to 4 primary tillers per seedling by November. The quick recovery of orchardgrass after cutting appears due primarily to the rapid growth rate of the young leaves of the large non-inducted tillers. Rudzits (37) found the number of tillers was greater in red fescue than perennial ryegrass. The tillers in the fescue were greatest in May and October, in ryegrass in May and September. In general there were more tillers at the end of the growing season than at the beginning.

The weather influenced the number.

Tillering in pasture swards is important in order to have an adequate LAI for light interception and maximum production and for fast plant recovery and regrowth.

CHAPTER III

METHODS AND MATERIALS

Field Experiments

The objective of this investigation was to compare dry matter production of native grass and bermudagrass under the same edaphic and climatic conditions and relate production to the factors used in the "growth analysis" of the grasses. Factors considered in the analysis were leaf area, LAI, NAR, relative growth rate, leaf-stem ratio and leaf area-weight ratio.

Bermudagrass (Cynodon dactylon, variety common) plots 12' x 16' were established April 20, 1965, at random in a well established native grass pasture seven miles west of Stillwater, Oklahoma. Plots of the same size, in a uniform stand native grass, and in the natural native condition, were randomly arranged among the bermudagrass plots. Little bluestem (Andropogon scoparius) made up 59% and Indiangrass (Sorghastrum nutans) 8% of the total plant composition of the native plant species with the remaining 33% consisting of miscellaneous grasses and weeds.

The plots for the bermudagrass were established by first removing the native sod to a depth of two to three inches and then transferring bermudagrass sod immediately to the prepared area. At the time of sodding the bermudagrass the air temperature was 92°F with the south wind of thirty miles per hour which had a severe drying effect on the bermudagrass plots. Water was supplied by hand to prevent complete drying of the bermudagrass sods. A sudden weather change occurred on April 25; the temperature dropped to 32°F and frost damaged both the native grass and the bermudagrass plots.

An application of 200 pounds of 25-25-0 was made to all plots to supply adequate plant nutrients during establishment. Two pounds of 2-4-D amine per acre were applied to all plots to control undesirable weed species. After establishment an application of 150 pounds of 33-0-0 was applied annually.

At two-week intervals starting May 25, 1965 and 1966, two 4.5 sq. ft. subplots from the native grass plots and one 4.5 sq. ft. subplot from the bermudagrass plots were harvested for determination of dry matter production from undisturbed areas within each plot. Subsamples of twenty stems from each subplot also were collected for "growth analysis" determinations.

Leaf area was determined by the photometric method. The photometer was calibrated for the four native species and bermudagrass (Figures 1, 2, 3, 4, and 5). Leaves were placed between two glass sheets on an area of 100 cm^2 and the reading was taken until all the leaves were removed. These readings were then fitted by regression so that the leaf area could be readily determined at each harvest simply by placing leaves on the photometer, getting a dial reading and determining the area from the graph.

Leaf area, LAI, NAR, leaf to stem ratio, leaf area to dry weight ratio and relative growth rate were calculated from the samples collected.

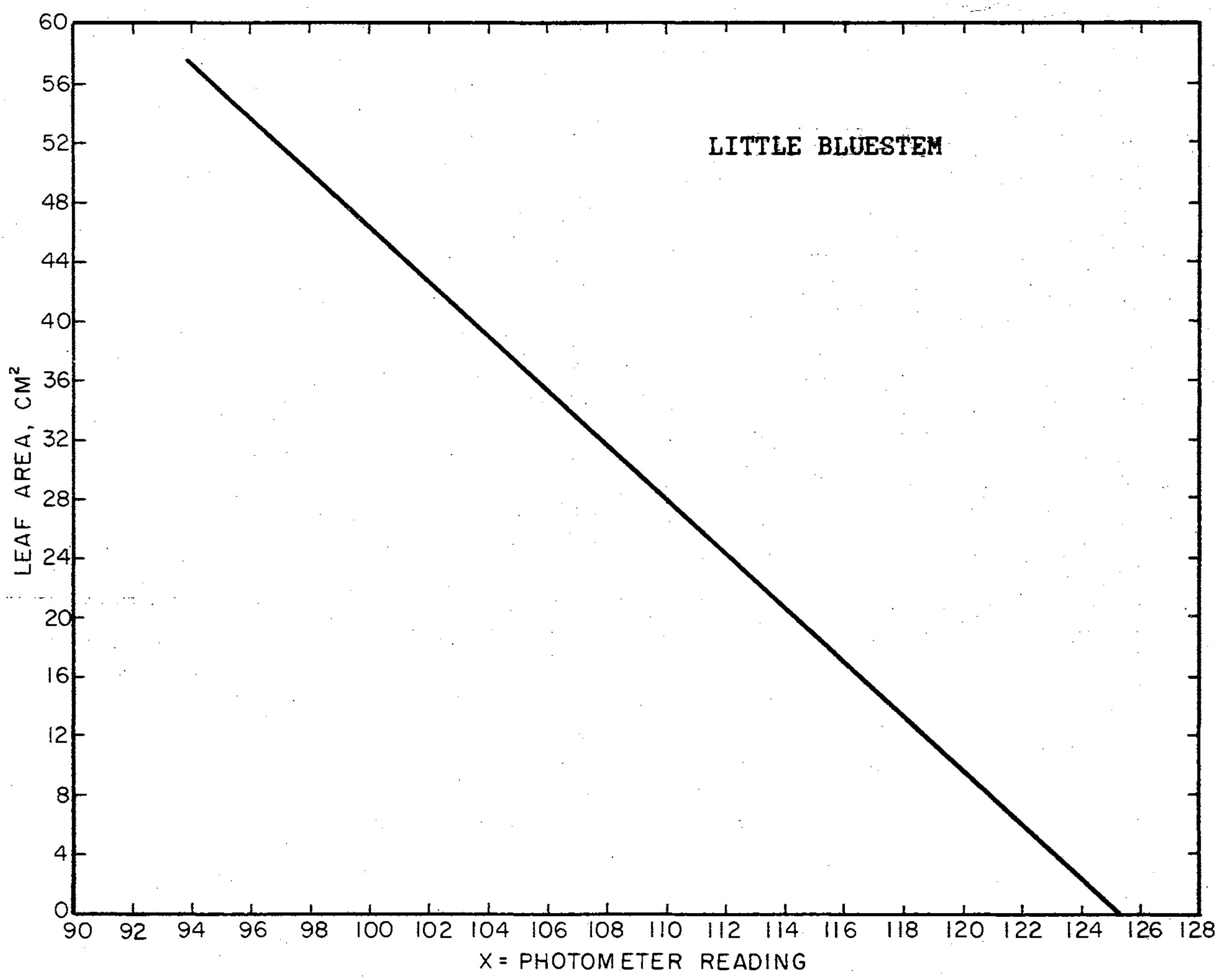

Figure 1. Regression for Photometer Reading for Leaf Area Determination for Little Bluestem.

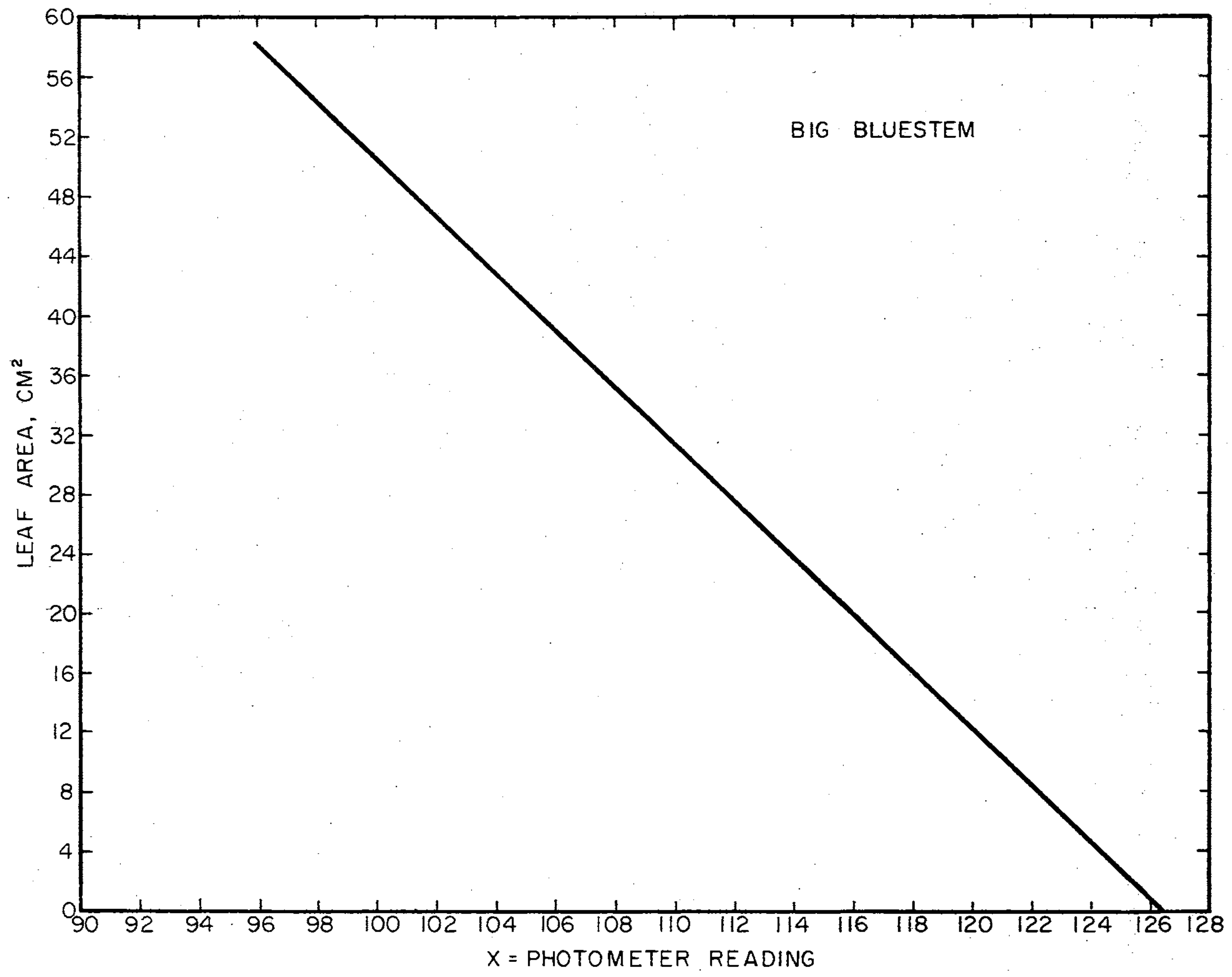

Figure 2. Regression for Photometer Reading for Leaf Area Determination for Big Bluestem.

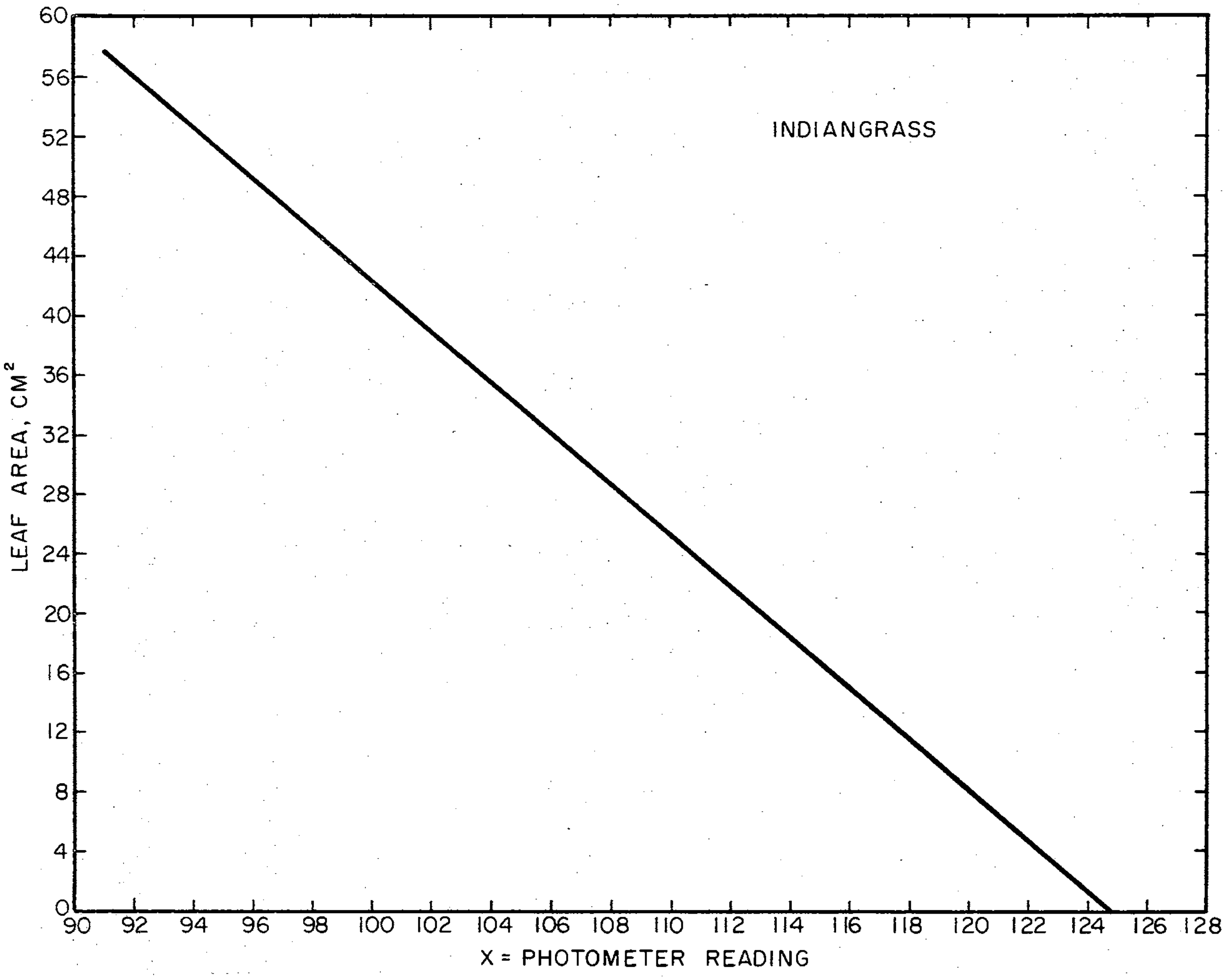

Figure 3. Regression for Photometer Reading for Leaf Area Determination for Indiangrass.

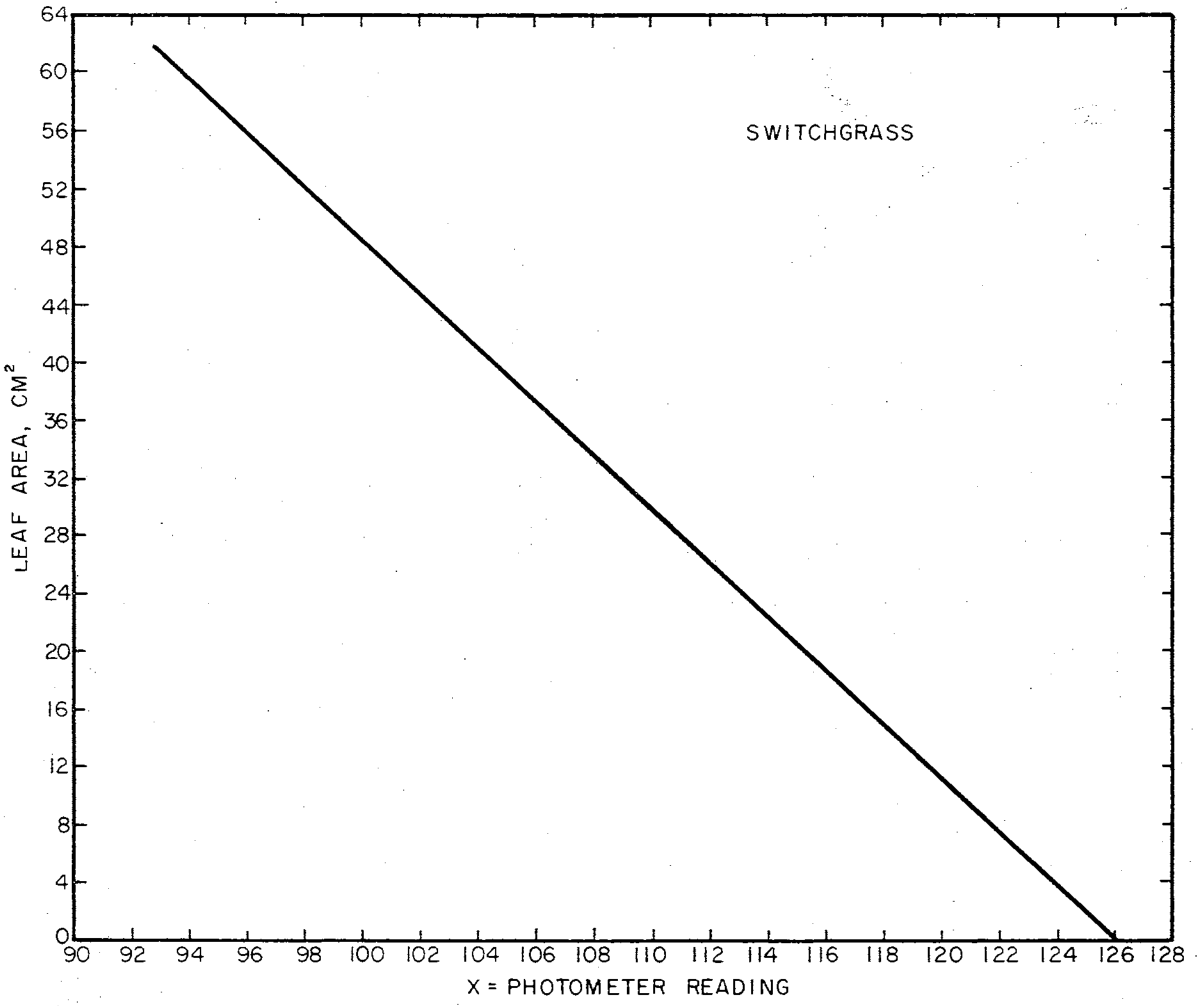

Figure 4. Regression for Photometer Reading for Leaf Area Determination for Switchgrass.

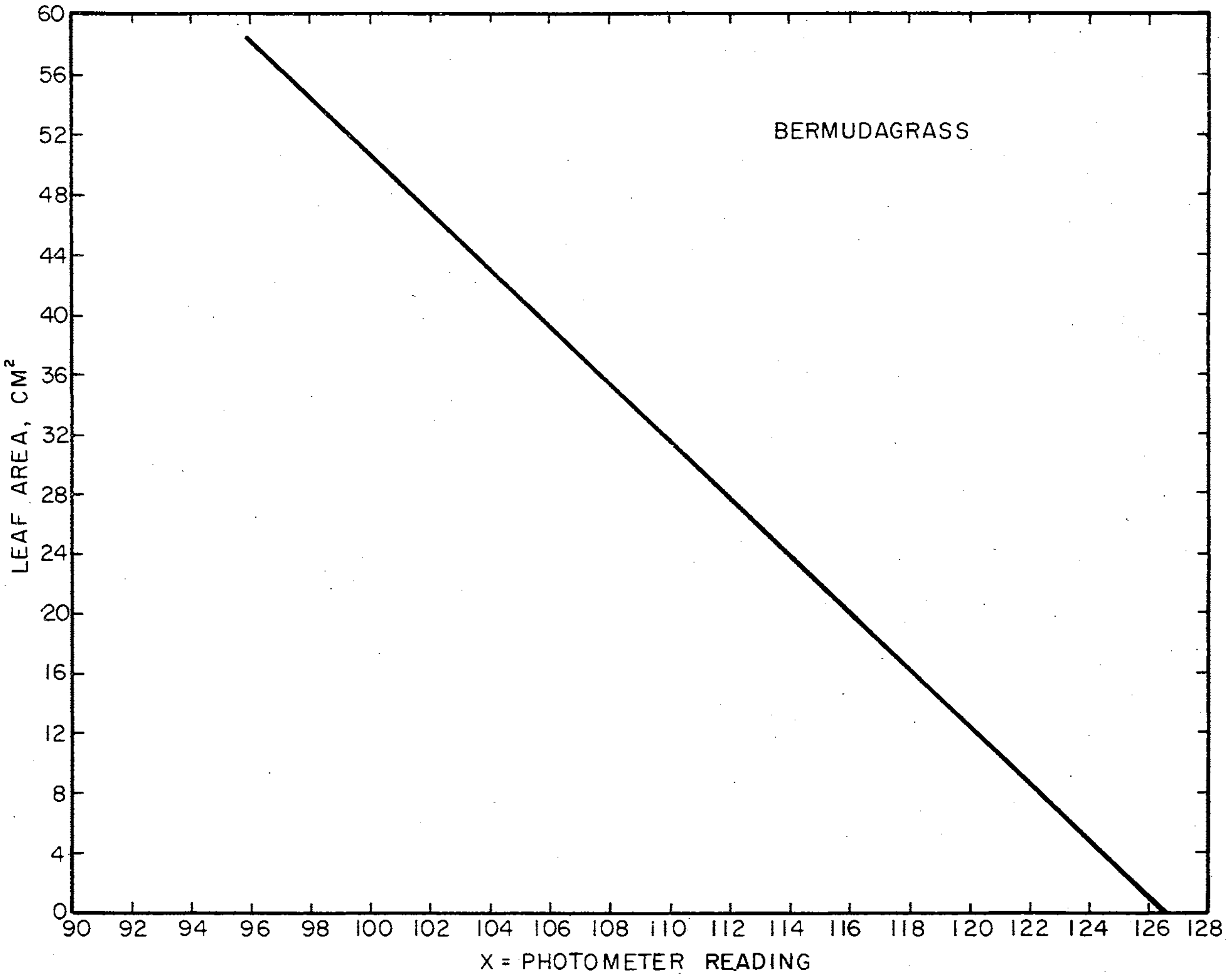

Figure 5. Regression for Photometer Reading for Leaf Area Determination for Bermudagrass.

Greenhouse Study

The objective of the greenhouse experiment was to study the comparative development of native grass species and bermudagrass as related to tillering, leaf area, plant weight, leaf-stem ratio, leaf area-dry weight ratio under two light regimes.

Fleshy viable rhizomes of four native grass species and of common bermudagrass were selected from a well established native meadow and from a bermudagrass pasture, respectively, and planted in 4" plastic pots containing four hundred grams of a fertile Norge fine sandy loam soil. A total of 240 pots were planted; 120 were selected at random and placed under 12 hours of Gro-lux light and 120 were placed under 16 hours of Gro-lux light. Pots were watered to maintain sufficient moisture. The greenhouse was manually controlled for temperature and humidity.

The leaf area was determined by the photometer method described in the field experiment part of this paper. Each clipping was oven dried at 100°C for 36 hours and weight recorded in grams for dry weight determinations.

Starting on February 9, 1966 four plots of each treatment were harvested at two-week intervals of clipping and entire growth accumulated between planting and the harvest date. Harvested pots were removed from the experiment. The first clipping was made 41 days after planting. Six clipping dates were employed and the growth analyzed.

Growth Chamber Experiment I

The objective of this experiment was to study the comparative development of native grass species and bermudagrass as related to leaf area, dry weight accumulation, plant height, tillering, leaf area to weight ratio and leaf weight to stem weight ratio under controlled environmental conditions.

On November 7, 1965, 25 pre-germinated seeds of the four native grass species (Andropogon gerardi, Sorghastrum nutans, Panicum virgatum, and Andropogon scoparius) and common bermudagrass (Cynodon dactylon) were each planted in quadruplicate in 4 inch plastic pots containing 400 grams of Norge fine sandy loam soil. Each species occurred 6 times in each of 4 replicates to permit 6 harvest intervals. The seed were germinated by the "rag doll" method and only well germinated seed were used to insure a good stand of all species. The seedlings were thinned to 10 plants per pot on December 18, 1965.

All pots of grass seedlings were placed in a Sherer chest type growth chamber immediately after planting. The day temperature was held to 90°F while the night time temperature was constant at 70°F. Light intensity was constant at 2400 f.c. for 16 hours. The plants were watered at frequent intervals to insure adequate moisture for proper growth.

The first harvest was made 29 days after planting and was continued at two-week intervals until 6 harvests were completed to determine the growth accumulation from planting to harvest. Each harvest was oven dried at 100°C for 36 hours and weights were recorded. Growth analysis was made as described in the field experiment.

Growth Chamber Experiment II

The objective of this investigation was to study the comparative development of native grass species and bermudagrass as related to leaf area, leaf area to leaf weight ratio, leaf weight to stem weight ratio and dry weight accumulation under controlled environmental conditions and two fertility levels.

On February 16, 1966, 25 pre-germinated seeds of four native grass species (Andropogon gererdi, Sorghastrum nutans, Panicum virgatum, and Andropogon scoparius) and bermudagrass (Cynodon dactylon) were planted in quadruplicates in 4 inch plastic pots containing about 400 grams of Bowie fine sandy loam soil. Each species occurred 6 times in each fertility level of 4 replicates to permit 6 harvest intervals.

All pots containing the seedlings were placed in a Sherer chest type growth chamber immediately after planting. The day temperature was maintained at 90°F and 70°F for the nighttime temperature. The light intensity was constant at 2400 f.c. for 16 hours per day. The plants were watered at frequent intervals to insure adequate moisture for normal growth.

After two weeks of growth one-half of the seedlings received 100 lbs. nitrogen and 80 pounds of phosphorus per acre. The nutrient solution was added at two-week intervals to maintain a high level of fertility in order to study its effect on growth.

The first harvest was 31 days after planting and at two-week intervals thereafter until three harvests were completed. Each harvest was oven dried at 100°C for 36 hours. Growth analysis was made as described in the field experiment.

CHAPTER IV

RESULTS

Growth Chamber Experiment I

The mean dry matter production from the five species for over all harvest dates are shown in Table I and Figure 6. The mean dry matter production over all harvest dates ranked from high to low as follows: big bluestem, bermudagrass, Indiangrass, switchgrass and little bluestem. Differences between species were significant at the 1% level (Table XVIII, Appendix A). Dry matter produced from all species increased linearly through the first four harvests but tended to be erratic thereafter probably reflecting nutrient deficiencies. Big bluestem was consistently more productive than the other species for the first four harvest dates. Bermudagrass was most productive for the fifth and sixth harvest dates. There was interaction between dates and species, significant at the 5% level (Table XXIII, Appendix A). It is interesting to note that mean production for all harvests of big bluestem and bermudagrass were of comparable production. Little bluestem was consistently the lowest producer of all the species for the first four harvests. Indiangrass tended to be intermediate in dry matter production and more productive than switchgrass throughout the experiment.

Leaf area, leaf weight and LAI expressed as average for four pots for all species are given in Table II, III, and IV and Figures 7 and 8.

The leaf area for the species ranked from high to low as follows: big bluestem, bermudagrass, switchgrass, Indiangrass and little bluestem. Bermudagrass ranked second in leaf area, but was last in leaf weight indicating a large surface per unit weight of leaf. Big bluestem consistently produced the highest leaf area and weight for the first five harvest dates, but on the sixth harvest date bermudagrass exceeded big bluestem in leaf area by 27%. For the first four clipping dates little bluestem was distinctly lower in leaf area and leaf weight than the other species. Differences in leaf weight and leaf area as shown in Tables XIX and XX, Appendix A, were significant at the 1% level. Interaction between dates and species was also highly significant arising primarily from the change in position of big bluestem and bermudagrass at the sixth harvest date. Differences in plant height (Table V) were significant and tended to follow the dry matter production as well as the leaf weight and leaf area pattern over the harvest period.

TABLE I

MEAN PLANT DRY WEIGHT IN GRAMS OF 5 GRASS SPECIES AT 6 CLIPPING DATES
GROWTH CHAMBER EXPERIMENT I

	Harvest						
Species	1	2	3	4	5	6	Mean
Big Bluestem	.14	.41	.73	.66	.77	.77	.58
Indiangrass	.11	.30	.49	.54	.70	.72	.48
Switchgrass	.06	.27	.47	.63	.60	.66	.45
Little Bluestem	.03	.10	.37	.50	.72	.73	.41
Bermudagrass	.03	.24	.48	.60	.99	.89	.54

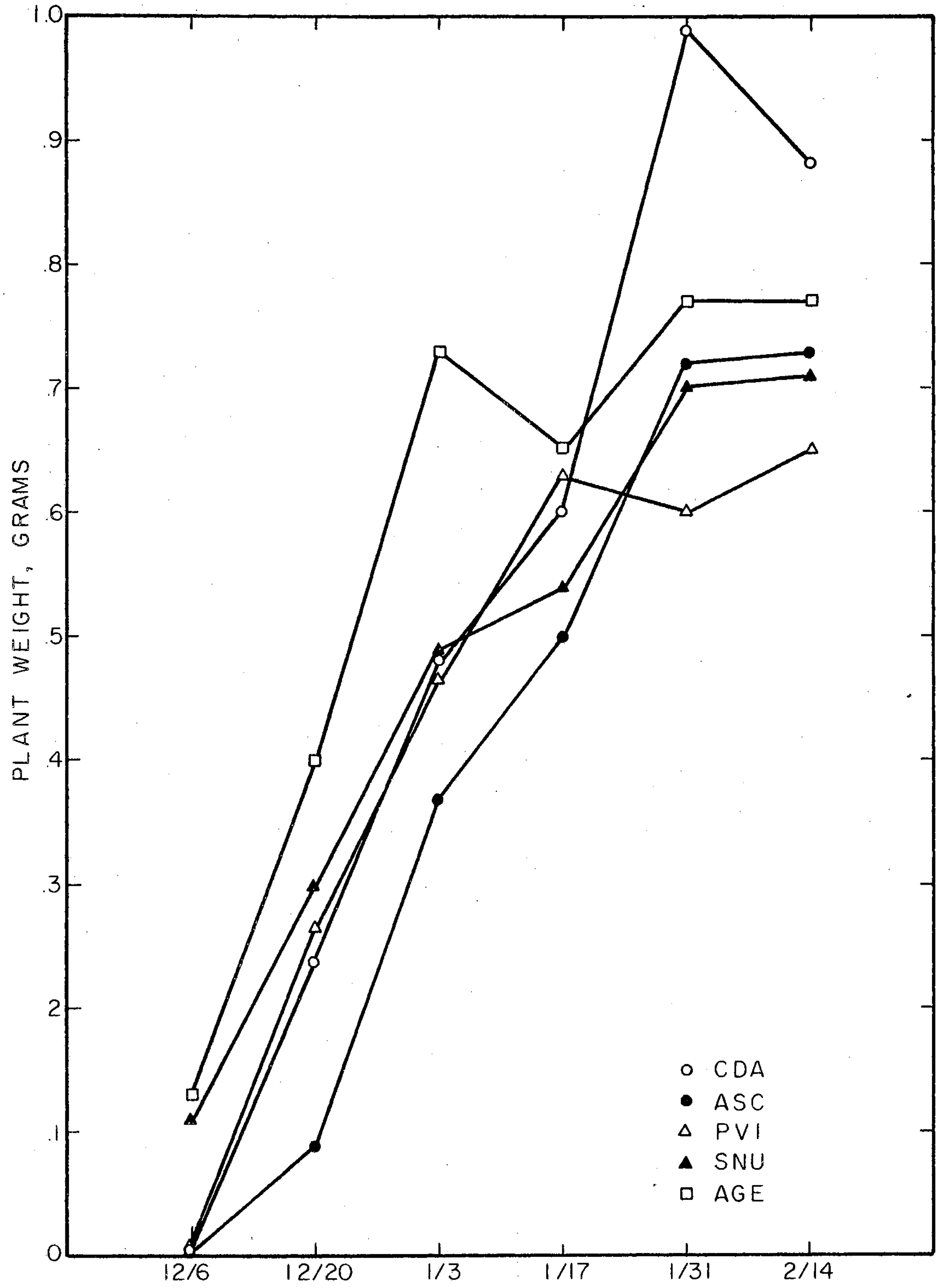

Figure 6. Plant Weight in Grams for Six Harvests of Four Native Grasses and Bermudagrass. Growth Chamber Experiment I.

TABLE II

MEAN LEAF AREA IN CM^2 OF 5 GRASS SPECIES AT 6 CLIPPING DATES IN GROWTH CHAMBER EXPERIMENT 1

	Harvests						
Species	1	2	3	4	5	6	Mean
Big Bluestem	60.1	101.6	103.5	110.3	130.6	77.2	97.2
Indiangrass	45.6	57.9	56.0	95.9	94.6	79.2	71.5
Switchgrass	37.1	82.3	76.3	105.1	88.6	83.9	78.9
Little Bluestem	12.4	21.2	36.0	74.2	95.9	96.1	55.9
Bermudagrass	22.8	99.4	89.6	103.3	123.4	105.6	90.7

TABLE III

MEAN LEAF WEIGHT IN GRAMS OF 5 GRASS SPECIES AT 6 CLIPPING DATES IN GROWTH CHAMBER EXPERIMENT 1

	Harvests						
Species	1	2	3	4	5	6	Mean
Big Bluestem	.01	.029	.051	.045	.054	.042	.038
Indiangrass	.008	.220	.037	.040	.055	.048	.035
Switchgrass	.004	.018	.030	.036	.035	.035	.026
Little Bluestem	.002	.007	.027	.036	.054	.048	.029
Bermudagrass	.003	.014	.028	.027	.044	.041	.026

TABLE IV

LEAF AREA INDEX FOR 5 GRASS SPECIES FOR GROWTH CHAMBER EXPERIMENT 1

Species	Harvests 1	2	3	4	5	6	Mean
Big Bluestem	.6	1.0	1.0	1.1	1.3	.8	.96
Indiangrass	.4	.6	.5	.9	1.1	.8	.71
Switchgrass	.4	.8	.7	1.0	.9	.8	.70
Little Bluestem	.1	.2	.3	.7	.9	.9	.50
Bermudagrass	.2	1.0	1.0	1.0	1.2	1.0	.90

TABLE V

MEAN PLANT HEIGHT IN CM OF 5 GRASS SPECIES AT 6 CLIPPING DATES IN GROWTH CHAMBER EXPERIMENT 1

Species	Harvests 1	2	3	4	5	6	Mean
Big Bluestem	13.5	24.3	28.0	23.7	23.3	25.0	22.96
Indiangrass	13.8	20.0	20.5	16.3	16.5	11.5	16.42
Switchgrass	9.0	22.3	22.8	23.8	22.5	23.5	20.63
Little Bluestem	6.3	13.5	17.8	18.5	17.5	13.5	14.50
Bermudagrass	5.5	21.5	21.5	24.3	26.2	21.8	20.13

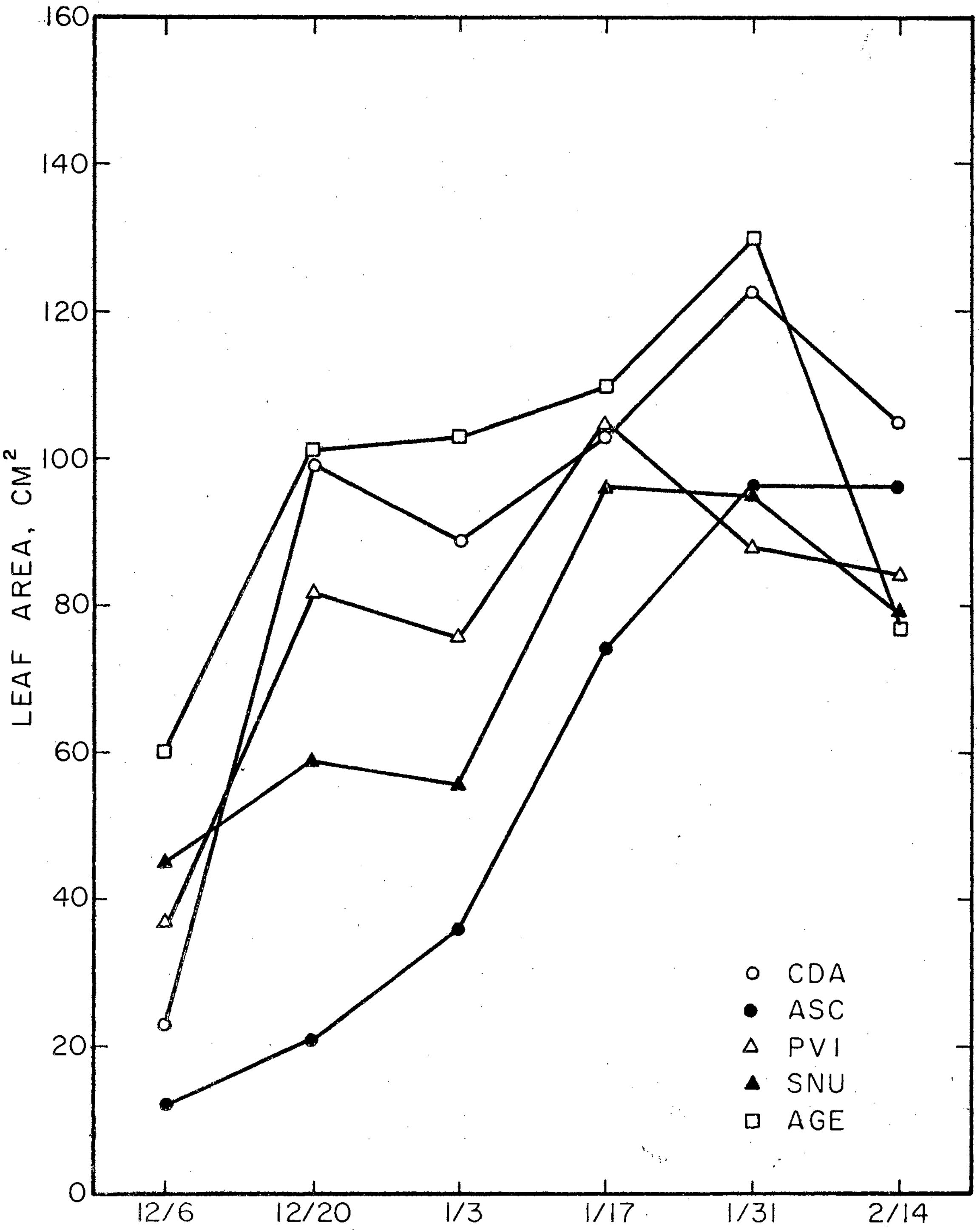

Figure 7. Leaf Area in CM^2 for Six Harvests for Four Native Grasses and Bermudagrass. Growth Chamber Experiment I.

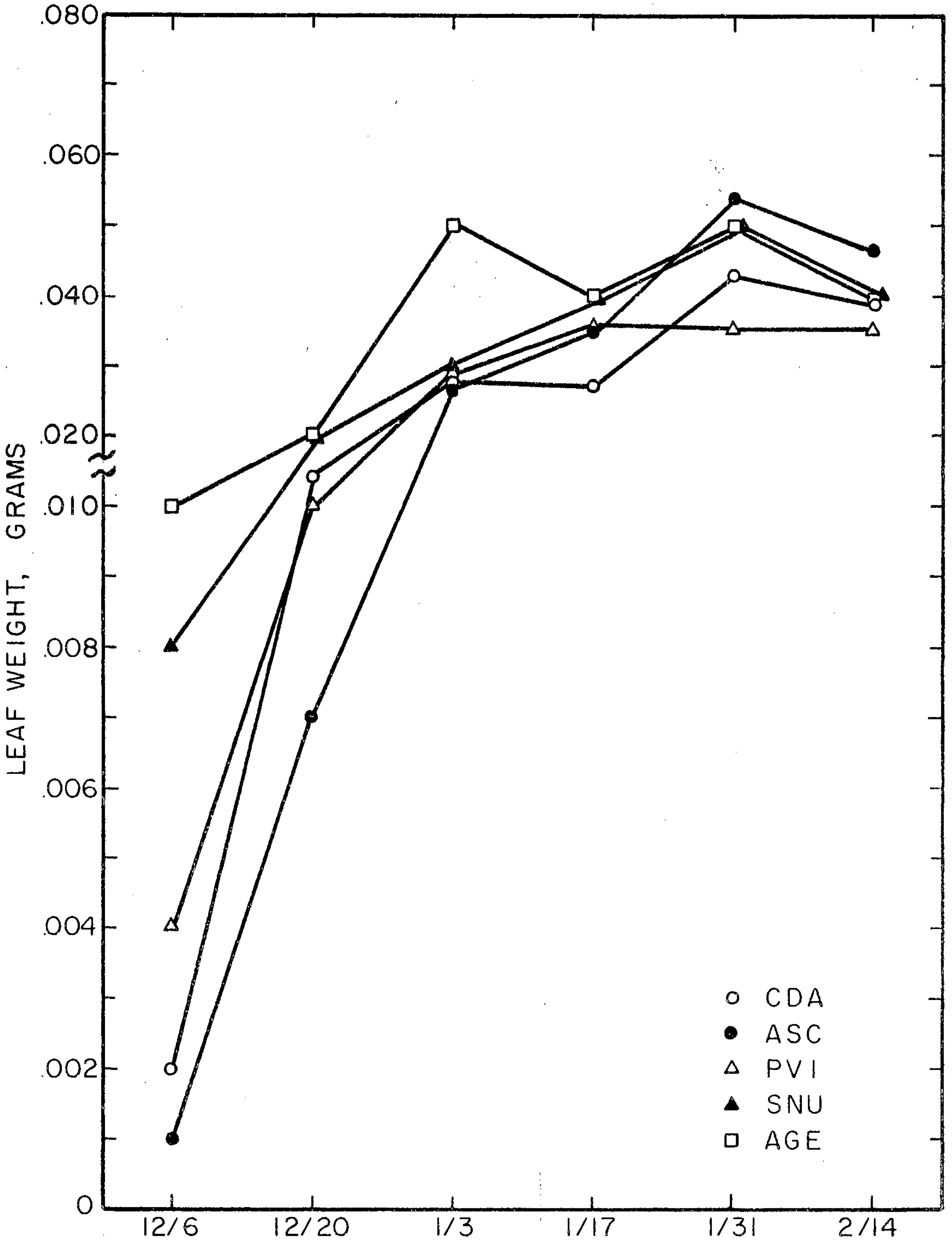

Figure 8. Leaf Weight in Grams for Six Harvests for Four Native Grasses and Bermudagrass. Growth Chamber Experiment I.

Stem weights tended toward an inverse relationship to leaf/stem ratios as can be seen in Tables VI and VII and Figures 9 and 10. Weight of stems for the species ranked from high to low as follows: bermudagrass, big bluestem, switchgrass, Indiangrass and little bluestem. Big bluestem had the greatest stem weights for the first three harvests, with bermudagrass producing the highest stem weights for the last three harvest dates. Indiangrass and little bluestem produced about the same stem weights from the third to the sixth harvest. Differences between species were significant for both stem weight and leaf/stem ratio at the 1% level. Interaction between dates and species was significant due primarily to the shift in stem weight of bermudagrass and big bluestem on the fifth and sixth harvest dates.

TABLE VI

MEAN STEM WEIGHT IN GRAMS OF 5 GRASS SPECIES AT 6 CLIPPING DATES IN GROWTH CHAMBER EXPERIMENT 1

Species	Harvests 1	2	3	4	5	6	Mean
Big Bluestem	.035	.120	.223	.205	.230	.340	.192
Indiangrass	.035	.078	.123	.145	.155	.233	.128
Switchgrass	.015	.093	.175	.270	.250	.303	.184
Little Bluestem	.006	.028	.100	.148	.178	.250	.118
Bermudagrass	.008	.100	.198	.325	.555	.480	.278

Table VIII and Figure 11 gives data on the mean leaf area to plant weight ratio. In descending order the species rank: bermudagrass, switchgrass, big bluestem, little bluestem and Indiangrass. All species tend to decrease in leaf area to total plant weight from the first to the last harvest. Bermudagrass tended to decline at a more rapid rate with switchgrass next. This tendency is indictative of the rapid stem development in proportion to the total plant weight of these two species. Big bluestem and little bluestem presented the same trend in leaf area to plant weight ratio while Indiangrass declined at the slowest rate.

TABLE VII

MEAN LEAF WT/STEM WT RATIO OF 5 GRASS SPECIES AT 6 CLIPPING DATES IN GROWTH CHAMBER EXPERIMENT 1

Species	Harvests 1	2	3	4	5	6	Mean
Big Bluestem	.293	.238	.257	.224	.245	.203	.243
Indiangrass	.227	.284	.302	.283	.359	.222	.279
Switchgrass	.287	.194	.179	.138	.141	.128	.178
Little Bluestem	.258	.252	.277	.247	.309	.222	.291
Bermudagrass	.354	.158	.145	.082	.085	.085	.152

TABLE VIII

MEAN LA/PLANT WT RATIO OF 5 GRASS SPECIES OF 6 CLIPPING DATES IN GROWTH CHAMBER EXPERIMENT 1

Species	Harvests 1	2	3	4	5	6	Mean
Big Bluestem	427	253	141	165	174	106	211
Indiangrass	402	204	115	175	135	112	190
Switchgrass	679	300	164	167	148	131	265
Little Bluestem	495	248	98	148	137	133	210
Bermudagrass	699	459	183	172	122	117	292

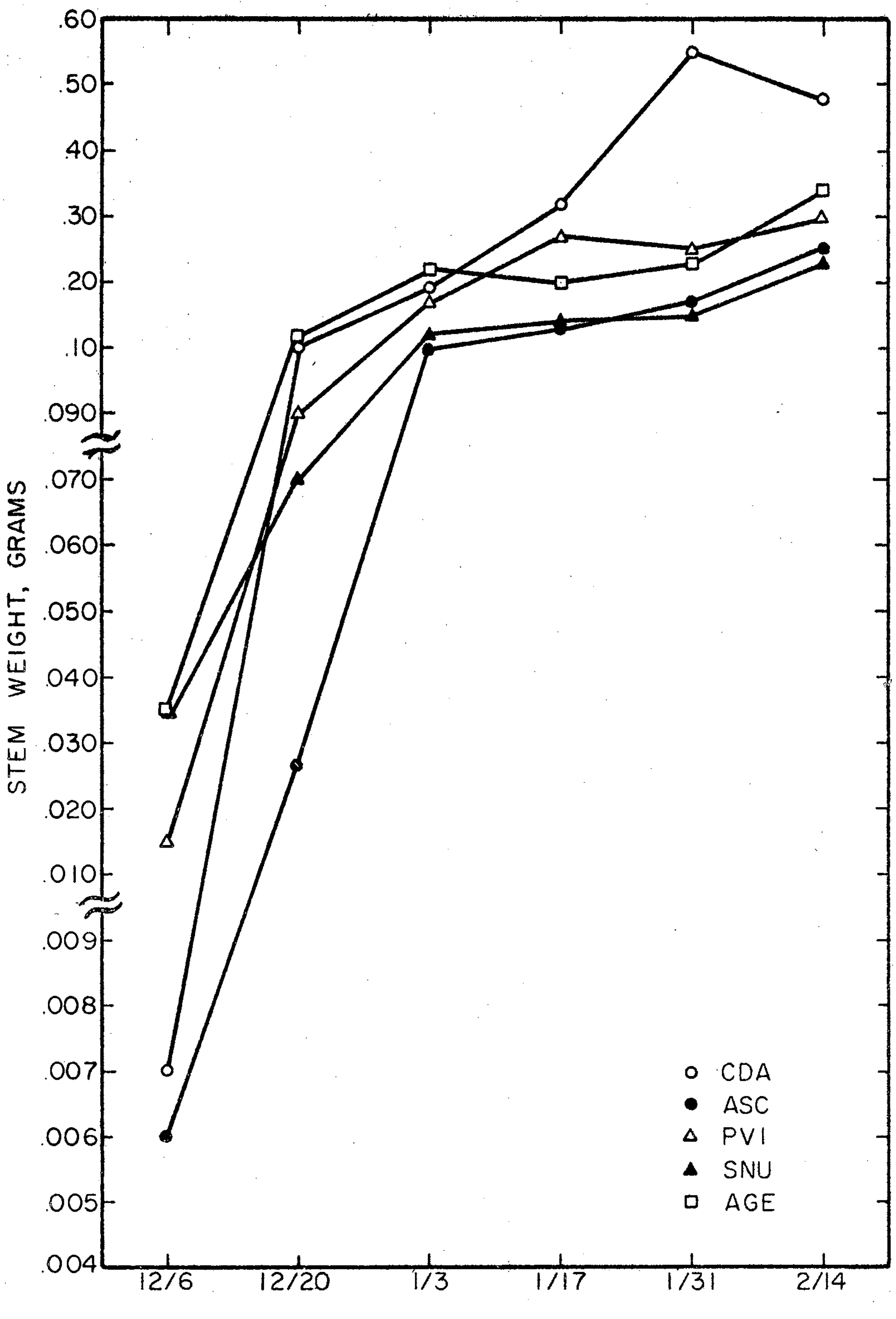

Figure 9. Stem Weight in Grams for Six Harvests for Four Native Grasses and Bermudagrass. Growth Chamber Experiment I.

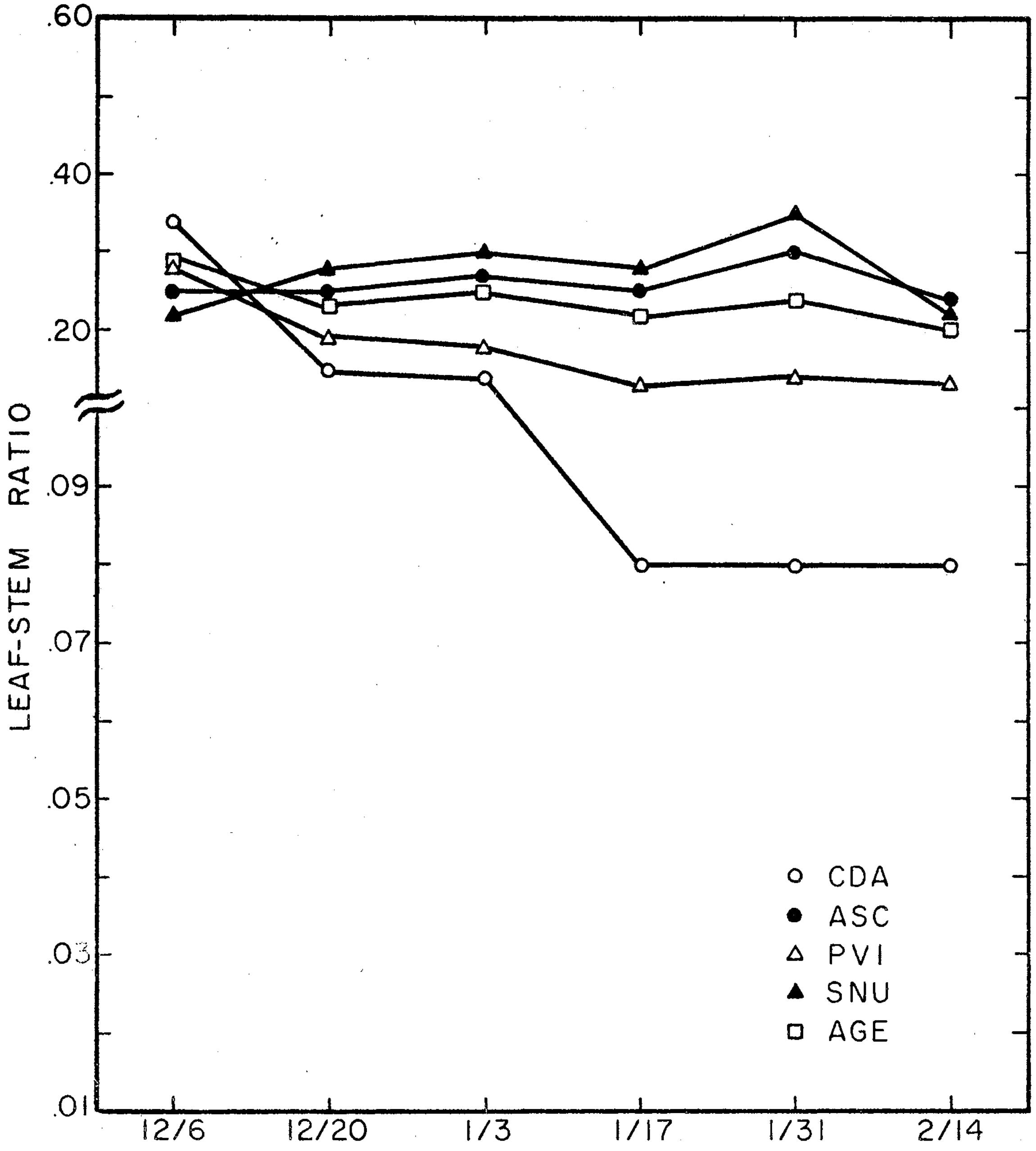

Figure 10. Leaf/Stem Ratio for Six Harvests for Four Native Grass Species and Bermudagrass. Growth Chamber Experiment I.

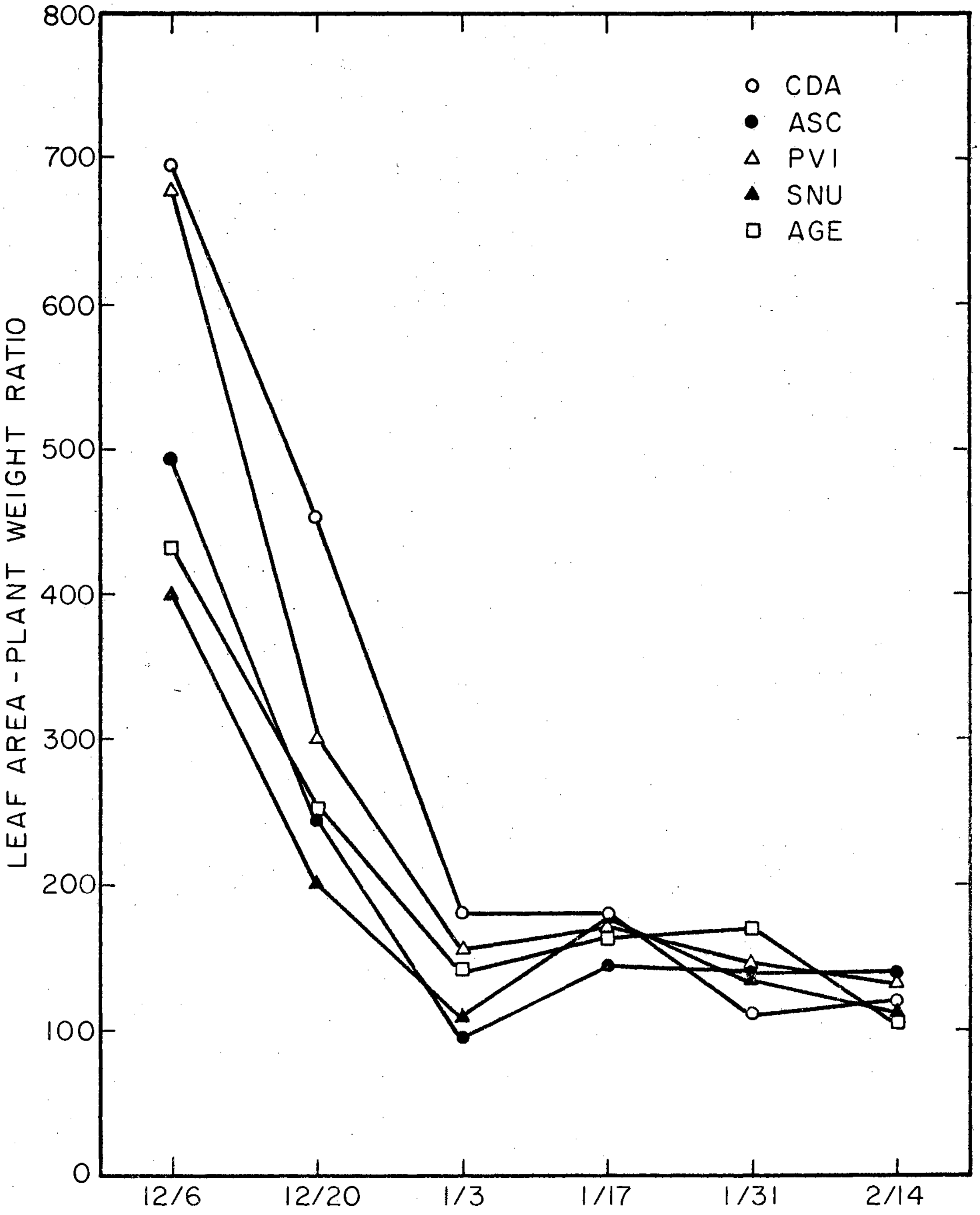

Figure 11. Leaf Area/Plant Weight Ratio for Six Harvests for Four Native Grasses and Bermudagrass. Growth Chamber Experiment I.

A LAI of 1.0 was reached by the second harvest date by big bluestem and bermudagrass and remained at about 1.0 throughout the entire experimental period. Indiangrass and switchgrass tended to increase in LAI from the first to the last clipping date, but they obtained a LAI of 1.0 on the fourth date. Little bluestem gradually increased LAI until a maximum of .9 was obtained at the fifth and sixth harvest dates. LAI values were not analyzed statistically.

The relative growth rates for all species decreased from the first to the last harvest but were erratic. Bermudagrass tended to show a higher relative growth rate (Figure 12).

NAR (Table IX) for all species generally declined with advancement of maturity but differences between species were erratic and inconclusive. Little bluestem increased in NAR at the second and fourth dates. There was a tendency for all other species to decline to about the same degree.

TABLE IX

NAR FOR 5 SPECIES FOR 6 CLIPPING DATES
GROWTH CHAMBER EXPERIMENT 1

	NAR (g./dm^2/wk.)				
Species	1	2	3	4	5
Big Bluestem	0.34	0.32	0.04	0.09	0.001
Indiangrass	0.28	0.27	0.07	0.28	0.020
Switchgrass	0.35	0.25	0.17	0.03	0.050
Little Bluestem	0.18	0.60	0.25	0.34	0.001
Bermudagrass	0.27	0.25	0.12	0.34	0.880

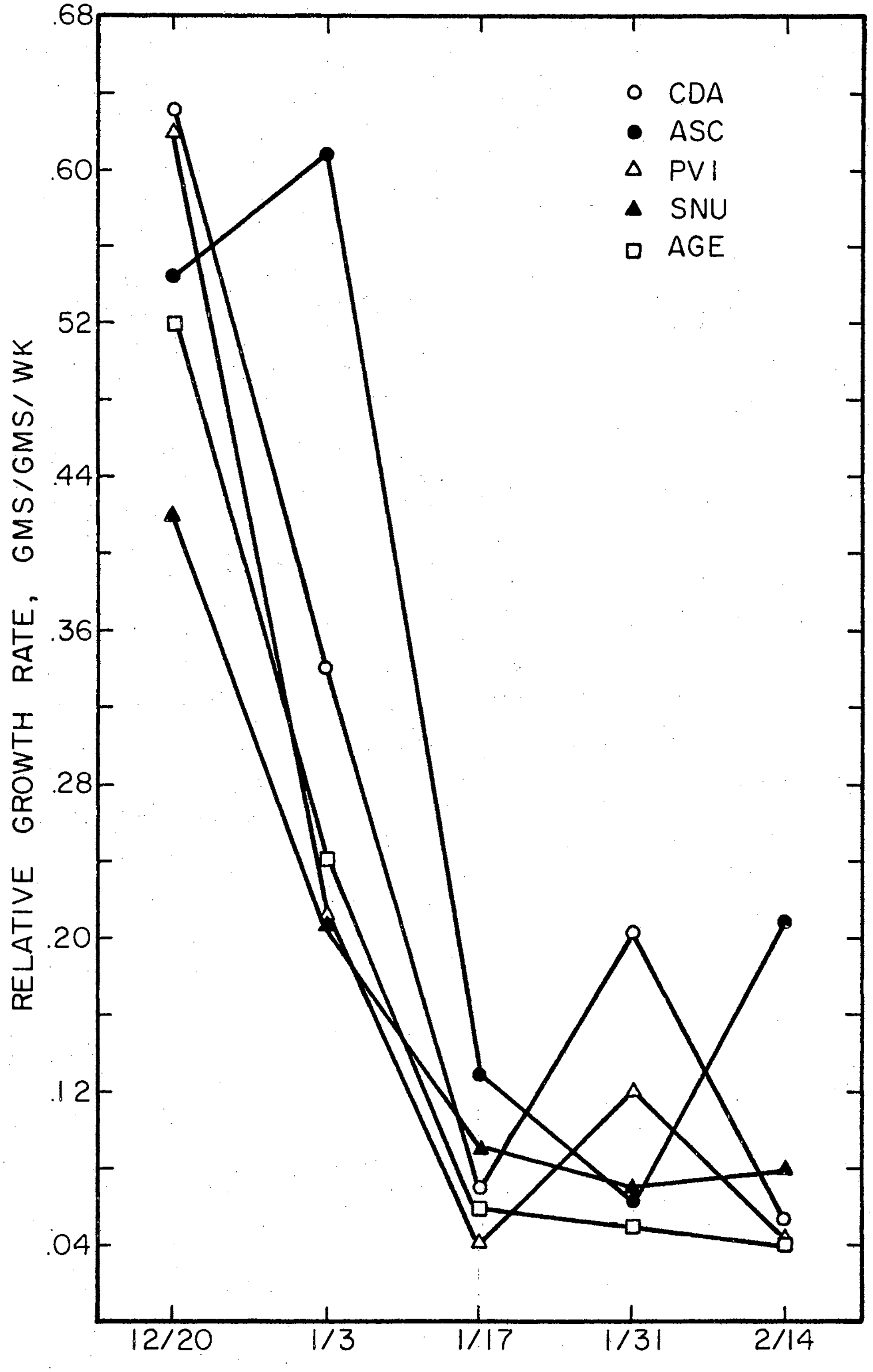

Figure 12. Relative Growth Rate for Six Harvests for Four Native Grasses and Bermudagrass. Growth Chamber Experiment I.

Growth Chamber Experiment II

The mean dry weight with two fertility levels for five grass species is shown in Table X and Figure 13. Ranked in descending order dry matter production with fertilizer addition from the five species was: bermudagrass, big bluestem, switchgrass, Indiangrass and little bluestem. The rank in production changed with no nutrients added as follows: big bluestem, switchgrass, Indiangrass, bermudagrass and little bluestem. It is quite noticeable that little bluestem ranks last at both fertility levels. Big bluestem produced the most dry matter on the first clipping date with fertilizer, switchgrass was second and bermudagrass third. By the second and third harvests bermudagrass produced more dry matter than the other species. Differences between species were significant at the 1% level. Interaction between species and dates, species and fertilizer treatments, and dates and fertilizer treatments were significant at the 1% level (Table XXV Appendix A). Under low fertility big bluestem produced more dry matter on the first and second harvest, but was third to Indiangrass and switchgrass on the final harvest. With high fertility, bermudagrass consistantly produced the most dry matter except for the first harvest which probably resulted from the small seed size. Conversely, bermudagrass ranked near the bottom at all harvests under low fertility.

The mean leaf weight was greatly influenced by soil amendments as is noted in Table XI and Figure 14. Big bluestem and bermudagrass rank first and second, respectively, in leaf weight with switchgrass and Indiangrass third and fourth and little bluestem last. Species were significant at the 1% level. The interaction between leaf weight and harvest dates was significant at the 1% level (Table XXVII, Appendix A).

TABLE X

MEAN DRY WEIGHT IN GRAMS OF 5 GRASS SPECIES WITH AND WITHOUT FERTILIZER FOR 3 CLIPPINGS GROWTH CHAMBER EXPERIMENT II

	Harvests							
	1		2		3		Mean	
Species	Fert.	None	Fert.	None	Fert.	None	Fert.	None
Big Bluestem	.344	.169	1.201	.354	1.875	.417	1.140	.316
Indiangrass	.257	.115	.758	.295	1.446	.467	.831	.292
Switchgrass	.336	.132	1.235	.337	1.554	.455	1.041	.308
Little Bluestem	.142	.079	.580	.233	1.206	.380	.642	.231
Bermudagrass	.293	.085	1.311	.351	3.295	.351	1.633	.262

TABLE XI

MEAN LEAF WEIGHT IN GRAMS OF 5 GRASS SPECIES WITH AND WITHOUT FERTILIZER AT 3 CLIPPING DATES GROWTH CHAMBER EXPERIMENT II

	Harvests							
	1		2		3		Mean	
Species	Fert.	None	Fert.	None	Fert.	None	Fert.	None
Big Bluestem	.217	.111	.834	.249	1.185	.148	.745	.169
Indiangrass	.194	.082	.591	.224	1.117	.271	.634	.192
Switchgrass	.271	.093	.658	.139	1.005	.171	.644	.134
Little Bluestem	.098	.063	.402	.172	.651	.135	.250	.123
Bermudagrass	.170	.057	.631	.177	1.216	.127	.672	.120

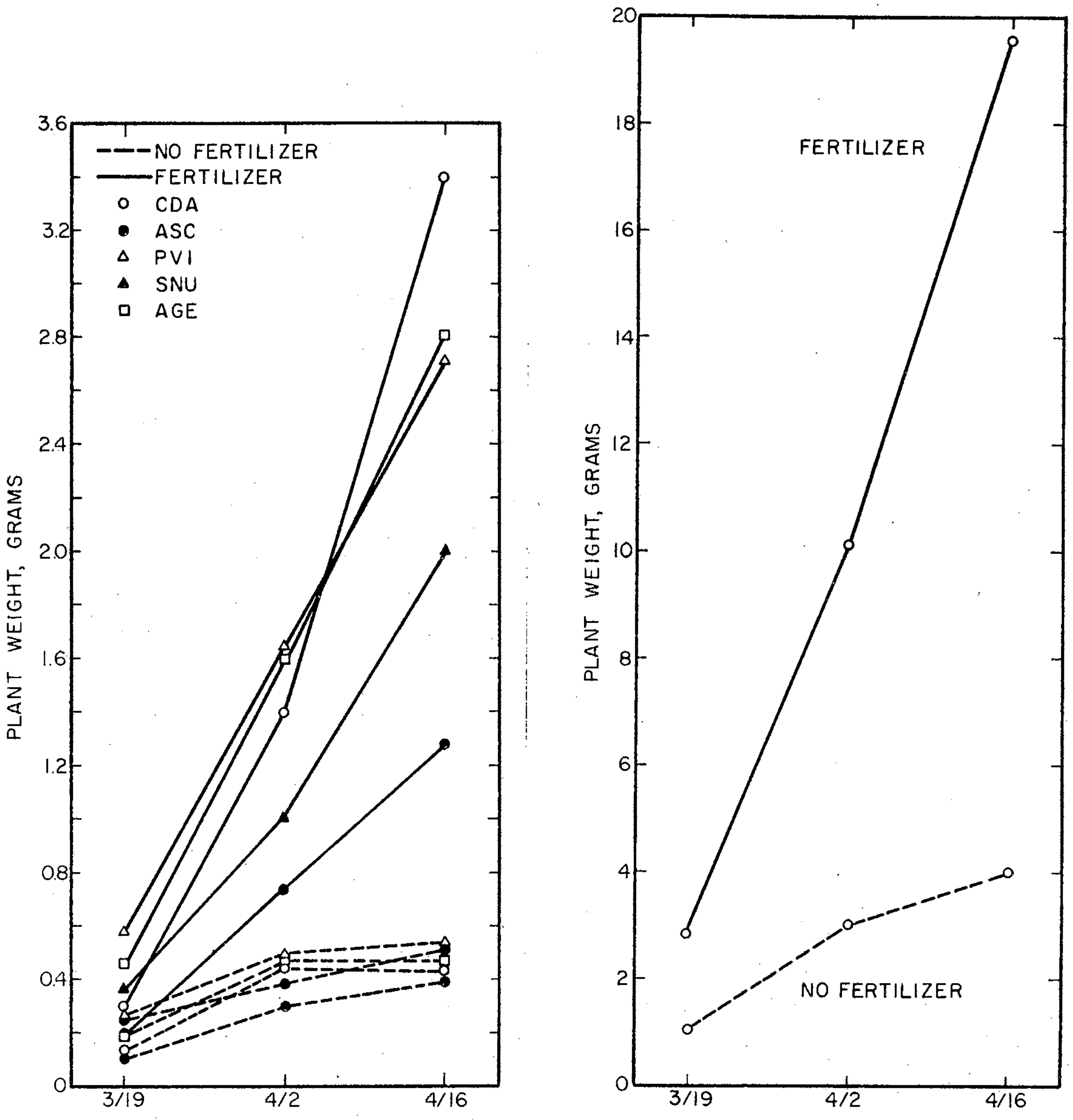

Figure 13. a. (left) Plant Weight in Grams for Three Harvest Dates for Four Native Grasses and Bermudagrass With and Without Fertilizer.

b. (right) Plant Weight in Grams for Three Harvest Dates for All Species With and Without Fertilizer. Growth Chamber Experiment II.

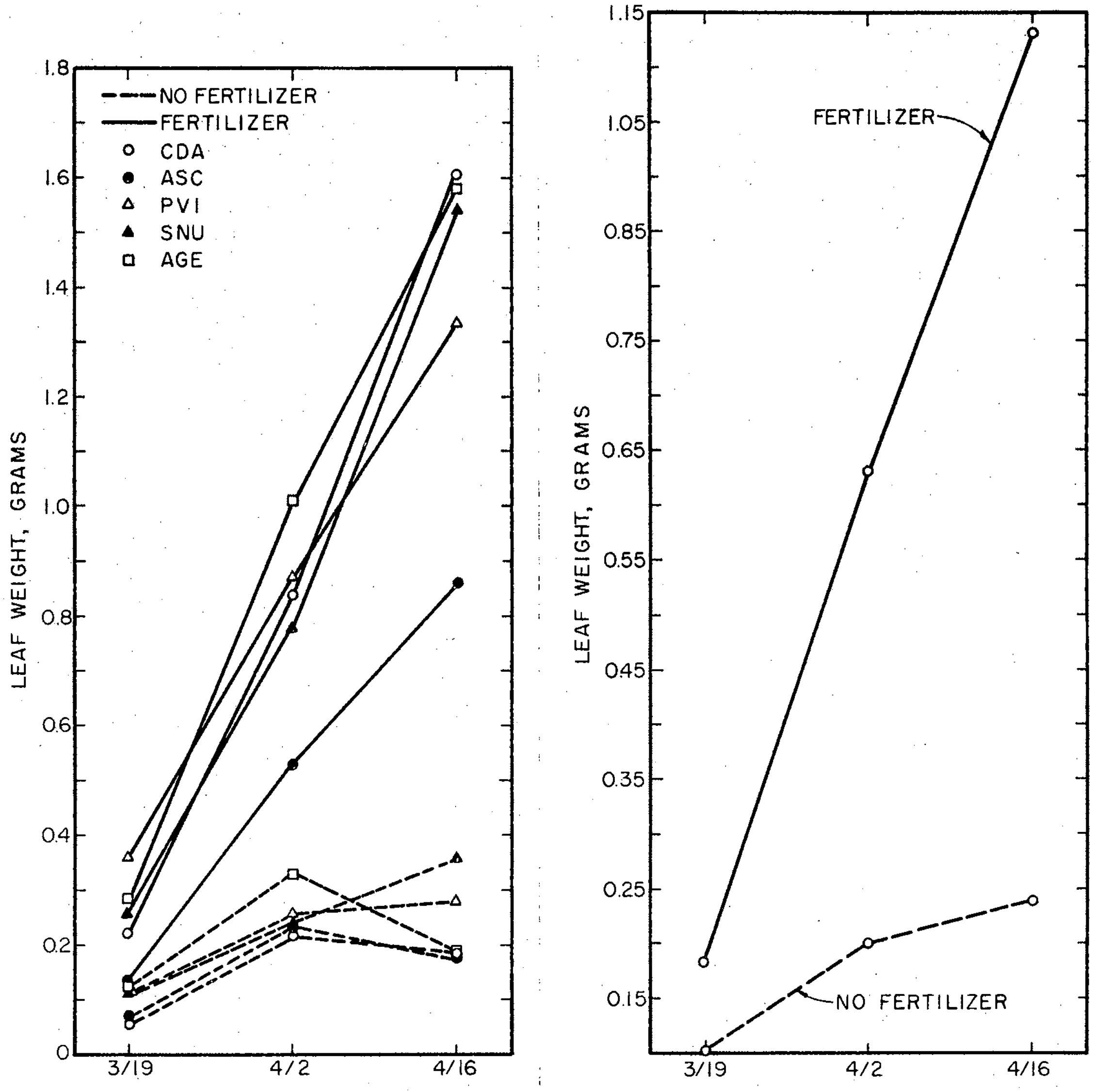

Figure 14. a. (left) Leaf Weight in Grams for Three Harvests for Four Native Grasses and Bermudagrass With and Without Fertilizer.
b. (right) Leaf Weight in Grams for Three Harvests for All Species With and Without Fertilizer. Growth Chamber Experiment II.

Stem weights (Figure 15 and Table XII) ranked in descending order were: bermudagrass, switchgrass, big bluestem, Indiangrass and little bluestem. The leaf/stem ratio as noted in Table XIII and Figure 16 declined with maturity generally for all species. Differences in stem weight were significant at the 1% level and for leaf/stem ratio at the 5% level. Without fertilizer, bermudagrass, big bluestem and Indiangrass had LAI values about equal (Figure 18). Switchgrass and little bluestem had lower LAI values. LAI increased with the application of fertilizer and species ranked in descending order for LAI were: bermudagrass, big bluestem, Indiangrass, switchgrass and little bluestem (Figure 19).

Relative growth rates were generally higher for the fertilized plants for all species while NAR was not affected by fertilizer.

TABLE XII

MEAN STEM WEIGHT IN GRAMS OF 5 GRASS SPECIES WITH AND WITHOUT FERTILIZER AT 3 CLIPPING DATES GROWTH CHAMBER EXPERIMENT II

	Harvests							
	1		2		3		Mean	
Species	Fert.	None	Fert.	None	Fert.	None	Fert.	None
Big Bluestem	.124	.048	.367	.105	.781	.140	.424	.097
Indiangrass	.082	.033	.167	.070	.414	.108	.221	.070
Switchgrass	.169	.039	.577	.148	1.036	.139	.594	.108
Little Bluestem	.046	.016	.178	.061	.316	.168	.193	.082
Bermudagrass	.123	.028	.678	.179	1.347	.143	.716	.116

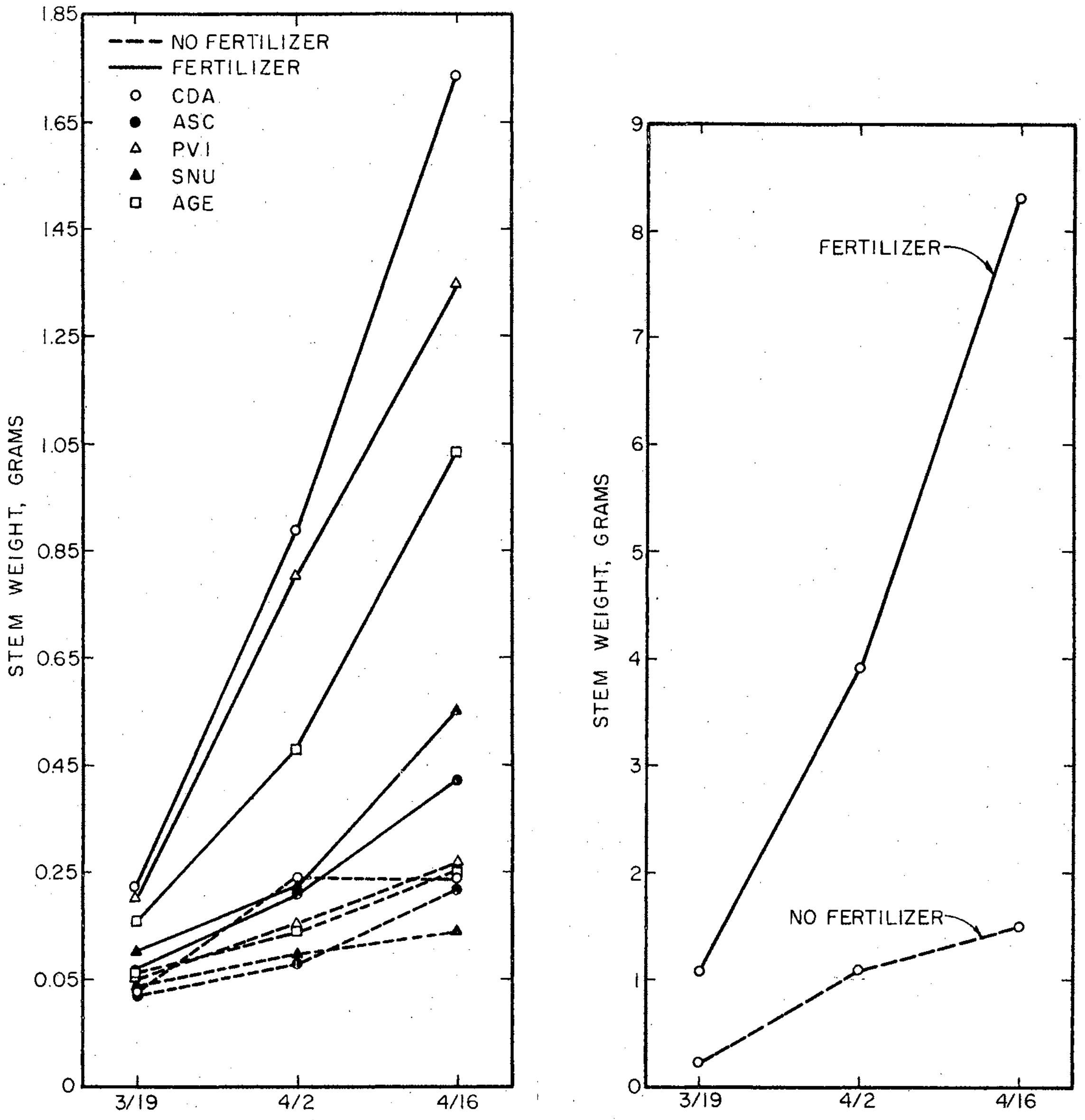

Figure 15. a. (left) Stem Weight for Three Harvests for Four Native Grasses and Bermudagrass With and Without Fertilizer.
b. (right) Stem Weight for Three Harvests for All Species With and Without Fertilizer. Growth Chamber Experiment II.

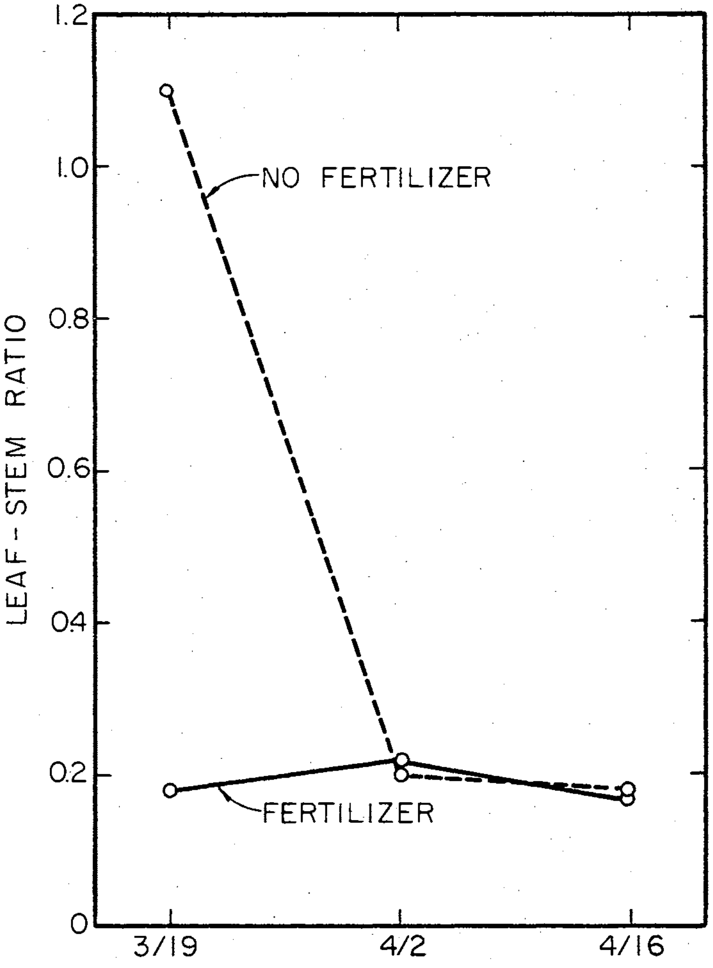

Figure 16. Mean Leaf/Stem Ratio for Three Harvests of Native Grasses and Bermudagrass Combined With and Without Fertilizer. Growth Chamber Experiment II.

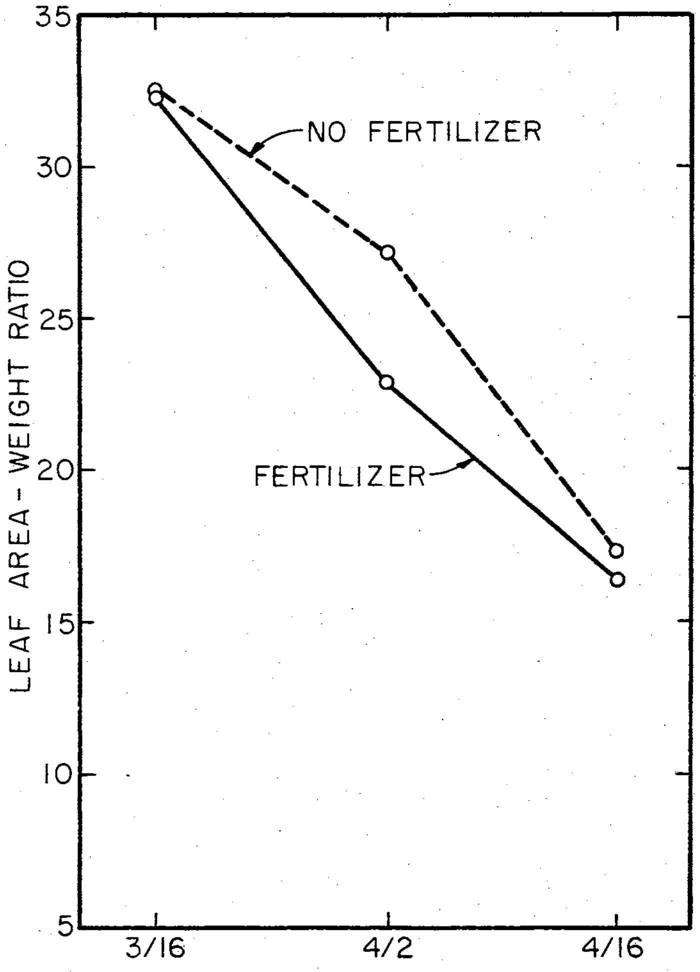

Figure 17. Mean Leaf Area/Plant Weight Ratio for All Harvests of Native Grasses and Bermudagrass Combined With and Without Fertilizer.

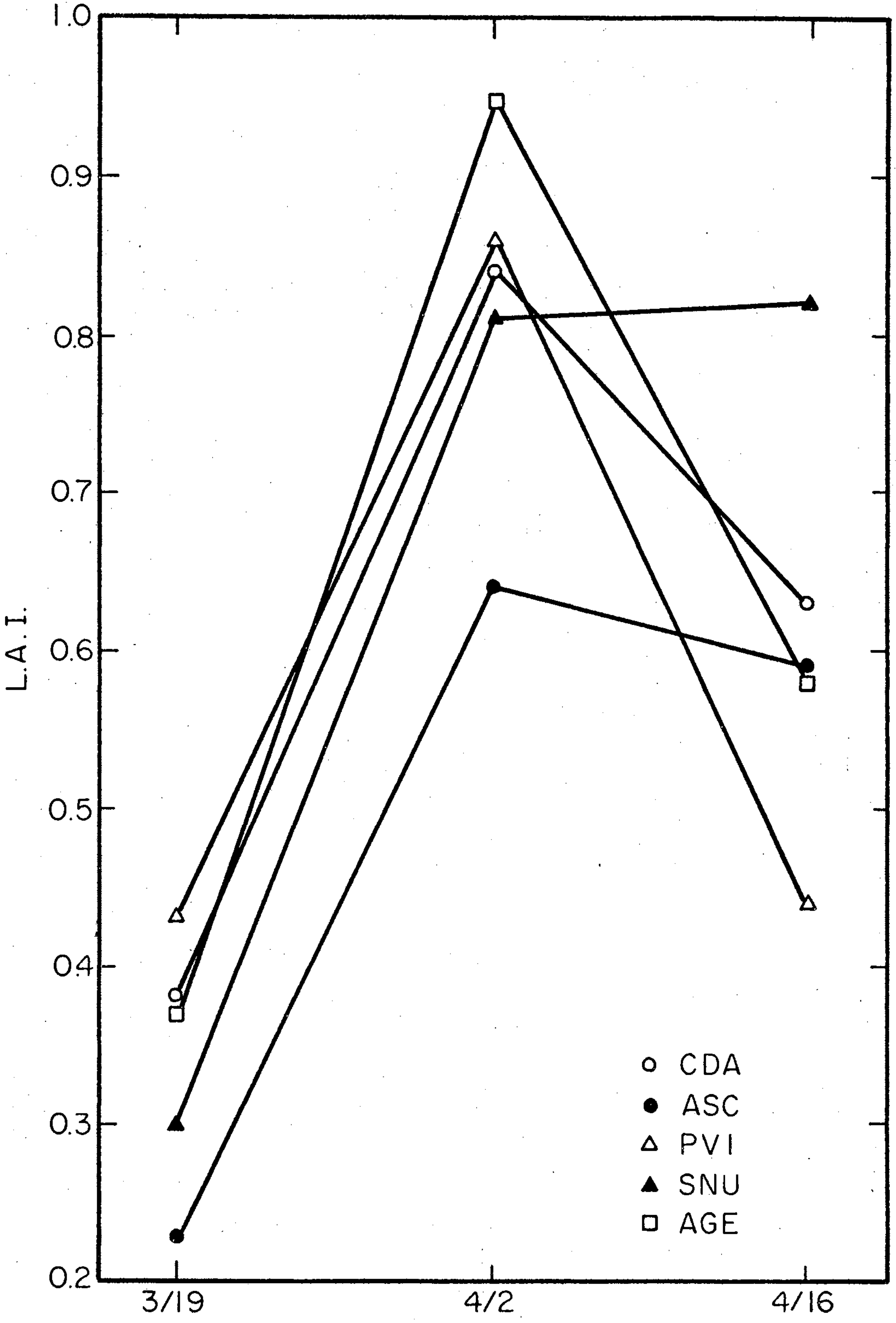

Figure 18. LAI for Three Harvests of Four Native Grasses and Bermudagrass Without Fertilizer. Growth Chamber Experiment II.

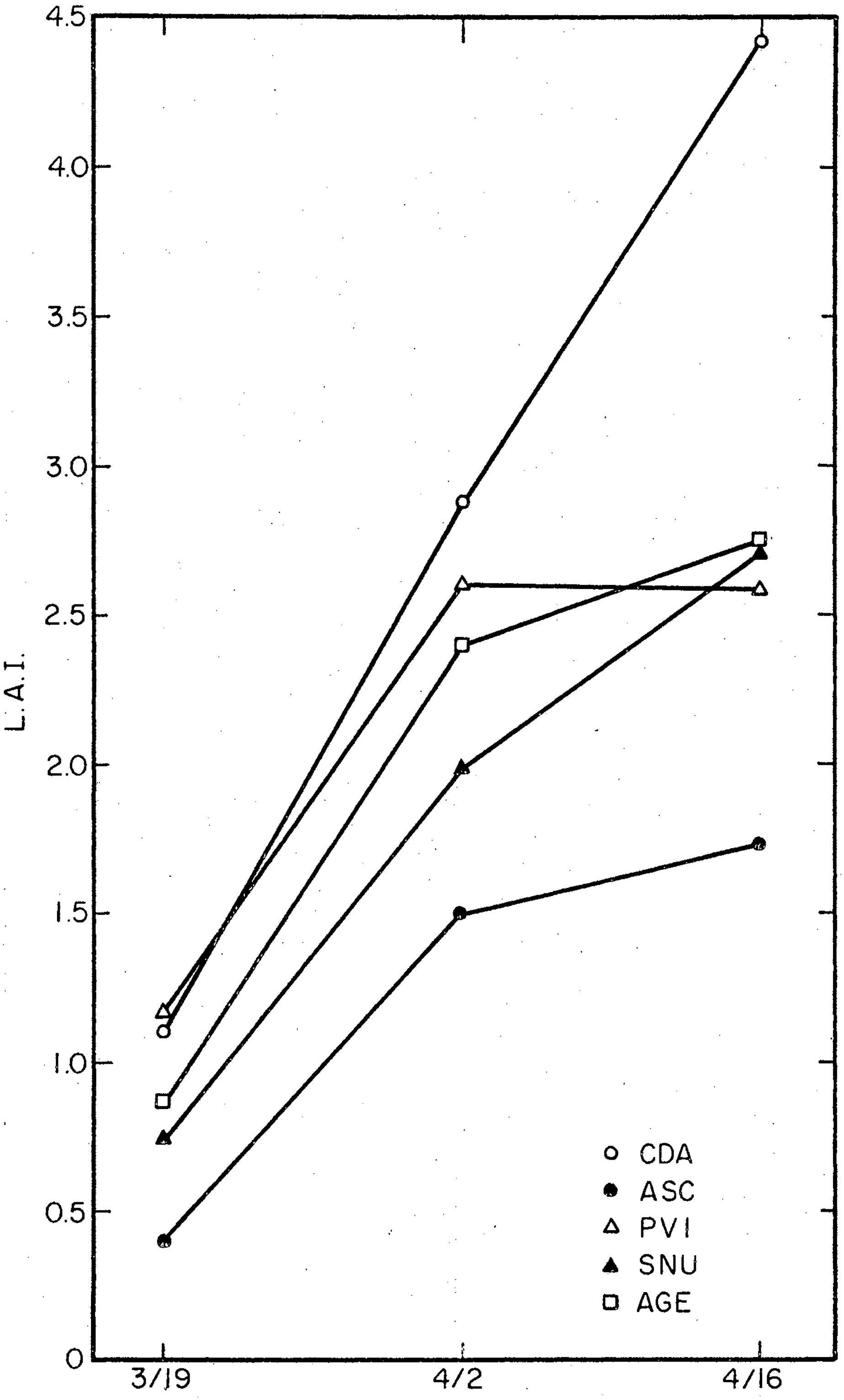

Figure 19. LAI for Three Harvests for Four Native Grasses and Bermudagrass Showing the Effects of Fertilizer. Growth Chamber Experiment II.

TABLE XIII

LEAF/STEM RATIO OF 5 GRASS SPECIES WITH AND WITHOUT FERTILIZER AT 3 CLIPPING DATES GROWTH CHAMBER EXPERIMENT II

	Harvests							
	1		2		3		Mean	
Species	Fert.	None	Fert.	None	Fert.	None	Fert.	None
Big Bluestem	1.75	2.31	2.27	2.37	1.52	1.78	1.84	2.15
Indiangrass	2.39	2.48	3.53	3.20	2.70	2.51	2.87	2.73
Switchgrass	1.60	2.35	1.14	1.27	.97	.91	1.27	1.51
Little Bluestem	2.11	3.97	2.25	2.79	2.05	1.82	2.14	2.86
Bermudagrass	1.38	2.05	.93	1.00	.90	.89	1.07	1.31

Field Experiment Results

Figure 20 and Table XIV shows the dry matter per acre accumulation that had occurred by various harvest dates. The native grass species yielded up to 3700 pounds of dry matter per acre, while bermudagrass only produced a maximum of 2000 pounds for 1965 and 2400 pounds for 1966. The general trend for dry matter yield is up from the first harvest to the last with a general trend to level out or to drop toward the end of the experimental period. Bermudagrass followed about the same trend for the two years, except the last harvest when there was some fluctuation. There was significance between species at the 1% level. There was a wide variation of LAI's for both native grass species and bermudagrass for both 1965 and 1966. Native grasses reached a maximum LAI of 4.7 for 1965, but only obtained LAI value of 3.5 for 1966. Bermudagrass, on the other hand, only had LAI's of 1.6 and 1.7 for 1965 and 1966 respectively. The general pattern for native

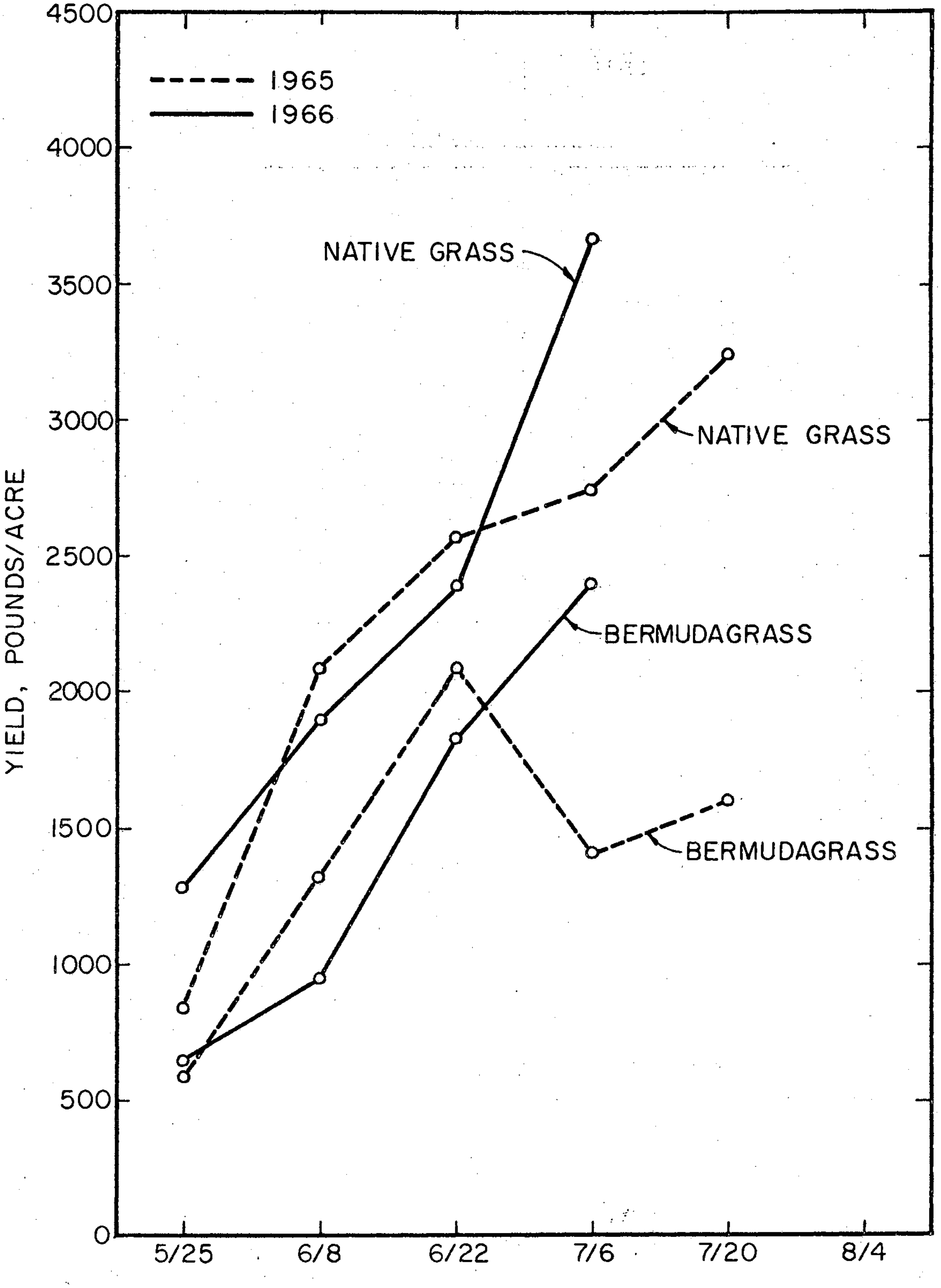

Figure 20. Dry Matter Production in Pounds Per Acre for Years 1965 and 1966 for Native Grass and Bermudagrass.

grass and bermudagrass was to increase in yield of dry matter as LAI increased as noted in Table XV and Figure 21.

TABLE XIV

MEAN DRY WEIGHT IN POUNDS PER ACRE FOR 1965 AND 1966 FOR A NATIVE GRASS MEADOW AND BERMUDAGRASS

	Field Experiment			
	Native Grass		Bermudagrass	
Harvest	1965	1966	1965	1966
1	1076	1271	595	760
2	2100	1925	1120	905
3	2580	2419	2010	1839
4	2612	3719	1240	2419
5	3340	3336	1371	2250
6	3262	3341	1415	2340

TABLE XV

LAI FOR NATIVE GRASS MEADOW AND BERMUDAGRASS FOR 1965 AND 1966

	Field Experiment			
	Native Grass		Bermudagrass	
Harvest	1965	1966	1965	1966
1	3.6	2.0	1.6	1.2
2	3.8	2.0	1.3	0.9
3	4.4	3.5	1.4	1.2
4	4.2	2.9	0.9	1.7
5	3.5	3.4	1.0	1.7
6	3.9	2.5	1.0	2.0

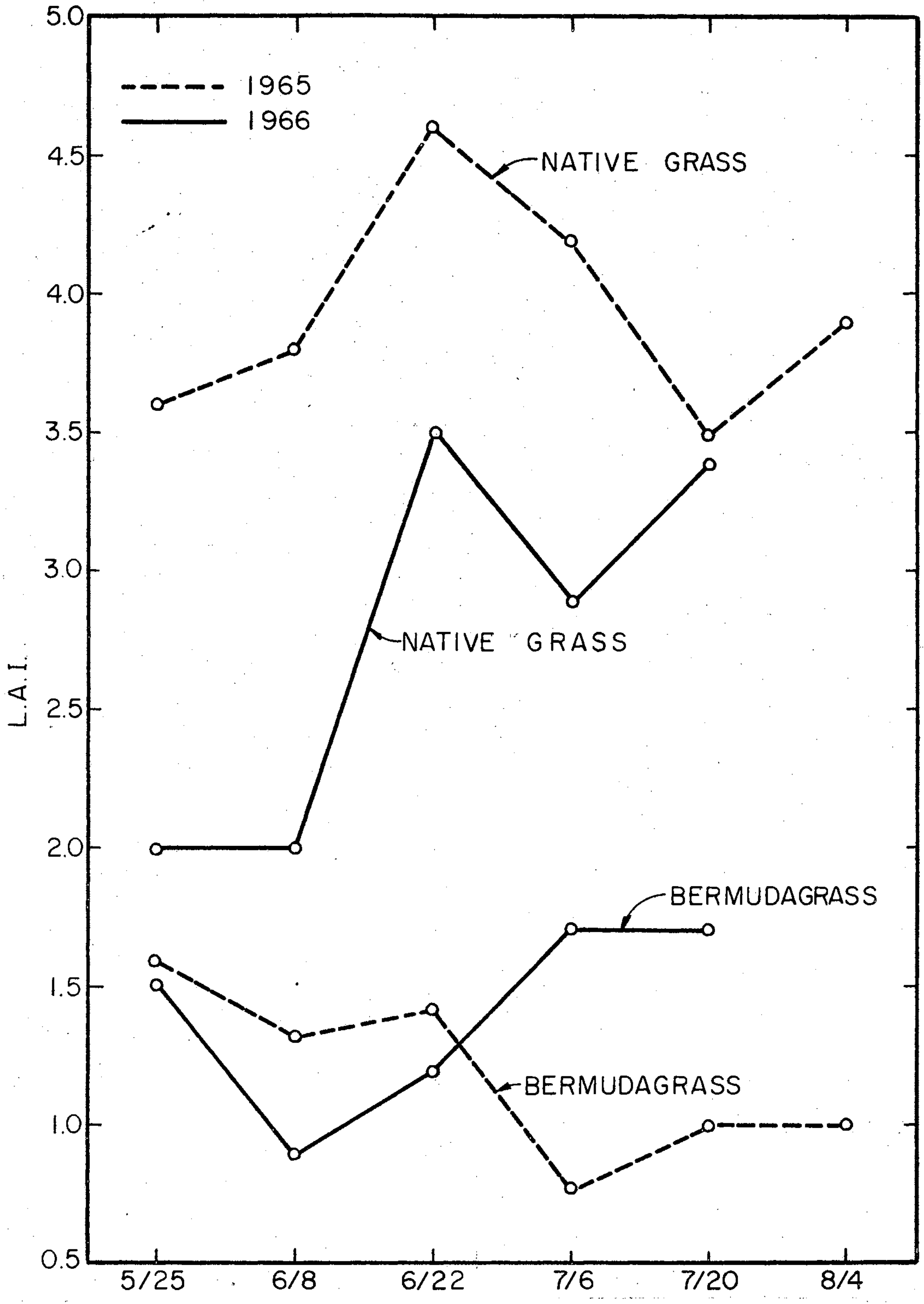

Figure 21. LAI of Native Grass and Bermudagrass for Years 1965 and 1966. Field Experiment.

The La/Plt Wt ratio is found in Table XVI and Figure 22 the trend for native grass species and bermudagrass was a rapid decline in leaf area/plant weight ratio. The trend was similar for two years data.

The Lv/St ratio pattern is much the same as the Growth Chamber Experiments. There was a decline in the ratio with each succeeding harvest date.

TABLE XVI

MEAN LEAF AREA/WEIGHT RATIO FOR NATIVE GRASS MEADOW AND BERMUDAGRASS FOR 1965 AND 1966

	Field Experiment			
	Native Grass		Bermudagrass	
Harvest	1965	1966	1965	1966
1	303	215	488	280
2	163	247	176	272
3	154	157	122	265
4	141	175	122	215
5	92	37	120	31
6	12	51	61	31

CO_2 Gas Analyzer Results

Four native grass species and bermudagrass were placed in a closed CO_2 gas analyzer system to measure CO_2 absorption of the leaf area. Each species was placed in an air tight bell jar and CO_2 was circulated through the system. One set of four native grass plants and bermudagrass which had been supplied with a complete plant nutrient solution and one set with no nutrient solution added were used for this experiment. The results are given in the Table XVII. From the results shown

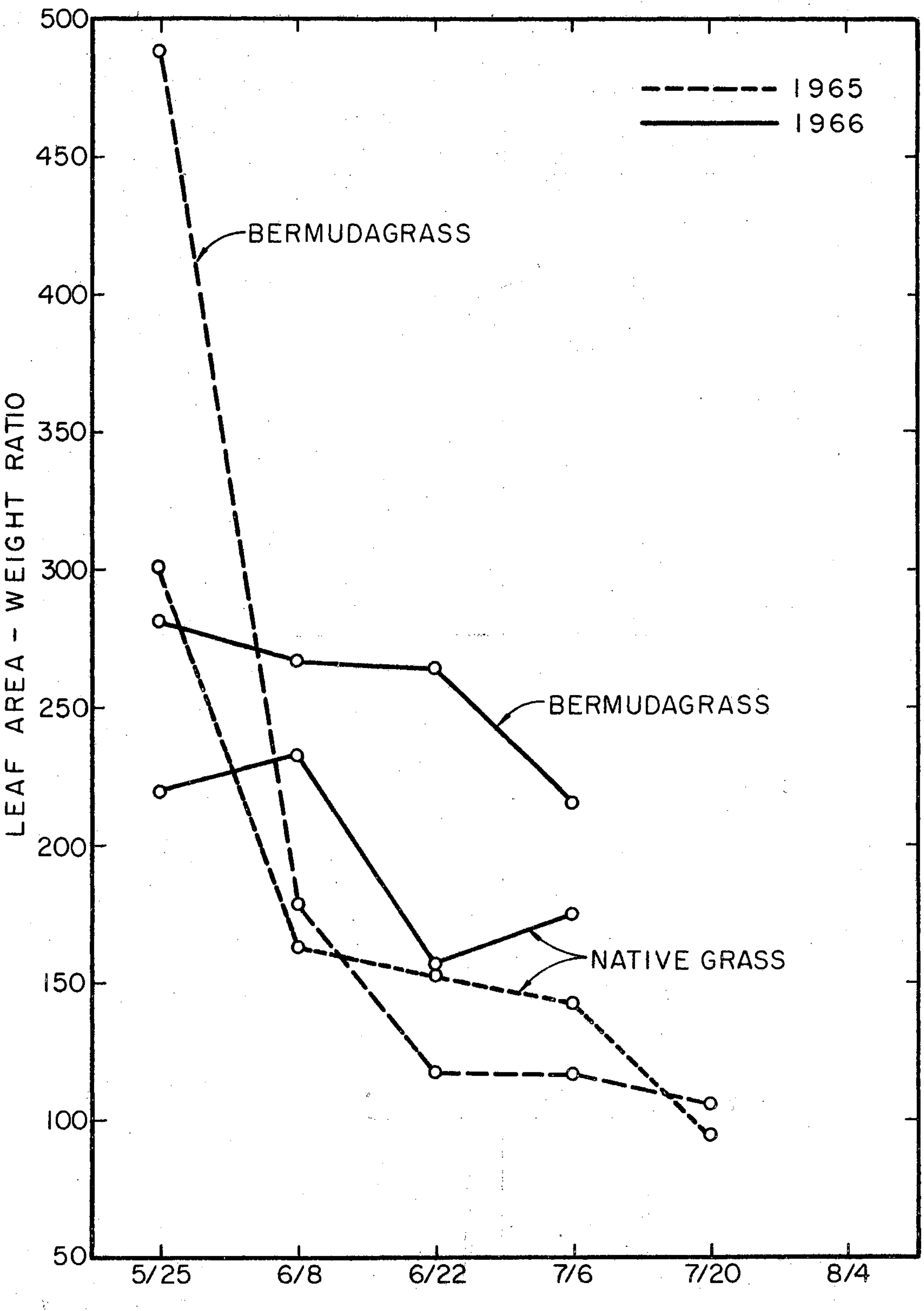

Figure 22. Leaf Area/Plant Weight of Native Grass and Bermudagrass for 1965 and 1966. Field Experiment.

in this table bermudagrass and Indiangrass absorbed more CO_2 than did the other species with nutrients added, however without the addition of nutrients bermudagrass absorbed much less. Big bluestem and Indiangrass absorbed about the same, with switchgrass and little bluestem absorbing equal amounts. Since this experiment was not replicated no statistical analysis was conducted, but the results indicate some differences in species for their ability to absorb CO_2.

TABLE XVII

Mg CO_2/10 cm^2 LA/MINUTE FOR FOUR NATIVE GRASS SPECIES AND BERMUDAGRASS WITH TWO FERTILITY LEVELS

Species	Fertilizer	No Fertilizer
Big Bluestem	.0015	.0009
Indiangrass	.0026	.0013
Switchgrass	.0019	.0009
Little Bluestem	.0024	.0010
Bermudagrass	.0047	.0001

CHAPTER V

DISCUSSION

Bermudagrass is known to out yield native grass species when treated as a cultivated pasture grass. In these series of experiments bermudagrass produced less dry matter consistantly, except when plant nutrients were added. Even with the addition of plant nutrients bermudagrass did not out yield native grasses in the field in this study.

Bermudagrass's growth habit is such that when moisture or nutrient supply is limited it heads out and growth slows or ceases. When moisture and nutrients are adequate growth resumes. Native grasses, on the other hand, are well adapted to the lower soil fertility and low moisture conditions and growth seldom ceases completely.

In the field experiment the bermudagrass did not become well established and grow as rapidly and as vigorously as was expected. Fertilizer was added when the sod was transferred and again was top dressed with nitrogen during the growing season. The same amount was applied to the native grass stand, which responded more than bermudagrass. The reason for its lack of expected growth was not resolved but the disparity probably resulted to a great extent because a full growing season was not utilized since the objective was to compare the grasses from dormancy through their grand period of growth. After clipping, production of native grasses and bermudagrass would hardly be comparable.

This study supports the hypothesis that native grasses are effective producers when adequate leaf area is presented for light interception. NAR values for both types of grasses were similiar and dry matter yields closely paralleled the leaf surfaces displayed. Only in the CO_2 absorption experiment did bermudagrass indicate a greater rate of carbon fixation per unit of leaf area. This test was not repeated, however. Information on respiration rate was not obtained but from all the data presented, it appears that photosynthetic efficiency is comparable among the species studied. It appears reasonable to assume from these data that low production of native grass more than likely results from low LAI values which results from overgrazing, weed competition and other factors of mismanagement.

Bermudagrass under high fertility produces large amounts of leaf area which results in high values of LAI.

In the controlled conditions of the Growth Chamber Experiment I where all species were established from seed, bermudagrass was the slowest to develop adequate leaf area in which to manufacture photosynthates. Little bluestem too, was slow in developing and never did produce as well as the other native species. All species displayed fairly good plant vigor at first, but within a short period of growth the lower leaves of all species began to develop chlorosis and die, consequently the later yield was effected by this physiological disease. Bermudagrass reacted similarly to growth chamber conditions as it did to field conditions.

The photosynthetic ability of bermudagrass was enhanced by the application of plant nutrients. This was due chiefly to the extra leaf production that was observed on bermudagrass. More leaf surface allows more incident light to be absorbed. As noted in the Gas Analyzer Experiment bermudagrass absorbed more CO_2 than other species, this was due to the large amount of leaf area which had developed by the application of plant nutrients. Bermudagrass without fertilizer produced less leaf area and absorbed less CO_2.

In Growth Chamber Experiment II the ratio of leaf area required to produce a gram of dry weight is shown with fertilizer to be less with big bluestem and bermudagrass followed by little bluestem, switchgrass, and Indiangrass. The ratios were 172:1, 177:1, 192:1, 213:1, and 214:1 respectively.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Four native grass species and bermudagrass were compared under controlled environment with and without fertilizer and under field conditions for growth and dry matter production in relation to certain growth functions. Dry matter, leaf area, leaf weight, stem weight, leaf area/plant weight ratio, leaf/stem ratio, NAR, relative growth rate, and CO_2 absorption were determined.

Under controlled conditions without fertilizer big bluestem was highest in the mean production of dry matter, leaf area, leaf weight, and LAI. Bermudagrass was highest in mean stem weight, NAR, and relative growth rate. Indiangrass and switchgrass were intermediate for these measurements, except Indiangrass was highest in leaf area/weight ratio. Little bluestem was consistently lowest in all growth functions, except it was second in leaf area/weight ratio, NAR, and RGR.

Under controlled conditions with fertilizer bermudagrass was highest in mean dry weight, leaf area, stem weight, leaf/stem ratio, LAI, and CO_2 absorption. Big bluestem ranked first in mean leaf weight, leaf area/weight ratio and NAR. Indiangrass and switchgrass were intermediate. Little bluestem was consistently last in all growth functions. Under field conditions native grass produced more mean dry matter, leaf area, leaf weight, and had a greater LAI value than bermudagrass. NAR declined with maturity. Relative growth rate was erratic among species.

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APPENDIX A

TABLE XVIII

ANALYSIS OF VARIANCE FOR PLANT WEIGHT OF 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GROWTH CHAMBER EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F.
Total	119	10.921	0.44000	
Reps	3	0.264	0.08825	3.7**
Species	4	0.457	0.11442	4.7**
Date	5	7.496	1.49921	6.2**
Reps x Species	12	0.714	0.05958	
Reps x Dates	15	0.357	0.02381	1.2
Species x Dates	20	0.583	0.02916	.024
Residual	60	1.047	0.01746	

*Significantly different at the 5% level of probability

**Significantly different at the 1% level of probability

TABLE XIX

ANALYSIS OF VARIANCE OF LEAF AREA FROM 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GROWTH CHAMBER EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F.
Total	119	166,517.759		
Reps	3	8,999.107	2,999.702	5.4**
Species	4	25,300.60	6,325.151	11.6**
Date	5	63,422.820	12,684.563	23.2**
Reps x Species	12	13,118.104	1,093.175	1.9
Reps x Dates	15	4,396.136	293.075	
Species x Dates	20	21,154.225	1,057.711	1.9
Residual	60	30,126.761	502.112	

* Significantly different at the 5% level of probability
** Significantly different at the 1% level of probability

TABLE XX

ANALYSIS OF VARIANCE FOR LEAF WEIGHT OF 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GROWTH CHAMBER EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F.
Total	119	0.04005		
Reps	3	0.00070	0.00023	2.5*
Species	4	0.00289	0.00072	8.0**
Date	5	0.02627	0.00525	58.3**
Reps x Species	12	0.00232	0.00019	
Reps x Dates	15	0.00099	0.00007	
Species x Dates	20	0.00229	0.00011	1.1
Residual	60	0.00459	0.00008	.000009

* Significantly different at the 5% level of probability
** Significantly different at the 1% level of probability

TABLE XXI

ANALYSIS OF VARIANCE FOR STEM WEIGHT OF 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GROWTH CHAMBER EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F.
Total	119	2.80402		
Reps	3	0.6688	0.02229	28.2**
Species	4	0.38938	0.09734	123.2**
Date	5	1.30740	0.26148	330.8**
Reps x Species	12	0.21677	0.01806	
Reps x Dates	15	0.11448	0.00763	
Species x Dates	20	0.34896	0.01745	22.08**
Residual	60	0.36016	0.00600	.0079

* Significantly different at the 5% level of probability
** Significantly different at the 1% level of probability

TABLE XXII

ANALYSIS OF VARIANCE FOR LEAF/STEM RATIO OF 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GROWTH CHAMBER EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F.
Total	119	1.09425		
Reps	3	0.01090	0.00363	15.4**
Species	4	0.29120	0.07280	6.1*
Date	5	0.14446	0.02889	
Reps x Species	12	0.08357	0.00696	
Reps x Dates	15	0.07797	0.00520	
Species x Dates	20	0.23414	0.01171	2.4
Residual	60	0.25201	0.00420	.0047

* Significantly different at the 5% level of probability
** Significantly different at the 1% level of probability

TABLE XXIII

ANALYSIS OF VARIANCE FOR LEAF AREA-PLANT WEIGHT RATIO OF 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GROWTH CHAMBER EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F.
Total	119	3,416,488.00000		
Reps	3	23,365.83032	7,788.61011	2.7*
Species	4	175,809.97461	43,952.49365	15.3**
Date	5	2,642,412.68750	528,482.53125	183.4**
Reps x Species	12	50,124.09180	4,177.00763	
Reps x Dates	15	80,925.96875	5,395.06458	
Species x Dates	20	324,124.37500	16,206.21875	5.6**
Residual	60	119,725.12500	1,995.41875	2882.4

* Significantly different at the 5% level of probability
** Significantly different at the 1% level of probability

TABLE XXIV

ANALYSIS OF VARIANCE FOR PLANT HEIGHT OF 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GROWTH CHAMBER EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F.
Total	119	50.24323		
Reps	3	1.17625	0.39208	3.2*
Species	4	11.15283	2.78821	27.6**
Date	5	21.95175	4.39035	43.9**
Reps x Species	12	2.64250	0.22021	
Reps x Dates	15	1.33125	0.08875	
Species x Dates	20	7.11117	0.35556	3.5*
Residual	60	4.87749	0.08129	1.01

* Significantly different at the 5% level of probability
** Significantly different at the 1% level of probability

TABLE XXV

ANALYSIS OF VARIANCE FOR PLANT WEIGHT FOR FIVE GRASS SPECIES GROWTH CHAMBER EXPERIMENT II

Source	d.f.	S.S.	M.S.	F.
R	3	10.5	3.5	
S	4	323.4	80.8	11.82**
D	2	1922.1	961.0	140.50**
T	1	1991.5	1991.5	291.15**
R x S	12	63.6	5.3	
R x D	6	45.2	7.5	
R x T	3	6.7	2.2	
S x D	8	261.1	32.6	4.77**
S x T	4	297.7	74.4	10.88**
D x T	2	965.4	482.7	70.57**
R x S x D	24	180.3	7.5	
R x S x T	12	88.9	7.4	
R x D x T	6	36.4	6.0	
S x D x T	8	293.1	36.6	5.36**
Residual	24	173.9	7.2	6.84
Total	119	6660.4		

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE XXVI

ANALYSIS OF VARIANCE FOR LEAF AREA FOR FIVE GRASS SPECIES GROWTH CHAMBER EXPERIMENT II

Source	d.f.	S.S.	M.S.	F.
R	3	2085.3	695.1	
S	4	93958.5	23489.6	8.9**
D	2	333928.9	166964.4	63.42**
T	1	652082.6	652082.6	247.7**
R x S	12	21902.6	1825.2	
R x D	6	18254.0	3042.3	
R x T	3	1319.6	439.8	
S x D	8	18018.4	2252.3	
S x T	4	66261.8	16565.4	6.3**
D x T	2	156562.2	78281.1	29.7**
R x S x D	24	90490.5	3770.4	
R x S x T	12	7000.1	583.3	
R x D x T	6	10889.7	1814.9	
S x D x T	8	20167.2	2520.9	
Residual	24	79161.6	3298.4	2632.3
Total	119	1572083.7		

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE XXVII

ANALYSIS OF VARIANCE FOR LEAF WEIGHT FOR 5 GRASS SPECIES GROWTH CHAMBER EXPERIMENT II

Source	d.f.	S.S.	M.S.	F.
R	3	0.11	0.03	
S	4	0.64	0.16	3.15*
D	2	6.19	3.09	60.1**
T	1	6.67	6.67	129.5**
R x S	12	0.48	0.04	
R x D	6	0.35	0.05	
R x T	3	0.07	0.02	
S x D	8	0.89	0.11	2.2
S x T	4	0.53	0.13	2.5*
D x T	2	3.08	1.54	29.9**
R x S x D	24	1.30	0.05	
R x S x T	12	0.65	0.05	
R x D x T	6	0.29	0.04	
S x D x T	8	0.75	0.09	
Residual	24	1.32	0.05	.0515
Total	119	23.38		

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE XXVIII

ANALYSIS OF VARIANCE FOR STEM WEIGHT FOR FIVE GRASS SPECIES GROWTH CHAMBER EXPERIMENT II

Source	f.f.	S.S.	M.S.	F.
R	3	7.3	2.4	
S	4	173.4	43.3	4.8**
D	2	366.3	183.1	20.1**
T	1	357.8	357.8	39.4**
R x S	12	17.2	1.4	
R x D	6	2.9	0.4	
R x T	3	6.3	2.1	
S x D	8	88.8	11.1	1.21
S x T	4	125.9	31.4	3.5**
D x T	2	187.0	93.5	10.3**
R x S x D	24	27.9	1.1	
R x S x T	12	20.1	1.6	
R x D x T	6	4.4	0.7	
S x D x T	8	92.1	11.5	1.2
Residual	24	34.2	1.4	.908
Total	119	1512.3		

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE XXIX

ANALYSIS OF VARIANCE FOR LEAF/STEM RATIO FOR FIVE GRASS SPECIES GROWTH CHAMBER EXPERIMENT II

Source	d.f.	S.S.	M.S.	F.
R	3	2.9	0.9	
S	4	12.1	3.0	3.0*
D	2	5.8	2.9	2.9*
T	1	3.1	3.1	3.1*
R x S	12	11.7	0.9	
R x D	6	5.6	0.9	
R x T	3	2.8	0.9	
S x D	8	21.2	2.6	2.6*
S x T	4	10.6	2.6	2.6*
D x T	2	6.0	3.0	3.0*
R x S x D	24	21.9	0.9	
R x S x T	12	11.6	0.9	
R x D x T	6	6.3	1.0	
S x D x T	8	20.9	2.6	2.6*
Residual	24	21.4	0.8	1.00
Total	119	164.60		

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE XXX

ANALYSIS OF VARIANCE FOR LEAF AREA/PLANT WEIGHT RATIO FOR FIVE GRASS SPECIES GROWTH CHAMBER EXPERIMENT II

Source	d.f.	S.S.	M.S.	F.
R	3	134.7	44.9	
S	4	741.2	185.3	7.7**
D	2	4995.4	2497.7	104.0**
T	1	81.5	81.5	
R x S	12	305.7	25.4	
R x D	6	215.3	35.8	
R x T	3	49.6	16.5	
S x D	8	1634.6	204.3	8.4**
S x T	4	28.5	7.1	
D x T	2	51.9	25.9	
R x S x D	24	1159.3	48.3	
R x S x T	12	344.8	28.7	
R x D x T	6	289.1	48.1	
S x D x T	8	128.0	16.0	
Residual	24	594.7	24.7	24.00
Total	119	10755.0		

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE XXXI

ANALYSIS OF VARIANCE FOR PLANT WEIGHT OF 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GREENHOUSE EXPERIMENT

Source of Variation	d.f.	S.S.	M.S.	F.
1	3	408.7	136.2	
2	4	1950.1	487.5	8.1**
3	5	909.5	181.9	3.3*
4	1	422.1	422.1	7.7**
12	12	818.5	68.2	
13	15	777.2	51.8	
14	3	120.7	40.2	
23	20	931.6	46.5	
24	4	152.6	38.1	
34	5	198.5	39.7	
123	60	3457.6	57.6	
124	12	577.5	48.1	
134	15	814.1	54.2	
234	20	1180.2	59.0	
Residual	60	3029.5	50.4	54.2
Total	239	15749.1		

*Significant at 5% level of probability
**Significant at 1% level of probability

TABLE XXXII

ANALYSIS OF VARIANCE FOR LEAF AREA FOR NATIVE GRASS AND BERMUDAGRASS GREENHOUSE EXPERIMENT

Source of Variation	d.f.	S.S.	M.S.
1	3	78961.0	26320.3
2	4	569539.2	142384.8
3	5	172321.0	34464.2
4	1	62361.7	62361.7
12	12	42066.3	3505.5
13	15	31102.2	2073.4
14	3	3025.7	1008.5
23	20	194539.6	9726.9
24	4	49181.3	12295.3
34	5	37075.8	7415.1
123	60	225204.8	3753.4
124	12	46579.0	3881.5
134	15	37560.5	2504.0
234	20	156653.6	7832.6
Residual	60	132188.3	2203.1
Total	239	1838360.7	

*Significant at the 5% level of probability
**Significant at the 1% level of probability

TABLE XXXIII

ANALYSIS OF VARIANCE FOR LEAF WEIGHT FOR 4 NATIVE GRASS SPECIES AND BERMUDAGRASS GREENHOUSE EXPERIMENT

Source of Variation	d.f.	S.S.	M.S.	F.
1	3	1.28	0.42	
2	4	1.52	0.38	
3	5	4.02	0.80	3.1*
4	1	0.55	0.55	
12	12	0.62	0.05	
13	15	0.46	0.03	
14	3	0.18	0.06	
23	20	0.62	0.03	
24	4	0.16	0.04	
34	5	0.17	0.03	
123	60	1.84	0.03	
124	12	0.37	0.03	
134	15	0.39	0.02	
234	20	0.87	0.04	
Residual	60	1.51	0.02	.255
Total	239	14.64		

*Significant at the 5% level of probability
**Significant at the 1% level of probability

TABLE XXXIV

ANALYSIS OF VARIANCE FOR DRY MATTER PRODUCTION FOR NATIVE GRASSES AND BERMUDAGRASS FIELD EXPERIMENT

Source	d.f.	S.S.	M.S.	F.
Reps	3	2,075.4	691.8	
Species	1	59,033.7	59,033.7	164.4**
Date	5	83,588.3	16,717.6	46.5**
Year	1	1,407.4	1,407.4	3.9**
Rep x Sp	3	3,344.3	1,114.7	
Rep x Date	15	4,696.7	313.11	
Rep x Year	3	3,077.4	1,025.8	
Sp x Date	5	8,510.7	1,702.1	
Sp x Year	1	59.1	59.1	
Date x Year	5	13,585.0	2,717.0	
R x S x D	15	2,476.0	165.0	
R x S x Y	3	2,012.3	670.7	
R x D x Y	15	5,546.4	369.7	
S x D x Y	5	1,622.3	324.4	
R x S x D x Y	15	3,623.6	241.5	359.0
Total	95	194,659.49		

* Significant at 5% level
** Significant at 1% level

TABLE XXXV

ANALYSIS OF VARIANCE FOR LEAF AREA FOR NATIVE GRASS AND BERMUDAGRASS FIELD EXPERIMENT

Source	d.f.	S.S.	M.S.	F.
Reps	3	1,554,259.4	518,086.4	5.04**
Species	1	2,700,879.0	2,700,879.0	1,046.1**
Date	5	1,590,528.1	318,105.6	
Year	1	56,041,934.5	56,041,934.5	
Rep x Sp	3	3,509.731.6	1,169,910.5	
Rep x Date	15	7,066,195.0	471,079.6	
Rep x Year	3	393,235.5	131,078.5	
Sp x Date	5	2,636,784.5	527,356.9	
Sp x Year	1	2,641,652.5	2,641,652.5	
Date x Year	5	2,291,103.8	458,220.7	
R x S x D	15	3,202,985.9	213,532.3	
R x S x Y	3	2,054,692.5	684,897.5	
R x D x Y	15	7,990,948.0	532,729.8	
S x D x Y	5	1,640,227.2	328,045.4	
R x S x DxY	15	2,945,826.4	196,388.4	535,704.0
Total	95	98,260,985.0		

* Significant at 5% level
** Significant at 1% level

TABLE XXXVI

ANALYSIS OF VARIANCE FOR LEAF WEIGHT FOR NATIVE GRASS AND BERMUDAGRASS FIELD EXPERIMENT

Source	d.f.	S.S.	M.S.	F.
Reps	3	131.5	43.8	
Species	1	54,463.8	54,463.8	435.7**
Date	5	18,243.6	3,648.7	29.1**
Year	1	120.9	120.9	
Rep x Sp	3	1,216.5	405.5	
Rep x Date	15	1,018.7	67.9	
Rep x Year	3	337.2	112.4	
Sp x Date	5	4,364.6	872.9	
Sp x Year	1	133.1	133.1	
Date x Year	5	759.1	159.0	
R x S x D	15	978.1	65.2	
R x S x Y	3	1,227.1	409.0	
R x D x Y	15	2,214.7	147.6	
S x D x Y	5	257.7	51.5	
R x S x DxY	15	1,695.1	113.0	125.8
Total	95	87,198.3		

* Significant at 5% level
** Significant at 1% level

TABLE XXXVII

ANALYSIS OF VARIANCE OF STEM WEIGHT FOR NATIVE GRASS AND BERMUDAGRASS FIELD EXPERIMENT

Source	d.f.	S.S.	M.S.	F.
Reps	3	248,099.8	82,699.9	
Species	1	16,120.1	16,120.1	
Date	5	1,740,675.8	348,135.1	21.5**
Year	1	1,053.3	1,053.3	
Rep x Sp	3	12,159.9	4,053.3	
Rep x Date	15	339,060.8	22,604.0	
Rep x Year	3	47,296.8	15,765.6	
Sp x Date	5	289,802.5	57,960.5	
Sp x Year	1	42,672.6	42,672.6	
Date x Year	5	126,229.6	25,245.9	
R x S x D	15	216,809.3	14,453.9	
R x S x Y	3	19,984.7	6,661.5	
R x D x Y	15	572,911.1	38,194.0	
S x D x Y	5	182,587.3	36,517.4	
R x S x D x Y	15	480,071.2	32,004.7	16,164
Total	95	4,335,535.6		

* Significant at 5% level
** Significant at 1% level

TABLE XXXVIII

ANALYSIS OF VARIANCE FOR LEAF/STEM RATIO FOR NATIVE GRASS AND BERMUDAGRASS FIELD EXPERIMENT

Source	d.f.	S.S.	M.S.	F.
Reps	3	10,912.0	3,637.3	144.6**
Species	1	328,839,8	328,839,8	4.00**
Date	5	45,506.5	9,101.3	
Year	1	4,298.3	4,298.3	
Rep x Sp	3	17,436.6	5,812.2	
Rep x Date	15	24,611.1	1,640.7	
Rep x Year	3	5,665.9	1,888.6	
Sp x Date	5	13,863.9	2,772.7	
Sp x Year	1	7,008.1	7,008.1	
Date x Year	5	46,609.4	9,321.8	
R x S x D	15	30,420.7	2,028.0	
R x S x Y	3	1,537.9	512.6	
R x D x Y	15	42,943.0	2,862.8	
S x D x Y	5	36,492.1	7,298.4	3.2*
R x S x D x Y	15	34,302.6	2,286.8	2274
Total	95	650,448.6		

* Significant at 5% level
** Significant at 1% level

TABLE XXXIX

ANALYSIS OF VARIANCE FOR LEAF AREA/PLANT WEIGHT RATIO FOR NATIVE GRASS AND BERMUDAGRASS FIELD EXPERIMENT

Source	d.f.	S.S.	M.S.	F.
Reps	3	947,266.5	315,755.5	45.7**
Species	1	8,796,631.3	8,796,631.3	38.1**
Date	5	36,755,645.5	7,351,129.1	503.0**
Year	1	96,964,333.0	96,964,333.0	
Rep x Sp	3	5,853.0	1,951.0	
Rep x Date	15	4,592,512.0	306,167.4	
Rep x Year	3	229,327.9	76,442.6	
Sp x Date	5	1,967,960.8	393,592.1	
Sp x Year	1	15,735,333.2	15,735,333.2	
Date x Year	5	19,429,316.0	3,885,863.1	
R x S x D	15	3,280,067.5	218,671.1	
R x S x Y	3	67,717.6	22,572.5	
R x D x Y	15	2,573,072.8	171,538.1	
S x D x Y	5	2,257,166.4	451,433.2	2.34**
R x S x D x Y	15	2,598,581.0	173,238.7	192,455.0**
Total	95	196,200,784.0		

* Significant at 5% level
** Significant at 1% level

TABLE XL

NAR (GM/DM^2/WK FOR 4 NATIVE GRASSES AND BERMUDAGRASS WITH AND WITHOUT FERTILIZER

	Harvests							
	1		2		3		Mean	
Species	Fert.	None	Fert.	None	Fert.	None	Fert.	None
Big Bluestem	.019	.017	.020	.010	.049	.007	.029	.011
Indiangrass	.0007	.015	.012	.012	.025	.004	.0012	.010
Switchgrass	.018	.012	.015	.011	.017	.001	.016	.008
Little Bluestem	.014	.012	.002	.013	.008	.008	.008	.011
Bermudagrass	.012	.008	.022	.016	.015	.004	.016	.009

APPENDIX B

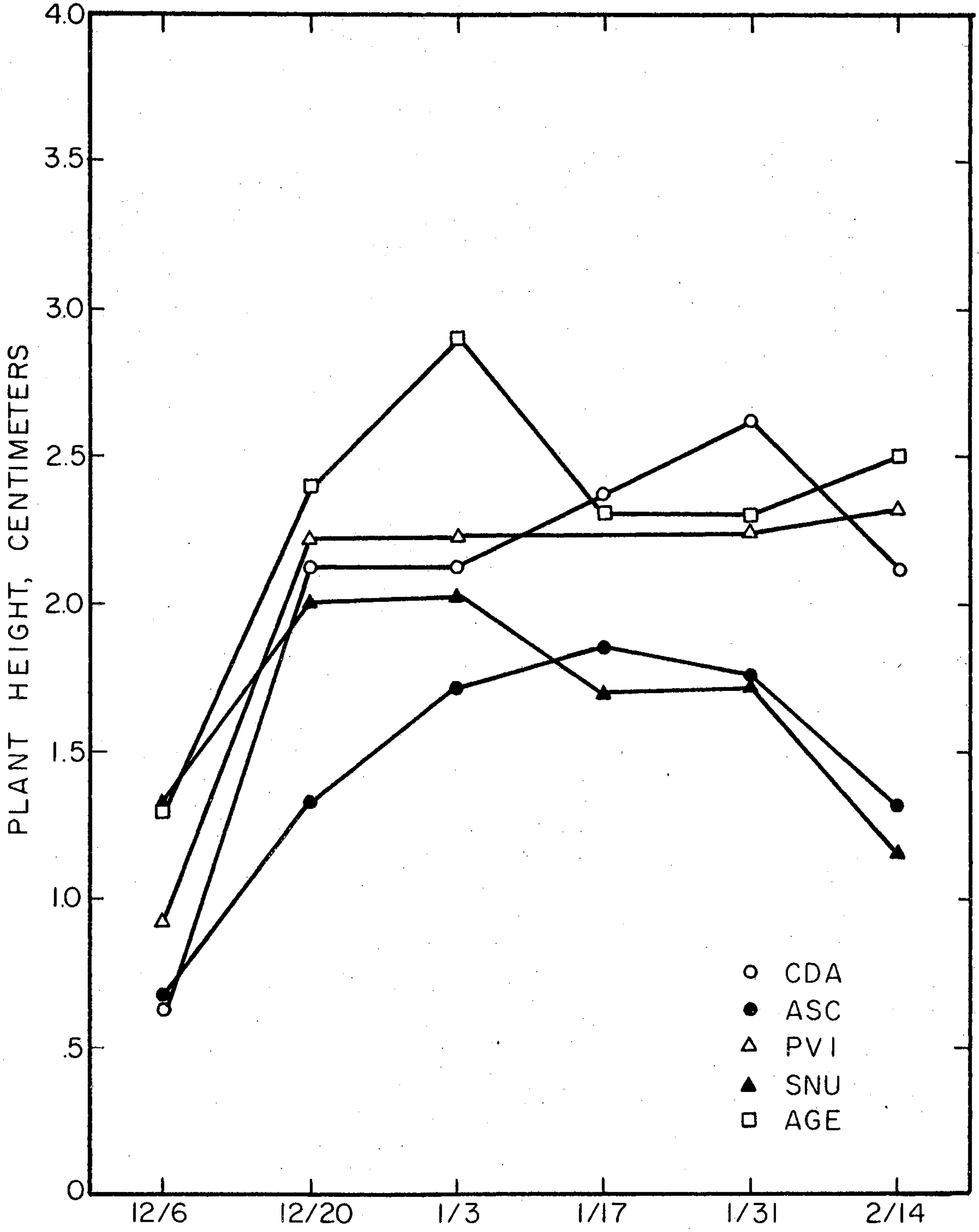

Figure 23. Plant Height in CM for Six Harvests for Four Native Grasses and Bermudagrass. Growth Chamber Experiment I.

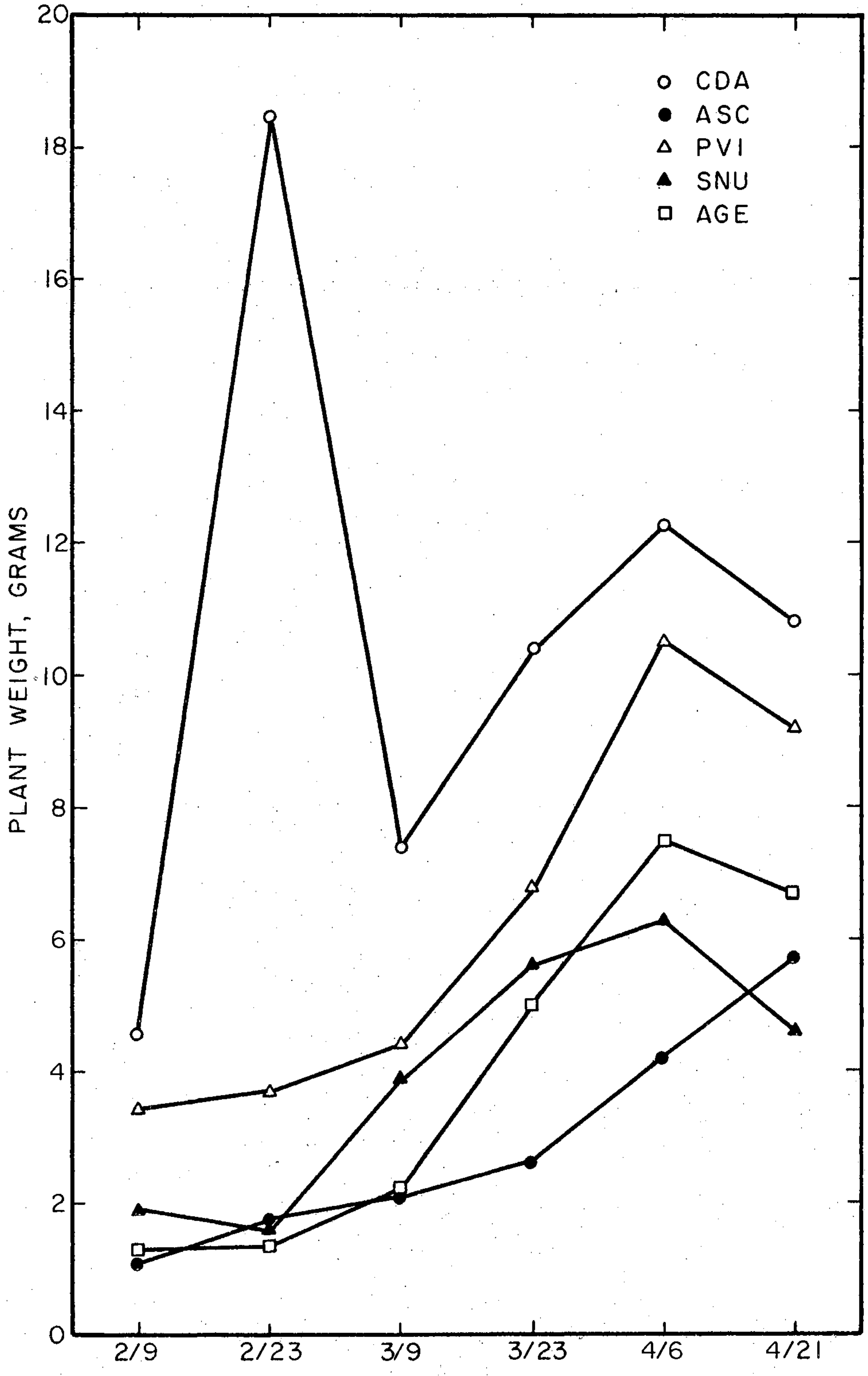

Figure 24. Plant Weight in Grams for Six Harvests for Four Native Grasses and Bermudagrass. Greenhouse Experiment.

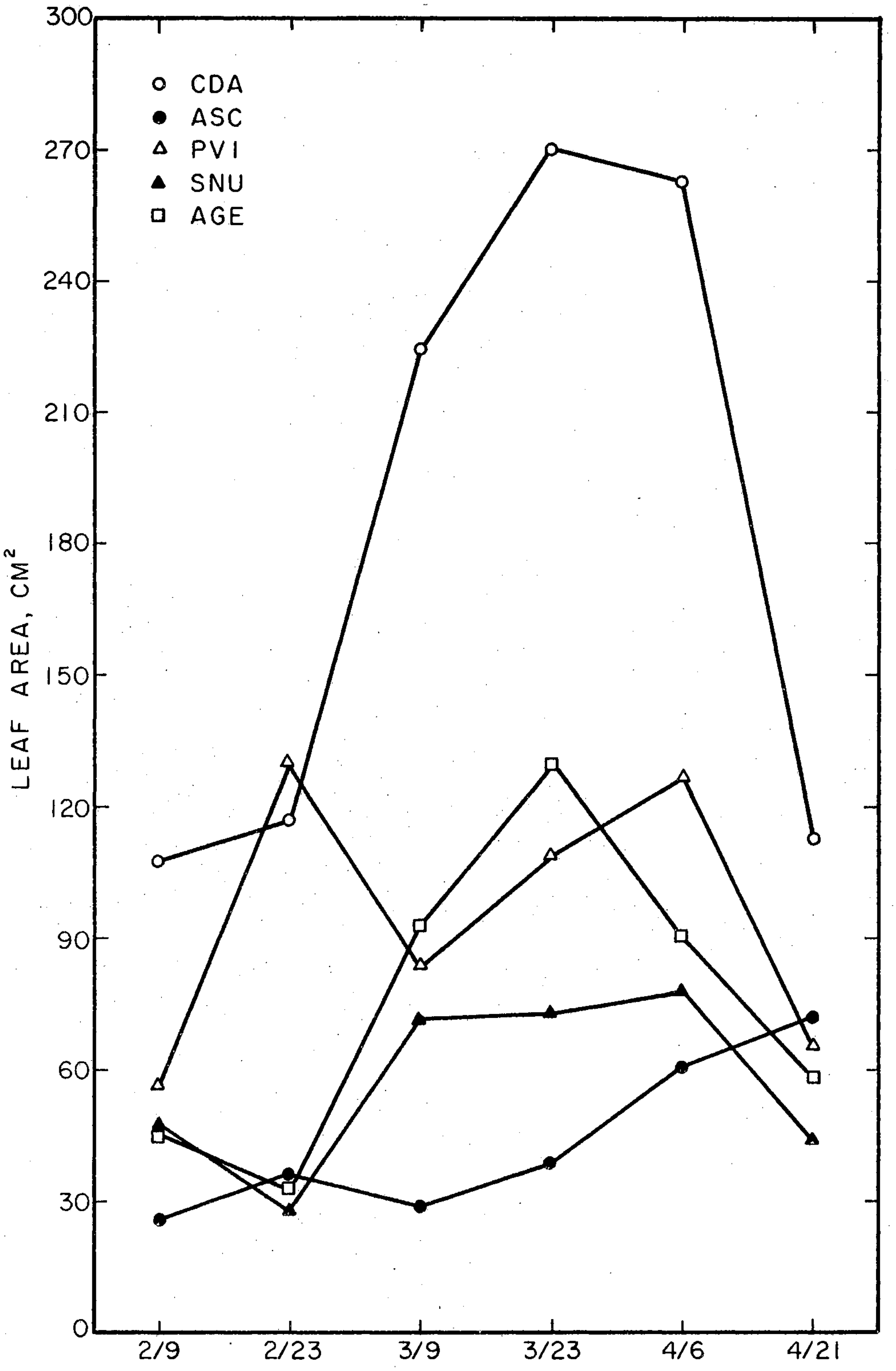

Figure 25. Leaf Area in CM^2 for Six Harvests for Four Native Grasses and Bermudagrass. Greenhouse Experiment.

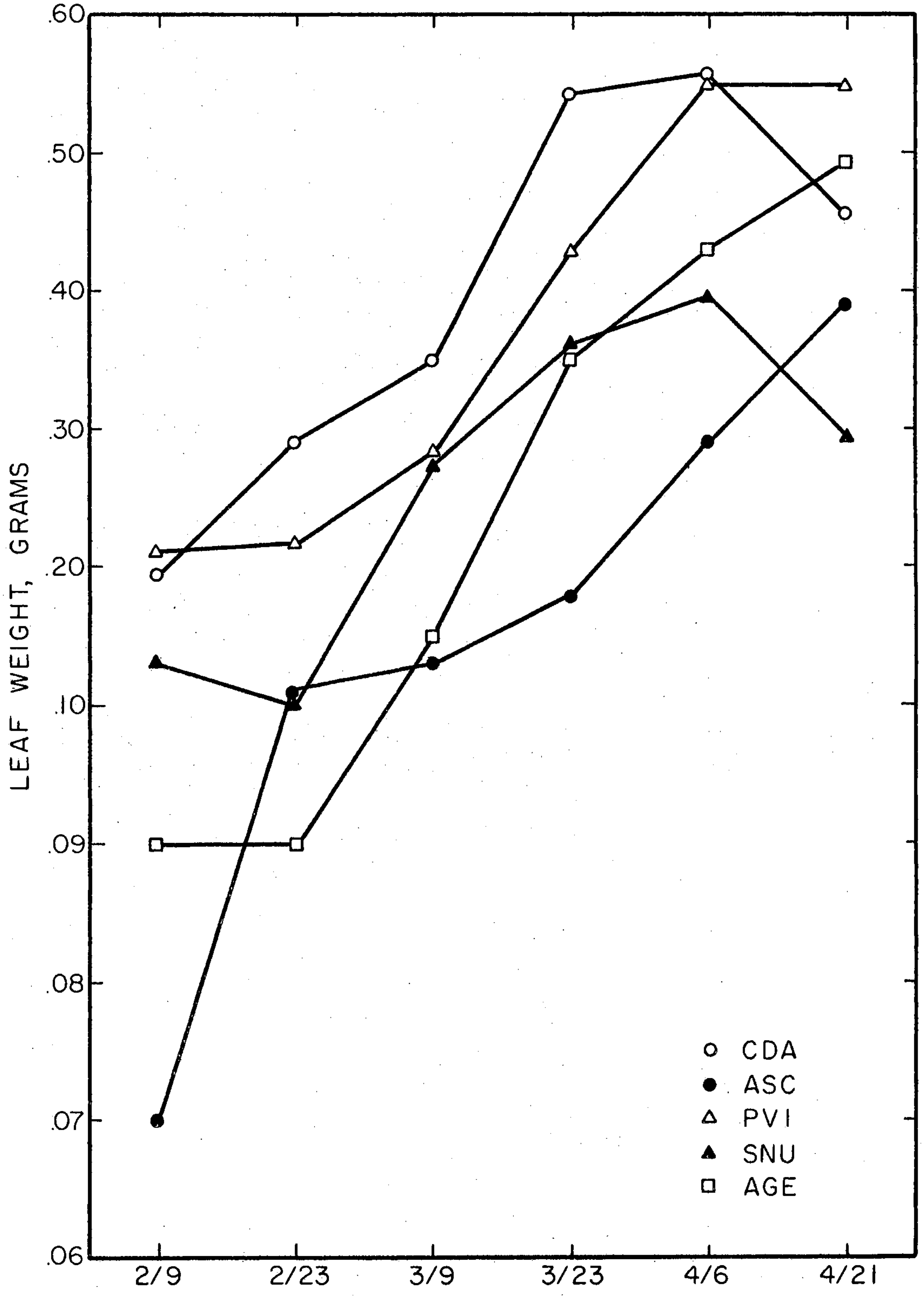

Figure 26. Leaf Weight in Grams for Six Harvests for Four Native Grasses and Bermudagrass. Greenhouse Experiment.

VITA

Emmett Watson McCord

Candidate for the Degree of

Doctor of Philosophy

Thesis: COMPARATIVE ANALYSIS OF LEAF SURFACES AND RELATED FUNCTIONS OF FOUR NATIVE GRASS SPECIES AND BERMUDAGRASS

Major Field: Agronomy

Biographical:

Personal Data: Born in Commerce, Oklahoma, May 18, 1923, the son of S. W. and Mae McCord.

Education: Attended grade school at Pleasant Valley, School District 37, Miami, Oklahoma; graduated from Fairland High School in 1941; received Bachelor of Science degree from Oklahoma State University in 1951 with a major in Agronomy; received the Master of Science degree from the Oklahoma State University, with a major in Agronomy, in May, 1959; completed requirements for the Doctor of Philosophy degree in July, 1967.

Professional experience: Entered the United States Air Force in December 1942. Research assistant with USDA 1951 to 1954; Assistant County Agent in Delaware County 1954-1956; Associate County Agent Osage County 1956-1963; County Agent Coal County 1963-1964; Extension Range and Forage Crop Specialist 1966 to present.

Professional societies: American Society of Agronomy, American Range Management Society, Epsilon Sigma Phi.