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To the Graduate Council:

I am submitting herewith a thesis written by Vagata Ramaiah entitled "The Morphological Development of Gahi-1 Pearlmillet as Affected by Management." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

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Major Professor

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THE MORPHOLOGICAL DEVELOPMENT OF GAHI-1 PEARLMILLET AS AFFECTED BY MANAGEMENT

A Thesis

Submitted to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Vagata Ramaiah

June 1960

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CHAPTER I

INTRODUCTION

Pearlmillet (Pennisetum glaucum L.) is one of the most important grasses used for supplemental summer forage in Tennessee and other southeastern states.

Pearlmillet is a summer annual and grows better than most forage crops during hot, dry, summer weather. It does not contain any prussic acid-forming glucosides or other known poisonous constituents. Being free from many diseases which affect Sudangrass, it produces more forage during southern summers and maintains a high level of production under unfavorable climatic conditions that often reduce the quality and production of perennial grasses. It may fit under certain conditions into a cropping system involving winter annuals. For example, land used for growing millet during the summer may be planted to oats in the fall to produce fall, winter and spring forage.

It is necessary to determine the influence of different cultural practices and cutting intensities on the morphology of the plant in order to determine appropriate ways of managing the crop to get maximum production and good seasonal distribution of forage. When grass plants are completely defoliated, new top growth is initiated at the expense of previously deposited food reserves. Unless these food reserves are sufficiently replenished before the next cutting, a further reduction in food reserves occurs, with resulting poor growth of the plant.

Adequate information is lacking regarding the stage of growth at

which millet should be cut or grazed, and the height of stubble to be left standing. To date, the density of the stand to produce maximum growth, the regrowth after cuttings and the distribution of production during the season have not been sufficiently investigated to the extent that satisfactory recommendations to growers can be made.

The present study was designed to consider the effects of 9 different cutting intensities, 3 row spacings, and 2 seeding rates, on the morphological development and forage yields of the Gahi-1 variety of pearlmillet.

CHAPTER II

REVIEW OF LITERATURE

The effect of the removal of photosynthetic area upon the growth of plants has received considerable study. Numerous investigations have been carried out on the cutting management of different grasses. However, literature relating to the morphological development of grasses, and particularly pearlmillet, as affected by cutting and cultural variables, is limited.

Roark et al. (1952) in Mississippi, as well as other authors, have found that pearlmillet is often superior to Tift Sudangrass and other sorghums as a summer pasture crop.

Marshall et al. (1953) reported that an average of over 2000 pounds of total nutrients per acre per year was obtained by dairy cows from a millet pasture in Florida. In Pennsylvania, Fortmann et al. (1950) reported that pearlmillet yielded 8635 pounds of dry matter and 618 pounds of protein per acre, whereas the highest yielding Sudangrass in the same test yielded 6098 pounds of dry matter and 526 pounds of protein.

Hoveland and McCloud (1957) and Hoveland[1] studied the effects of row spacing, height of plants before cutting and height of the stubble remaining after cutting, on the growth of pearlmillet in Florida. They

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[1]Hoveland, C. S. Defoliation of oats and pearlmillet as related to herbage yield. Unpub. Ph.D. Thesis, ~~Florida State University~~ University of Florida, Gainesville, Florida, 1959.

concluded that dry matter production of pearlmillet was generally in inverse proportion to the frequency of defoliation. Higher forage yields of pearlmillet resulted from row spacings of 7 and 19 inches than from 38-inch rows. They recommended that Starr pearlmillet be allowed to reach a height of 30 inches before grazing began, and that a stubble height of 10 to 18 inches be left after grazing. For silage or green feed, they found that highest total yield was produced when the plants were cut to a 4-inch stubble when 54 inches tall; however, under this management, the harvested plant parts were lowest in protein content. Number of live shoots on pearlmillet decreased during the growing season irrespective of cutting treatments. The reduction in numbers of shoots was greatest under high nitrogen fertilization.

Cathcart (1945) in South Carolina, reported that pearlmillet was as satisfactory for silage as for pasture; but results showed that pearlmillet yielded 740 pounds of total digestible nutrients per acre when grazed and only 518 pounds when made into silage. Under the conditions of the study, pearlmillet produced 43% more nutrients per acre when grazed than when harvested for silage. Comparing Tift Sudangrass and Starr pearlmillet in Georgia, Underwood et al. (1955) found that neither dry matter nor total digestible nutrient yields were significantly different.

At Knoxville, Tenn., Broyles and Fribourg (1959) found that Gahi-1 pearlmillet produced more total dry matter and nitrogen than did Piper or Sweet Sudangrass or German millet. Gahi-1, when cut at the early bloom stage to 4-inch stubble, produced the largest yields of dry matter.

Successively smaller yields were obtained from treatments where 30-inch growth was cut down to 10-inch stubble, 30-inch growth was cut down to 6-inch stubble and 20-inch growth was cut down to 6-inch stubble. They found that, as the yields of dry matter in any individual treatment increased, the percent nitrogen of forage in that treatment decreased. The best combination of both high yield and high percent nitrogen in the forage was obtained when the forage was allowed to grow to 30 inches before being cut to a stubble height of 6 or 10 inches.

In experiments conducted in New Zealand on ryegrass, red clover and white clover associations, Brougham (1956) found that, for maximum production of herbage and for continued maximum rate of growth, the amount of leaf left following mowing or grazing should be sufficient to insure complete interception of light. Pasture defoliated to 5 inches yielded approximately 20% more herbage than pasture defoliated to 1 inch during the experimental period. During the first 14 days of regrowth, the difference in yield was 100%.

In Pennsylvania, Sprague and Sullivan (1950) found that the tops, stubble and roots of orchardgrass clipped every five weeks underwent recurring and cyclic changes in dry weight during three inter-cutting periods. They concluded that clipping of orchardgrass resulted in the utilization of energy reserves. Those energy reserves stored in the stubble affect the growth of new tops if not removed.

At Whitehall, Ga., McCreery and Stelly (1949) studied the significant differences in yields of Bermudagrass, crabgrass and lespedeza when clipped at intervals of 1, 2, 3 and 4 weeks. The shorter clipping

intervals resulted in higher protein contents of the clippings.

Watkins and Severen (1951) in El Salvador, Central America, reported maximum dry matter yields of Guineagrass (Panicum maximum Jacq.) and of Napiergrass (Pennisetum purpureum Schumach.) when cut at 8-inch heights over three-month intervals. They found that high stubble weights were necessary to maintain the stand. In Michigan, Dexter (1936) found that frequently repeated complete defoliation of quackgrass prevented rhizome formation and killed the plants regardless of fertilization treatment. Blaser et al. (1952) reported that frequent and rather complete removal of foliage causes a drastic reduction in yield because of depleted organic food reserves in the roots of alfalfa and bromegrass grown in mixture.

At Beltsville, Md., Wagner (1952) reported that clipping twice reduced the amount of top and root growth of orchardgrass and bromegrass plants as compared to those cut only once. In a study with bluegrass at Blacksburg, Va., Ellett and Carrier (1915) found that total yields of dry matter varied inversely with the number of cuttings made during the season.

Bird (1943) in Canada, while comparing bromegrass, timothy, redtop and Kentucky bluegrass cut at six different stages of growth, concluded that the total seasonal yield increased with each successive delay in cutting from the earliest to early bloom.

In Wisconsin, Mortimer and Ahlgren (1936) reported that Kentucky bluegrass, 8 to 10 inches high when cut down to ground level, gave only 5.3% greater yields than when cut at 4 to 5 inches in height.

Cooper (1956) found that time of cutting of native grasses is not the primary factor in yield decline of flood meadows in Oregon.

Kuhn and Kemp (1939) compared two strains of Kentucky bluegrass and reported that increase in severity of defoliation caused a highly significant decrease in the production of tops. Sturkie (1930) obtained the largest yield of top growth with Johnsongrass when it was cut at the milk stage.

In Kansas, Albertson et al. (1953) made a study on short prairie grasses and reported that complete removal of top growth late in the season caused nearly as much reduction in yield of forage as when clipping had continued frequently throughout the season. Working on pinebunch grass, Johnson (1956) reported that herbage yield of perennial grasses was greatest on ungrazed range and progressively less on the slightly, moderately and heavily grazed ranges.

Harrison and Hodgson (1939) in Michigan, found that the greatest total yield of top growth of orchardgrass, timothy and quackgrass was obtained from those plants that were allowed to go unclipped. In general, the shorter a given grass was cut, the less top growth it produced. In Kansas, Aldous (1930) reported that the yield of big and little bluestems (Andropogon furcatus Muhl. and A. scoparius Michx.) varied inversely with the frequency of cutting, being least on the plots clipped at 2-week intervals throughout the season and highest where clipped once at maturity.

In experiments conducted in Nebraska on bromegrass and bluegrass, Robertson (1933) obtained similar results and showed that growth of tops of grass seedlings, as measured by dry weight and width and number of

leaves and number of tillers, was reduced by clipping.

At Tifton, Ga., Gordon and Burton (1956) found that the general effects of increasing the length of clipping intervals upon morphological measurements of Coastal Bermudagrass were increases in stem length, length of longest leaf-blade per stem, plant height, number of internodes per stem and internode length and decreases in leaf percentage.

At the University of Puerto Rico, Vicente et al. (1959) found that the quality of the forage of Napiergrass, Guineagrass and Paragrass decreased, though the yields increased with length of harvest interval.

In Pennsylvania, Sullivan and Sprague (1943) found that one partial defoliation of perennial ryegrass was followed by a rapid decline of sugars and fructosans in stubble and roots. In general, the more intensive and frequent the cutting treatment, the lower were the amounts of reserve carbohydrates in the storage organs.

In North Carolina, Lovvorn (1945) studying the effects of defoliation on dallisgrass and carpetgrass, observed that frequent cuttings were more effective in reducing yields of root growth than of top growth.

Sampson and Malmsten (1926) stated that any cropping which results in the reduction of the aerial growth is reflected in the root development and in the quantity of food stored in the underground parts of bluegrasses, wheat grasses and fescues. Burkey and Weaver (1939) working in Nebraska on little and big bluestem grasses found that there was a marked decrease in the percentages of invert sugar and water-

soluble hydrolyzable materials in the underground parts of grasses subjected to severe clipping.

Graber (1931) at the University of Wisconsin, found that food reserves in the roots, in relation to other factors, limited the top growth of grasses. Total weight of top growth tended to vary inversely with the frequency of defoliation; reduced growth sometimes occurred for several months subsequent to excessive defoliations of bluegrass, redtop, fescue and timothy.

Working at the University of Chicago, Harrison (1931) reported that clipping at different heights affected the root development of grasses. The shorter the grass was cut and the more the leaf area was reduced, the smaller was the quantity of roots produced. It was further reported that fescue tillered more when cut short than when cut long, and that bluegrass produced fewer rhizomes when cut short than when cut long. It was thought that killing of the grass was not due to cutting off the buds but to gradual carbohydrate starvation to a point beyond which the plants could not maintain themselves.

CHAPTER III

MATERIALS AND METHODS

This study was conducted during the summer of 1959, on soils varying from Sequatchie silt loam to Huntington silt loam, located on the Koella Farm leased by the Tennessee Agricultural Experiment Station in Blount County.

Two experiments were conducted concurrently, one to study the effects of cutting management, and the other to evaluate the effects of seeding rates and row spacings on production, regrowth potentials and structural changes in the plant.

Experiments and Treatments Studied

Cutting management experiment

In the cutting management experiment, each experimental plot consisted of five 22-foot rows, 21 inches apart. The middle 18-foot section of the center row was harvested for yield; the two rows adjacent to the center row furnished plant samples for morphological studies. The outer rows on either side of the three center rows were guard rows. The seeding rate was 13.8 pounds per acre in all treatments. Treatments were replicated three times and arranged in a randomized complete block design. Nine cutting intensities, as presented in table 1, were studied.

Cultural experiment

In the cultural experiment, the effects of 6 different treatments

Table 1.--Cutting intensity treatments used in cutting management experiment, Koella Farm, 1959

Symbols used in the text	Description of cutting intensities
20-3	20-inch growth cut down to a 3-inch stubble.
20-6	20 " " " 6 " "
20-10	20 " " " 10 " "
30-3	30 " " " 3 " "
30-6	30 " " " 6 " "
30-10	30 " " " 10 " "
30-14	30 " " " 14 " "
E.B.-4	Early bloom " " 4 " "
E.B.-8	" " " " 8 " "

replicated 4 times in a randomized complete block design were studied. Half the treatments were seeded at a rate approaching normal practice, and the other three were seeded at twice that rate. Within each seeding rate, three additional variables were introduced involving row spacings. Spacings of 7, 21 and 36 inches between rows were used, as detailed in table 2.

General Agronomic Information

Climate

The average minimum and maximum temperatures were 63.0 and 83.6° F., respectively, during the period of crop growth from May 21 to October 15. (Appendix E)

A total of 15.98 inches of rainfall was recorded at the U. S. Weather Bureau Station, Knoxville Airport, three miles from the experimental area, during the same period. The distribution of this precipitation during the season is presented in detail in Appendix F.

Fertilizer applications and plantings

An initial fertilizer application of 500 pounds per acre of 0-20-20 was drilled over the area of both cutting and cultural experiments and was followed with discing. Nitrogen in the form of ammonium nitrate was side-dressed in two equal applications, at seeding, and after the first cutting.

On May 21, both experiments were seeded with a "Planet, Jr." planter on a well-prepared seed bed at a depth of 0.5 inch. Cultivation was started when the millet reached a height of about 3 inches and, in

Table 2.--Treatments used in cultural experiment, Koella Farm, 1959.

Symbols used in the text		Treatments	
Seeding rate	Spacing	Seed per acre (pounds)	Spacing between rows (inches)
Normal rates of seeding:			
S	7	41.6	7
S	21	13.8	21
S	36	7.7	36
Double rates of seeding:			
2S	7	83.1	7
2S	21	27.7	21
2S	36	15.4	36

addition, for better weed control, the plots were hoed twice.

Harvesting

In both experiments, plots were cut with a hand-sickle. In order to insure correct height of cutting, appropriate guide boards were used for each of the stubble heights. Laths of the appropriate length were driven into the ground at one end of each plot for indicating, at harvest time, the height of growth desired. Heights of growth were taken to apply to the forage as it stood in the field, rather than to extended leaves.

Cutting experiment

In the cutting experiment, the crop was allowed to grow to different pre-determined heights (table 1) and cut down to the required stubble as often as necessary during the growing season. The area harvested in each plot measured 18 feet by 21 inches or .00072 acre. The first cutting was made on June 23 and the last on October 15.

Cultural experiment

All treatments were cut at a 30-inch growth down to a 6-inch stubble. The harvested area of each plot in the 7-inch row spacing was 18 feet by 7 inches (.00024) acre); in 21-inch row spacing, 18 feet by 21 inches (.00072) acre); and in 36-inch row spacing, 18 feet by 36 inches (.0012h acre).

Yield samples

Yield samples were collected in both experiments by harvesting

the middle 18 feet of the center row. For this purpose, the 22-foot center row for yield was trimmed by 2 feet at each end.

The harvested forage was placed in a cloth bag and oven-dried at 70° C, then weighed to the nearest hundredth of a pound. The dry matter yields were calculated on an acre basis for each plot of each treatment in both experiments.

Morphological samples

An approximate 18-inch length in the row on either side of the center row was selected at random for the purpose of collecting plant samples. One plant sample was removed with roots attached on each cutting date from each plot in 2 of the 3 or 4 replications of the cutting management and the cultural experiments, respectively. The samples were labeled, placed in plastic bags in the field, and frozen. Later in the season, the frozen samples were moved for morphological studies to the laboratory, a few at a time.

Morphological Measurements

The morphological characteristics studied in each sample were as follows:

1. Total number of primary (main) stems.
2. Total number of tillers.
3. Total number of dead stems.
4. Average height of apical bud above top-most roots.
5. Number of stems with apical buds occurring below scheduled height for topgrowth removal.

6. Number of tillers with apical buds occurring below scheduled height for topgrowth removal.
7. Number of stems with apical buds occurring above scheduled height for top-growth removal.
8. Number of tillers with apical buds occurring above scheduled height for top-growth removal.
9. Average number of live leaves on main stems.
10. Average number of live leaves on tillers.
11. Average number of dead leaves on main stems.
12. Average number of dead leaves on tillers.
13. Dry weight of stems below the scheduled height for top-growth removal.
14. Dry weight of stems above the scheduled height for top-growth removal.
15. Dry weight of tiller stems above the scheduled height for top-growth removal.
16. Dry weight of tiller stems below the scheduled height for top-growth removal.
17. Dry weight of all live leaves from stems.
18. Dry weight of all dead leaves from stems.
19. Dry weight of all live leaves from tillers.
20. Dry weight of all dead leaves from tillers.
21. Dry weight of all dead stems.

All the plants in the samples from two replications in each experiment were studied for these characteristics. Oven-dry weight was

determined from material dried in the oven at 70° C. The height of the apical bud was measured by splitting the stem open with a razor blade and measuring the length from the base of the plant (point of topmost root) to the point of the apical bud at the top of the split stem. To determine the average height of the bud in both main stems and tillers, the total of bud heights in all plants with buds below cut and above cut was divided by the total number of plants examined, respectively. The average number of live leaves and of dead leaves was determined by counting the total number of leaves in each category for all plants and dividing by the number of plants examined.

Morphological characteristics calculated

Main stems:

1. Percent of total stems with apical buds below scheduled height of cut.
2. Percent of total stems with apical buds above scheduled height of cut.
3. Stem dry weight per 100 plants for portions above scheduled height of cut.
4. Stem dry weight per 100 plants for portions below scheduled height of cut.
5. Percent stem weight above scheduled height of cut.
6. Dry weight of live leaves per 100 plants.
7. Dry weight of dead leaves per 100 plants.
8. Leaf to stem ratio on a dry weight basis.

The weights of live and dead leaves were combined to obtain

total leaf weight, and weights of stems below and above scheduled height of cut were combined to obtain total stem weight.

9. Percent of dead stems in total number of main stems.

Tillers:

1. Average number of tillers per plant.
2. Percent of tillers with apical buds below scheduled height of cut.
3. Percent of tillers with apical buds above scheduled height of cut.
4. Stem dry weight per 100 tillers for portions above scheduled height of cut.
5. Stem dry weight per 100 tillers for portions below scheduled height of cut.
6. Percent stem weight above scheduled height of cut.
7. Dry weight of live leaves per 100 plants.
8. Dry weight of dead leaves per 100 plants.
9. Leaf to stem ratio on a dry weight basis.

Average number of tillers per plant was calculated on the basis of total number of live and dead stems. The other calculations were made on the same basis as in the case of main stems.

Presentation of Data

All the data on the individual morphological characteristics

measured and calculated are presented in Appendices A, B, C and D. The important morphological characteristics for stems are graphically represented in the text. Heights are expressed in inches, weights in grams. All the morphological characteristics are expressed as the mean of two replications.

Dry matter yields of harvested forage are presented in terms of oven-dry yields in pounds per acre. The treatment mean dry matter yields for each cutting date and for the season are presented in tables 3 and 5.

In the text, the dry matter yields are reported as the mean of the three replications of the cutting management experiment and four of the cultural experiment, respectively.

The coefficients of variation (C.V.) for the seasonal yields are also tabulated. By the use of Duncan's Multiple Range Test (1955), the treatment means have been separated. Any two means underlined or joined by the same line are not significantly different from each other at the .05 level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

Cutting Management Experiment

All the data for the individual morphological characteristics measured for main stems and tillers in the cutting management experiment are presented in Appendices A and B as means of the two replications measured. Graphical analysis of the important morphological characteristics of main stems is presented in the text.

Average heights of apical buds below and above scheduled heights of cut

The average height of occurrence of apical meristems of primary stems for the various cutting intensities are presented graphically in figures 1, 3, and 6. Portions of plant samples obtained for morphological studies on different dates of cutting for 20-3, 30-6, 30-14 and E.B.-4 cutting intensities are photographically presented in figures 2, 4, 5 and 7, respectively.

It is apparent that under a 20-3 cutting intensity, buds were present under the scheduled height of cut only at the time of the first two harvests; thereafter, all apical buds were removed at the time of cutting, occurring anywhere between 3 to 6 inches above the cut. On the other hand, buds were present all season both above and below the cut under 20-6 and 20-10 cutting intensities. Buds occurring below the cut under 20-6 remained at a fairly constant height of 4 to 5 inches, but under 20-10 cutting intensity they ranged from a low of 5 inches at the beginning of the season to as much as 7 inches in October.

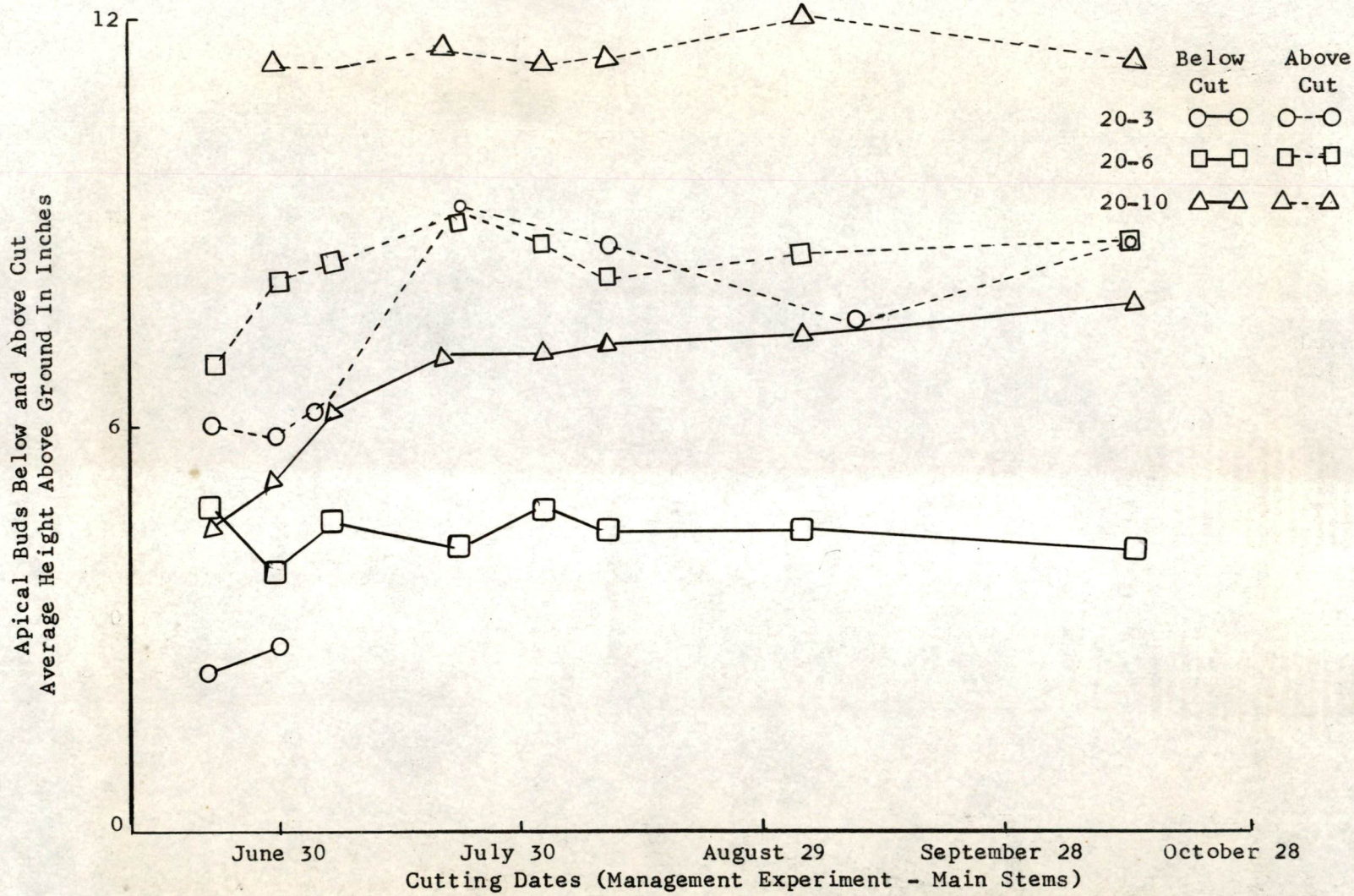


Figure 1--Seasonal distribution of average height of apical buds below and above scheduled cut in main stems under 20-3, 20-6 and 20-10 cutting intensities.

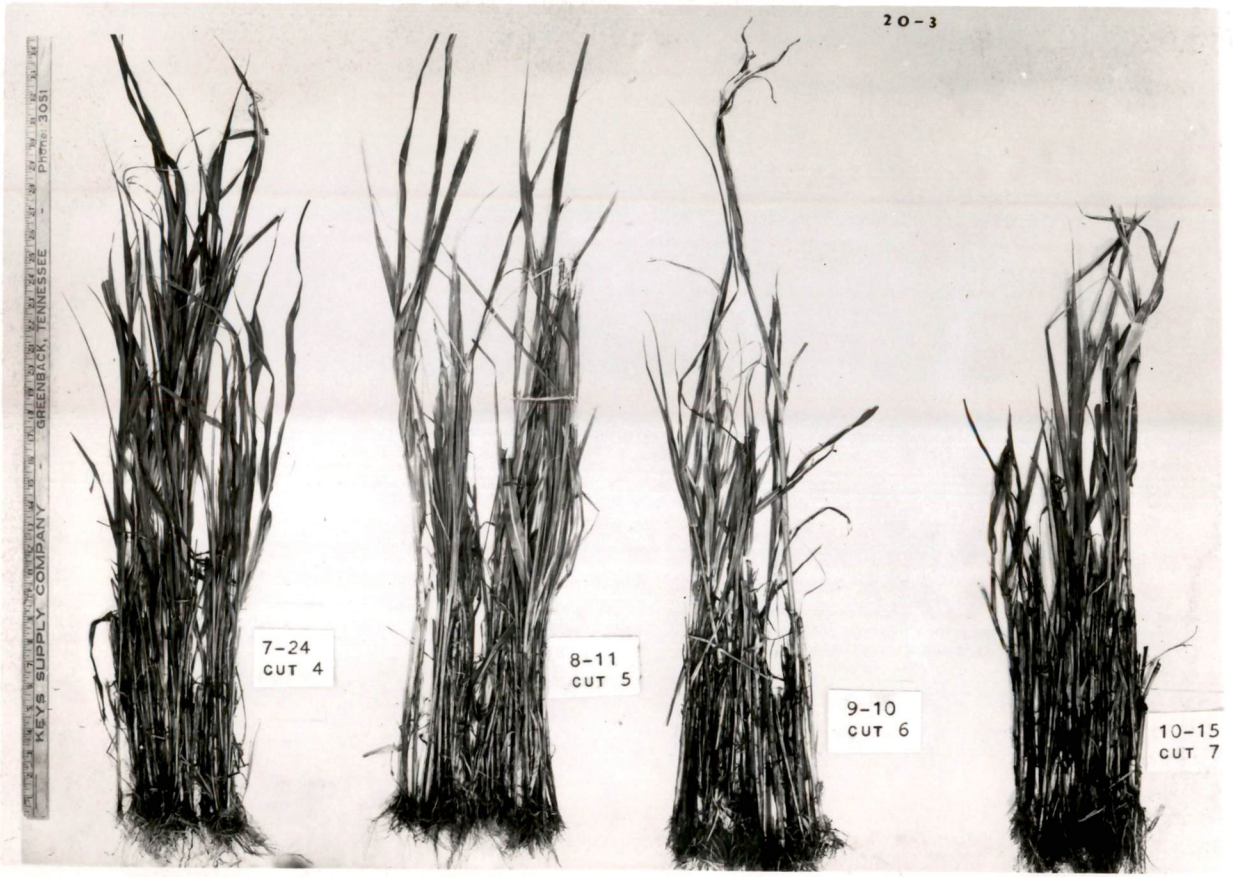


Figure 2.--Regrowth of Gahi-1 pearlmillet samples on selected cutting dates after being subjected to 20-3 cutting intensity.

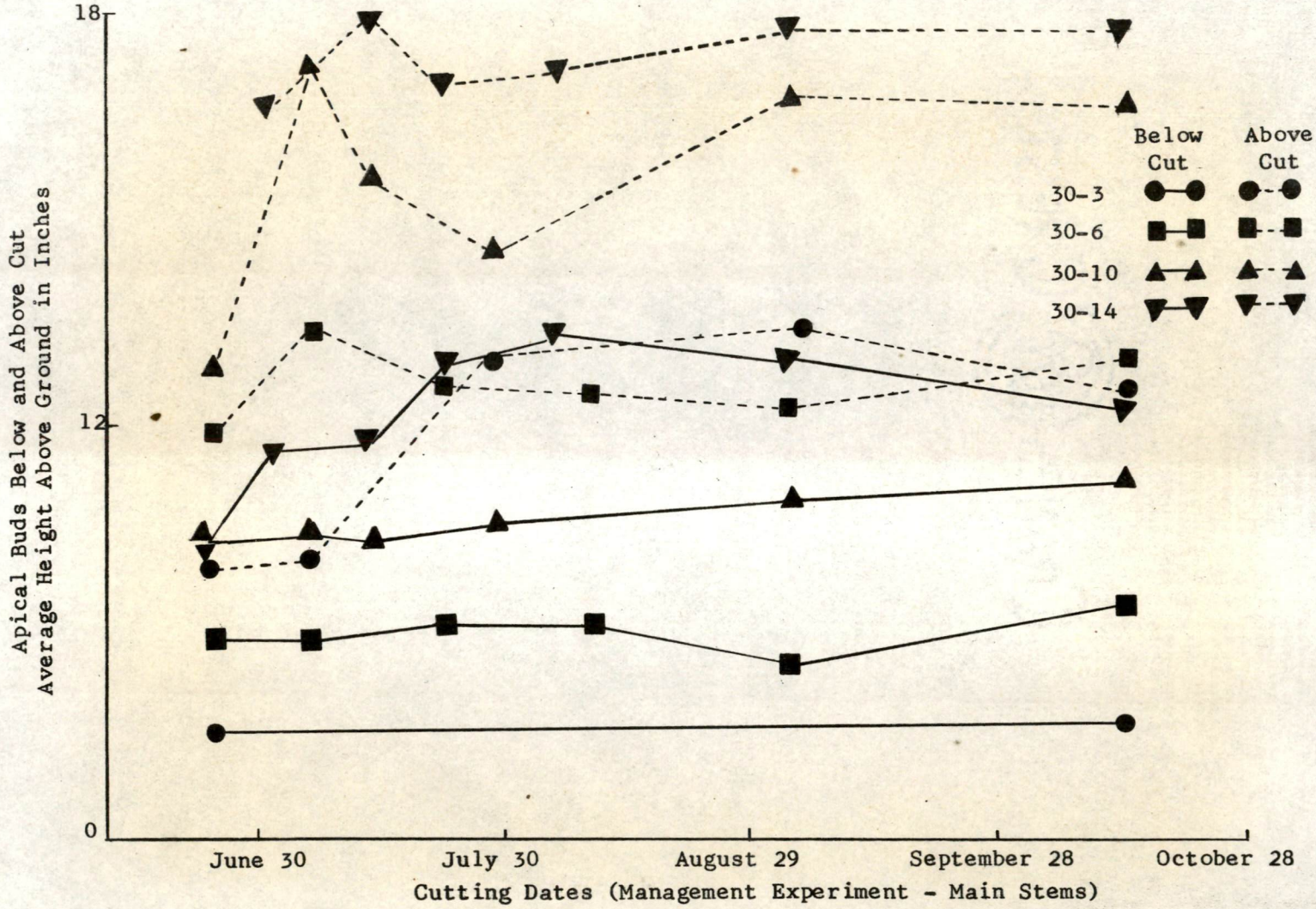


Figure 3--Seasonal distribution of average height of apical buds below and above scheduled cut in main stems under 30-3, 30-6, 30-10 and 30-14 cutting intensities.



Figure 4.--Regrowth of Gahi-1 pearlmillet samples on selected cutting dates after being subjected to 30-6 cutting intensity.



Figure 5.--Regrowth of Gahi-1 pearlmillet samples on selected cutting dates after being subjected to 30-14 cutting intensity.

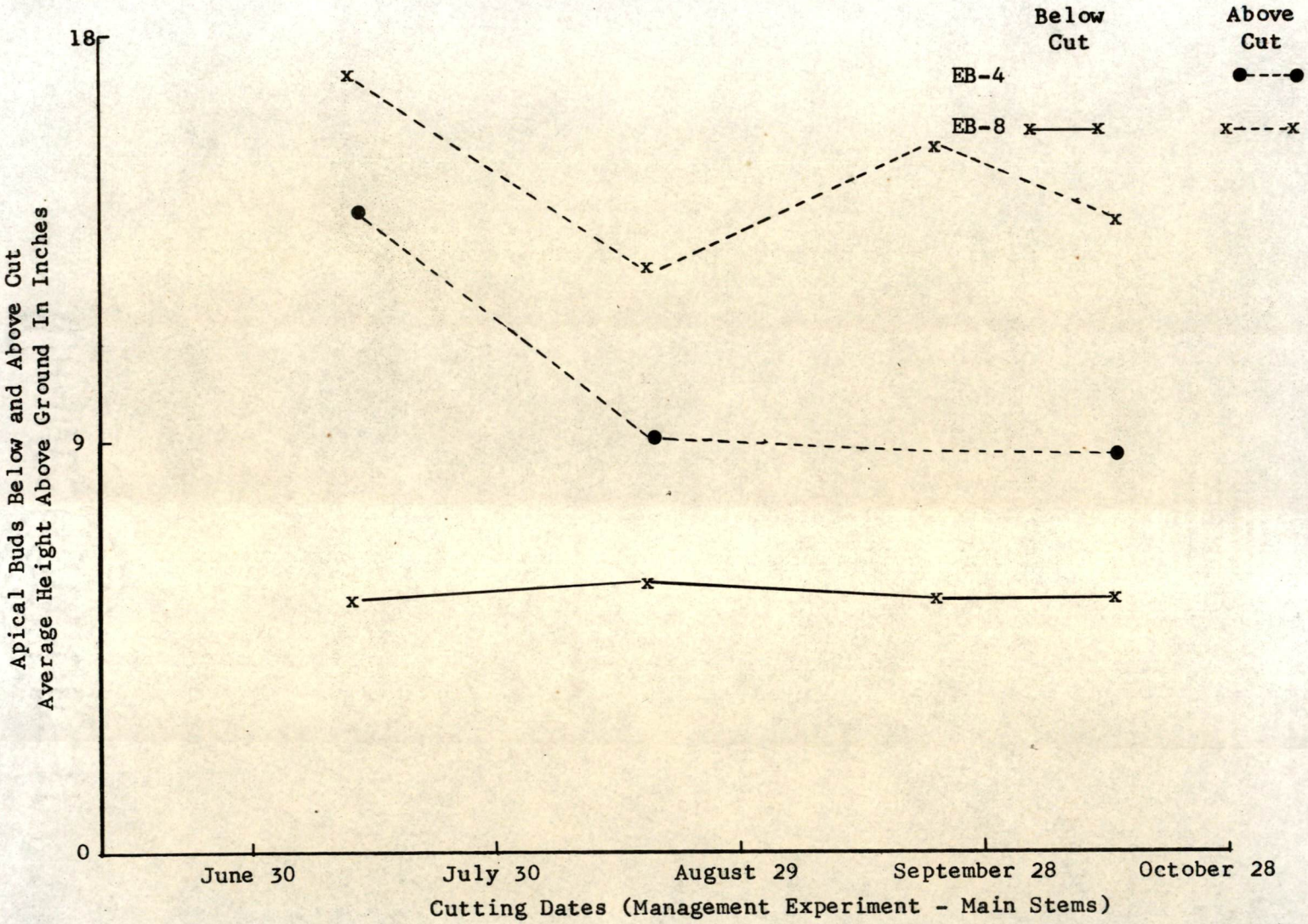


Figure 6--Seasonal distribution of average height of apical buds below and above scheduled cut in main stems under E.B.-4 and E.B.-8 cutting intensities.



Figure 7.--Regrowth of Gahi-1 pearlmillet samples on selected cutting dates after being subjected to E.B.-4 cutting intensity.

Buds occurring above the cut under 20-3 cutting intensity were at a height of about 6 inches in the first harvest and increased to about 9 inches at the time of the fourth harvest. Subsequently, the height ranged between 7 and 9 inches until the end of the growing season. On the other hand, the 20-6 cutting intensity did not show any sharp rise in the height of the bud above cut, but ranged between 7 and 9 inches. The 20-10 cutting intensity maintained a bud height above cut of between 11 and 12 inches.

The 30-3 cutting intensity had plants with apical buds below cut only at the first and at the last harvests, and the height of the buds averaged slightly less than 3 inches above ground. Under both 30-6 and 30-10 cutting intensity, the bud height was fairly constant at 4 to 5 inches under 30-6 and at 9 to 10 inches under 30-10. Under 30-14 cutting intensity, the height, which was about 9 inches at first, rose to 13 inches at fifth harvest and thereafter stayed at around 12 inches above ground.

The height of the apical buds occurring above cut under 30-3 cutting intensity underwent a sharp rise from the second to the third harvest, from 7 to 13 inches. The height was maintained at 13 inches during the fourth harvest and subsequently decreased to 12 inches toward the last cut. In the case of 30-6 cutting intensity, there was not much increase or decrease in the height of the bud above cut, this height ranging between 12 and 13 inches during the season. The 30-10 cutting intensity showed a sudden rise from 12 to 17 inches from first to second harvest. The bud height above cut gradually decreased to 14 inches

during the next two harvests and then returned to a height of about 17 inches. Under the 30-14 cutting intensity, the buds above cut fluctuated between 16 and 18 inches during the whole season.

There were no plants in E.B.-4 cutting intensity with buds below the cut. On the other hand, E.B.-8 cutting intensity started with an initial bud height below cut of about 6 inches and this height was almost constant throughout the season.

The E.B.-4 cutting intensity started with an initial bud height above cut of 15 inches which decreased to 9 inches in the second harvest and remained at that height. The E.B.-8 cutting intensity had a bud height above cut of about 18 inches in the first harvest; this height decreased to 14 inches in the second harvest and thereafter remained between 15 and 16 inches.

The regrowth of the stubble, formation of foliage and tillers, were distinctly affected by the different cutting intensities or frequency of defoliation. The cutting intensity 30-6 made better regrowth than the 20-3 intensity, but less rapid than the 30-14. The cutting intensity E.B.-4 showed a good stand of the crop because of fewer number of cuttings.

Percentages of stems with apical buds below and above scheduled heights of cuts

The percent of stems with apical buds below and above scheduled heights of cut are presented graphically in figures 8, 9, 10, 11 and 12.

Under the 20-3 cutting intensity, 20% or less of the primary

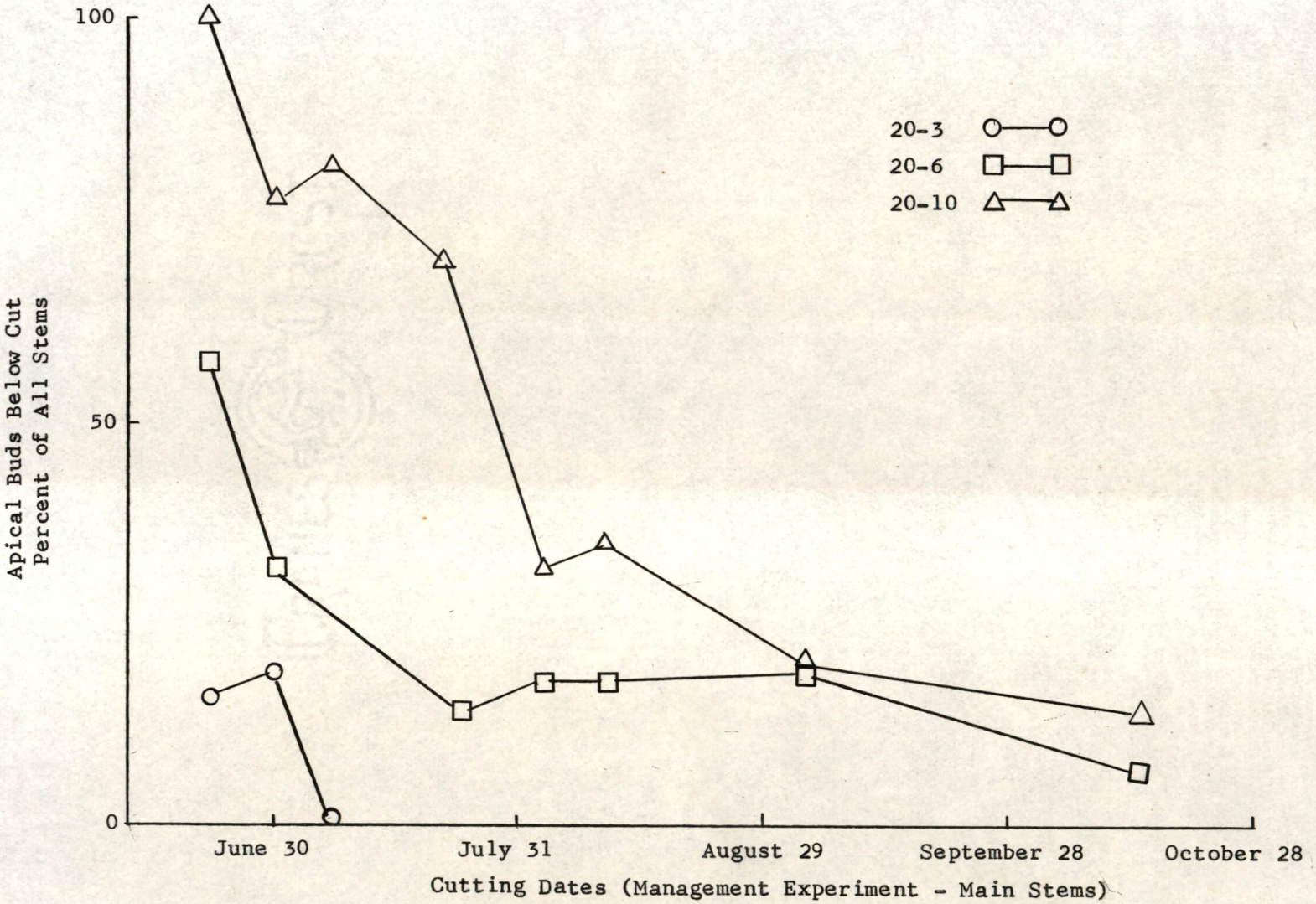


Figure 8--Seasonal distribution of percentages of main stems with apical buds below scheduled cut under 20-3, 20-6 and 20-10 cutting intensities.

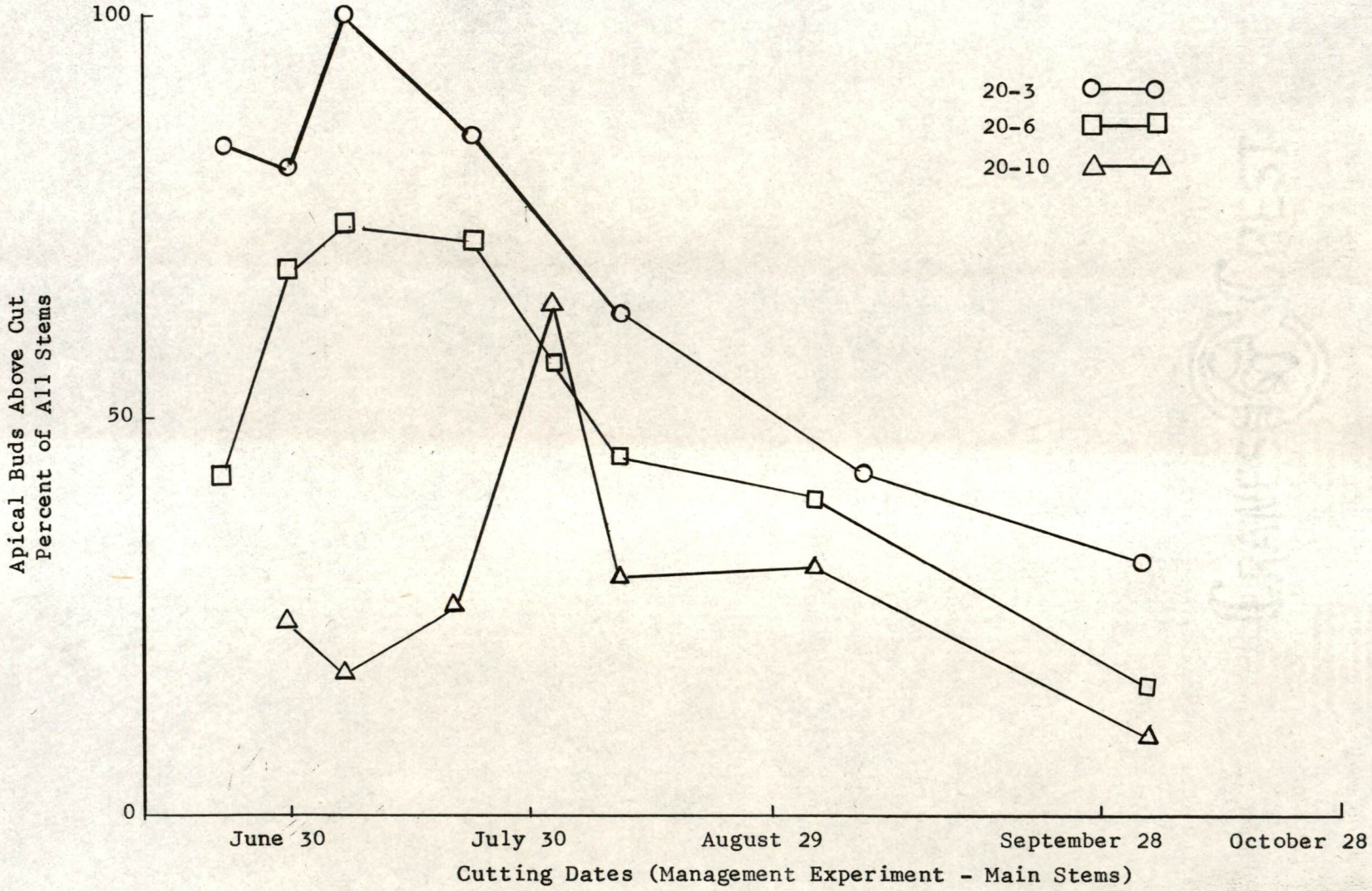


Figure 9--Seasonal distribution of percentages of main stems with apical buds above scheduled cut under 20-3, 20-6 and 20-10 cutting intensities.

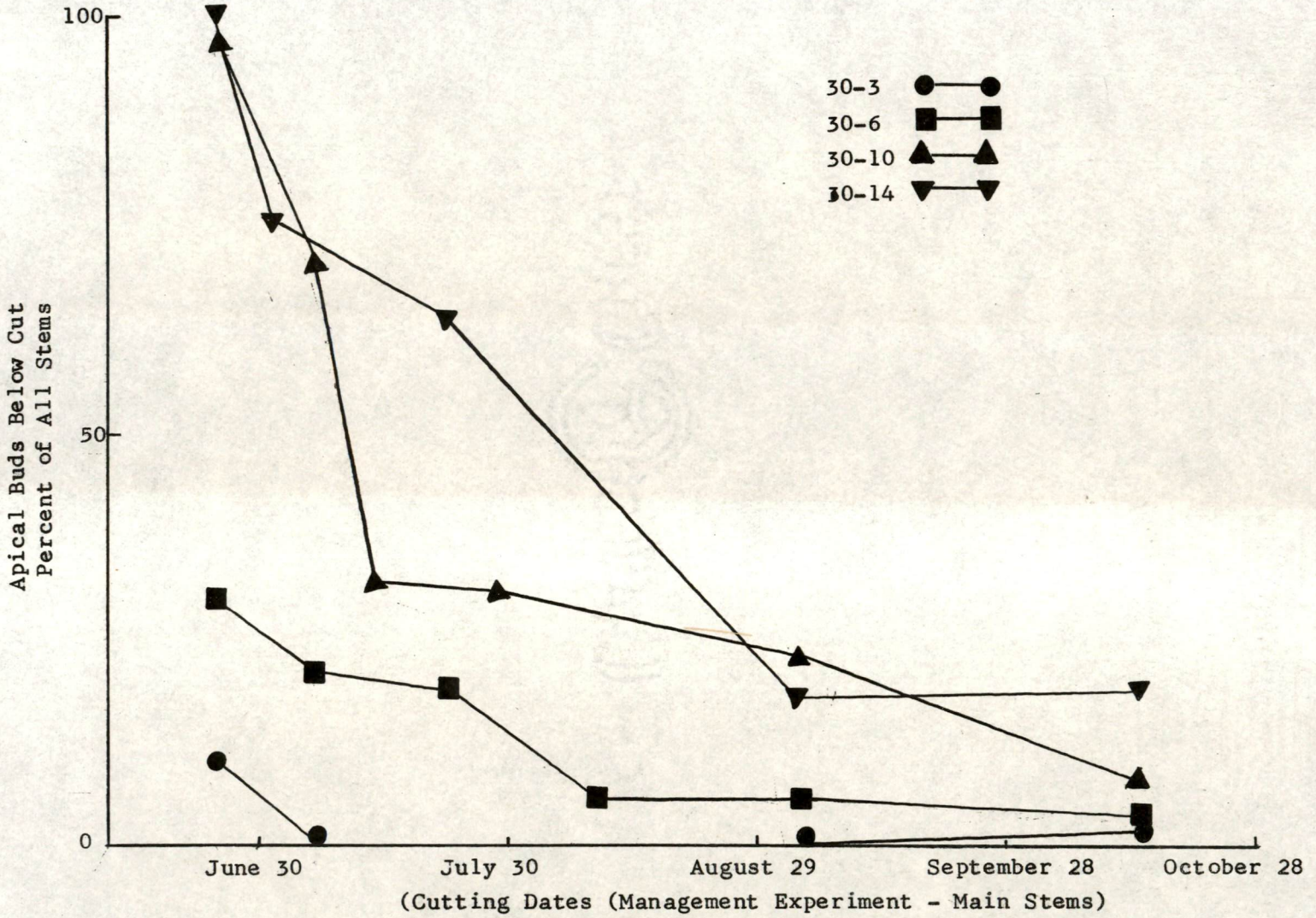


Figure 10--Seasonal distribution of percentages of main stems with apical buds below scheduled cut under 30-3, 30-6, 30-10 and 30-14 cutting intensities.

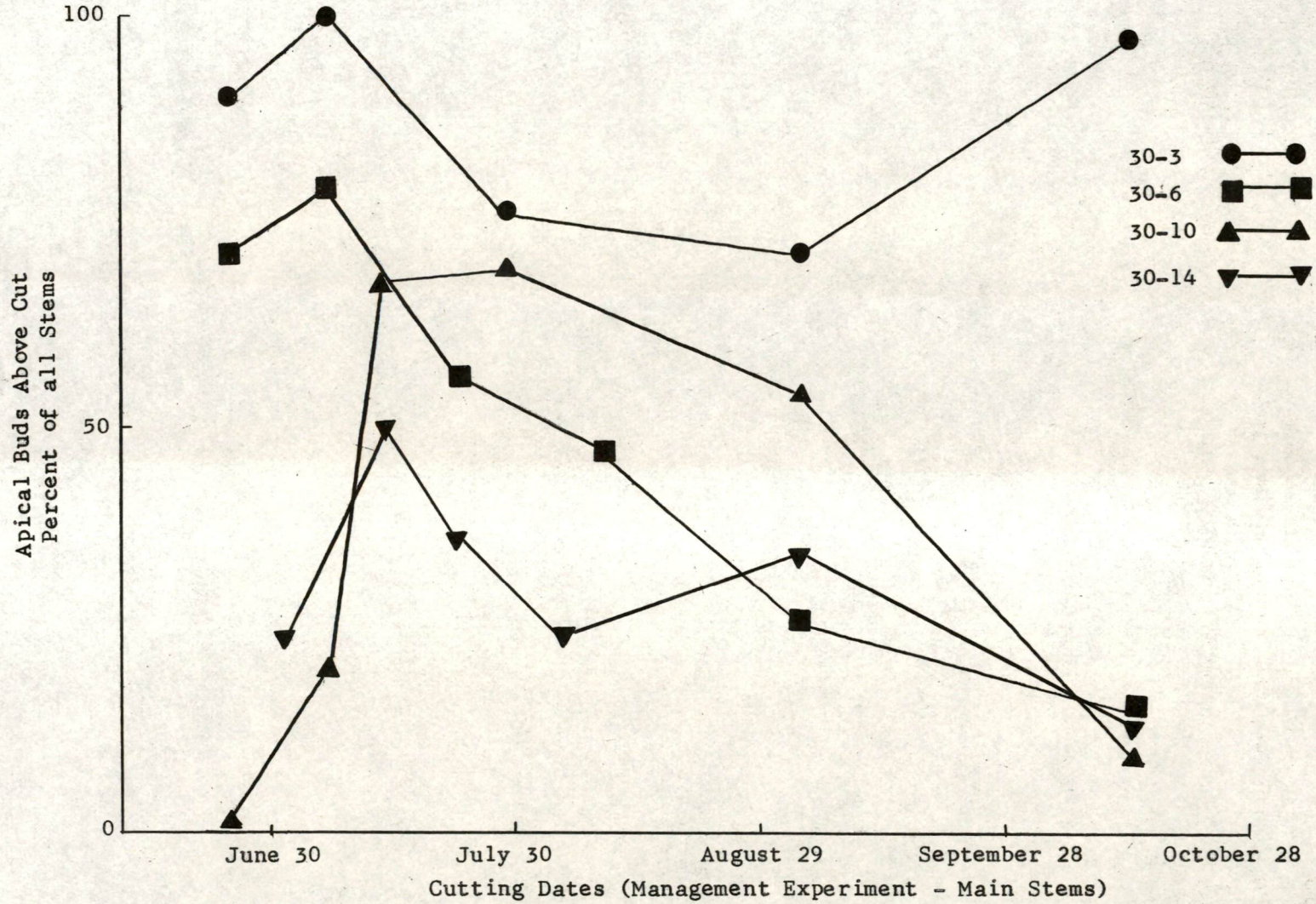


Figure 11--Seasonal distribution of percentages of main stems with apical buds above scheduled cut under 30-3, 30-6, 30-10 and 30-14 cutting intensities.

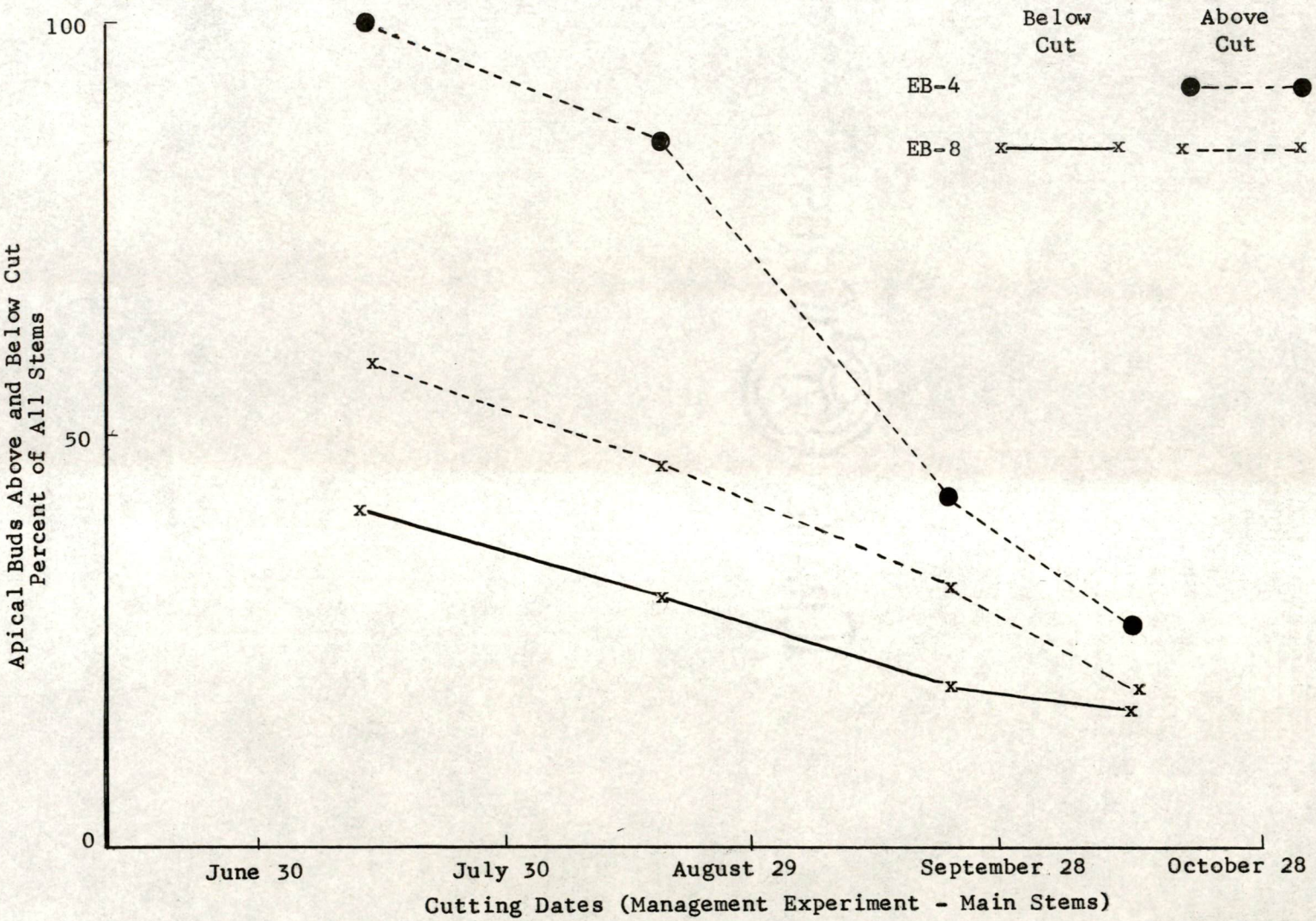


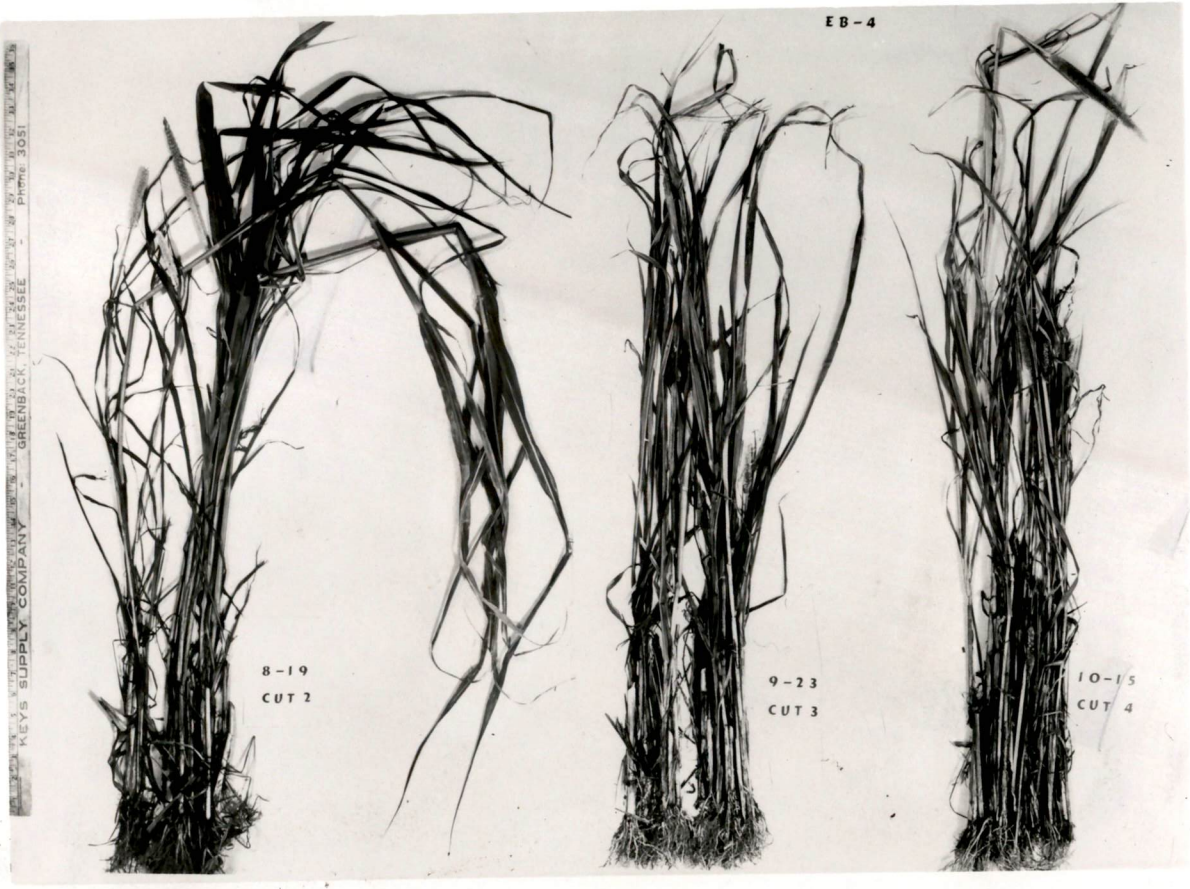
Figure 12--Seasonal distribution of percentages of main stems with apical buds below and above scheduled cut under E.B.-4 and E.B.-8 cutting intensities.

stems had buds below cut during the first and second harvest, and none thereafter. The 20-6 cutting intensity started with about 60% of its stems with buds below cut; this decreased gradually to about 10% toward the last harvest. All stems under the 20-10 cutting had apical buds below the cut at the first harvest, with a gradual decrease to about 20% toward the end of the season.

Although it might appear that the percent buds below cut and the percent above cut should be complementary and should add up to 100, this was not always the case. During the second half of the growing season some primary stems, through the removal of the apical buds, were killed either completely or at least back down to some adventitious bud as the season advanced.

Under 20-3 cutting intensity, about 80% of the stems in the first and second harvests and 100% in the third had buds above cut, but a general decrease during the remainder of the season reduced these percentages to 40 in October. Since no stems occurred at that time with buds below cut, it is apparent that 60% of the primary stems had no apical meristems at the end of the season. These main stems, then, were either dead or had tillered without growing back themselves. These characteristics will be discussed later. About 45% of the stems had buds above the cut under 20-6 treatment; this percentage increased up to 75 at the fourth harvest and gradually decreased to about 20 at the last harvest. This is consistent with the observed percentage of stems with buds below cut which gradually decreased from 55% down to 20% at the third harvest and remained fairly constant thereafter. The 20-10 cutting

EB-4



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intensity started with about 25% of its buds above cut in the first through the third harvest; however, this rose to 60% at the fourth harvest and then decreased sharply.

Under 30-3 cutting intensity only a few stems had buds below cut and then only at the first and the last harvest dates. Under 30-6 cutting intensity about 30% of the stems at first harvest had buds below cut and this gradually decreased to about 5%. Both 30-10 and 30-14 treatments had 100% of the stems with buds below the cut at first, but both decreased to about 20% at the end of the season. However, during July and August, there were slightly more stems with buds below cut under the 30-14 than under the 30-10 cutting intensity.

When a 30-inch crop was cut back to 3, 6, 10 and 14-inch stubble, large differences in the percentages of apical buds existed. Under 30-3 cutting intensity, at least 80% of the stems, at all times during the season, had buds above scheduled height of cut, and this occasionally increased to 90 or even 100%. The cutting intensity 30-6 had about 70 to 80% of the stems with apical buds above cut in the first and second harvests. The percentage gradually decreased to about 15% toward the end of the season. The 30-10 cutting intensity did not contain any plants with buds above cut at the first harvest, but the percentage had increased to 75% by the fourth harvest and then gradually decreased to the same level as that of 30-6 at the end of the season. The cutting intensity 30-14, with about 20% of the stems with buds above cut on the first harvest date, resulted in bud heights above cut in 50% of the stems at the second harvest, with a gradual decrease to the same level

as that of 30-6 and 30-10 cutting intensities on October 15, the last harvest date.

E.B.-4 had no plants with apical buds below the cut. E.B.-8 had about 45% of the stems with buds below cut on the first harvest date, with a decrease to about 20% by the end of the season.

Practically all stems under E.B.-4 cutting intensity had apical buds above cut, whereas only 60% of the stems under E.B.-8 were in that condition. Thus, 40% of the apical buds occurred between 4 and 8 inches above ground, and 60% above 8 inches, at time of early bloom. With the decrease in height of plants harvested at early bloom associated with advance of the season, percent of stems with buds above cut decreased to 30% or less.

Percentages of stem weights occurring above scheduled height of cut

The percentages of the stem weights occurring above the scheduled heights of cut for the various cutting intensities are presented graphically in figures 13, 14 and 15.

The 20-3 cutting intensity had about 50% of stem weight above the cut on the first harvest date and about 75% on the last. On the other hand, under both 20-6 and 20-10 cutting intensities, only 20% of the stem weight occurred above cut on the first cutting date. In the case of 20-6, this increased to about 60% in the third cut and then decreased to 30 to 40% thereafter.

Under 20-10 cutting intensity, only 20% of the stem weight occurred above cut through the middle of August; this percentage then increased up to 40% at the end of the season.

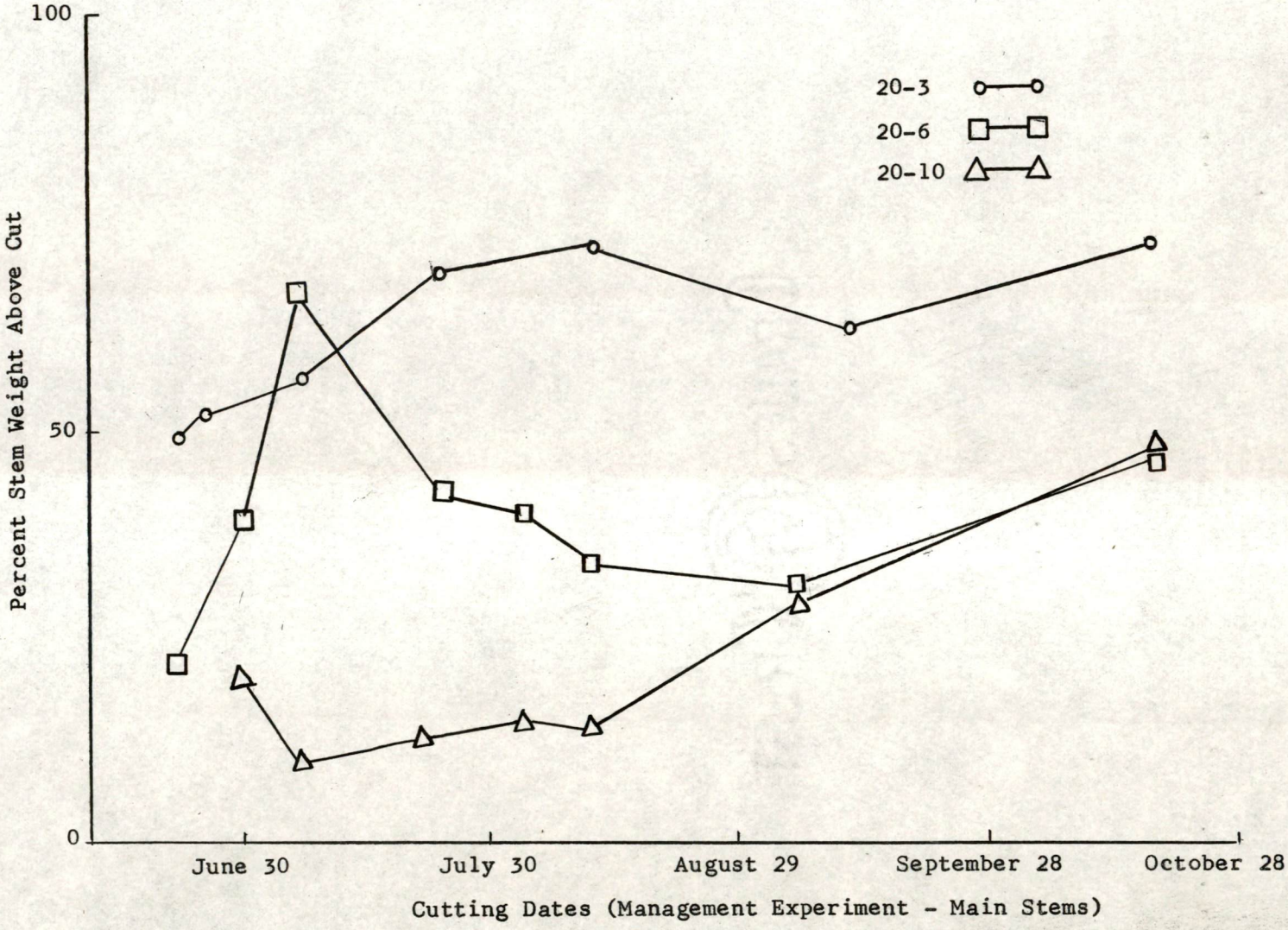


Figure 13--Seasonal distribution of percentages of main stem weights occurring above scheduled cut under 20-3, 20-6 and 20-10 cutting intensities.

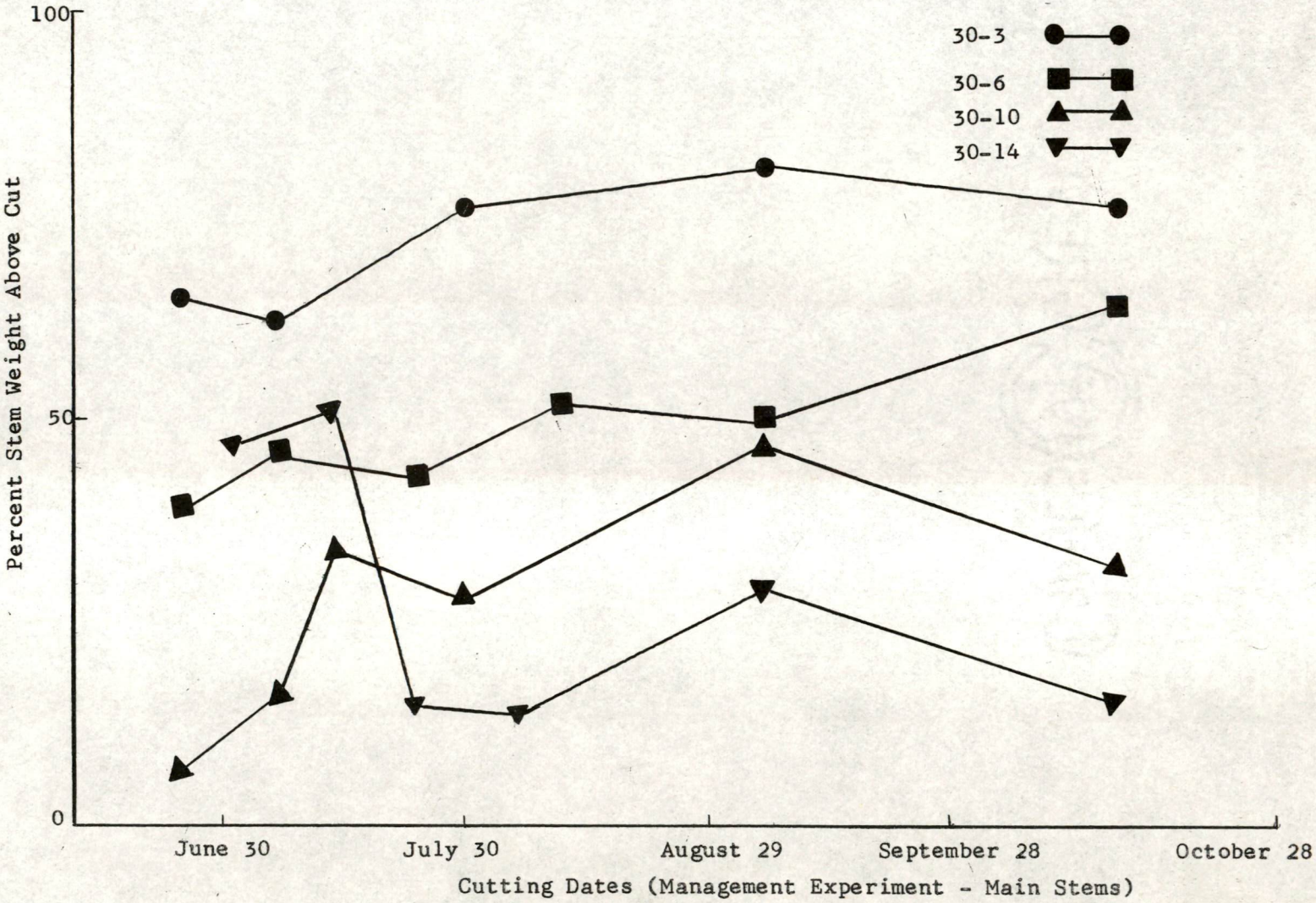


Figure 14--Seasonal distribution of percentages of main stem weights occurring above scheduled cut under 30-3, 30-6, 30-10 and 30-14 cutting intensities.

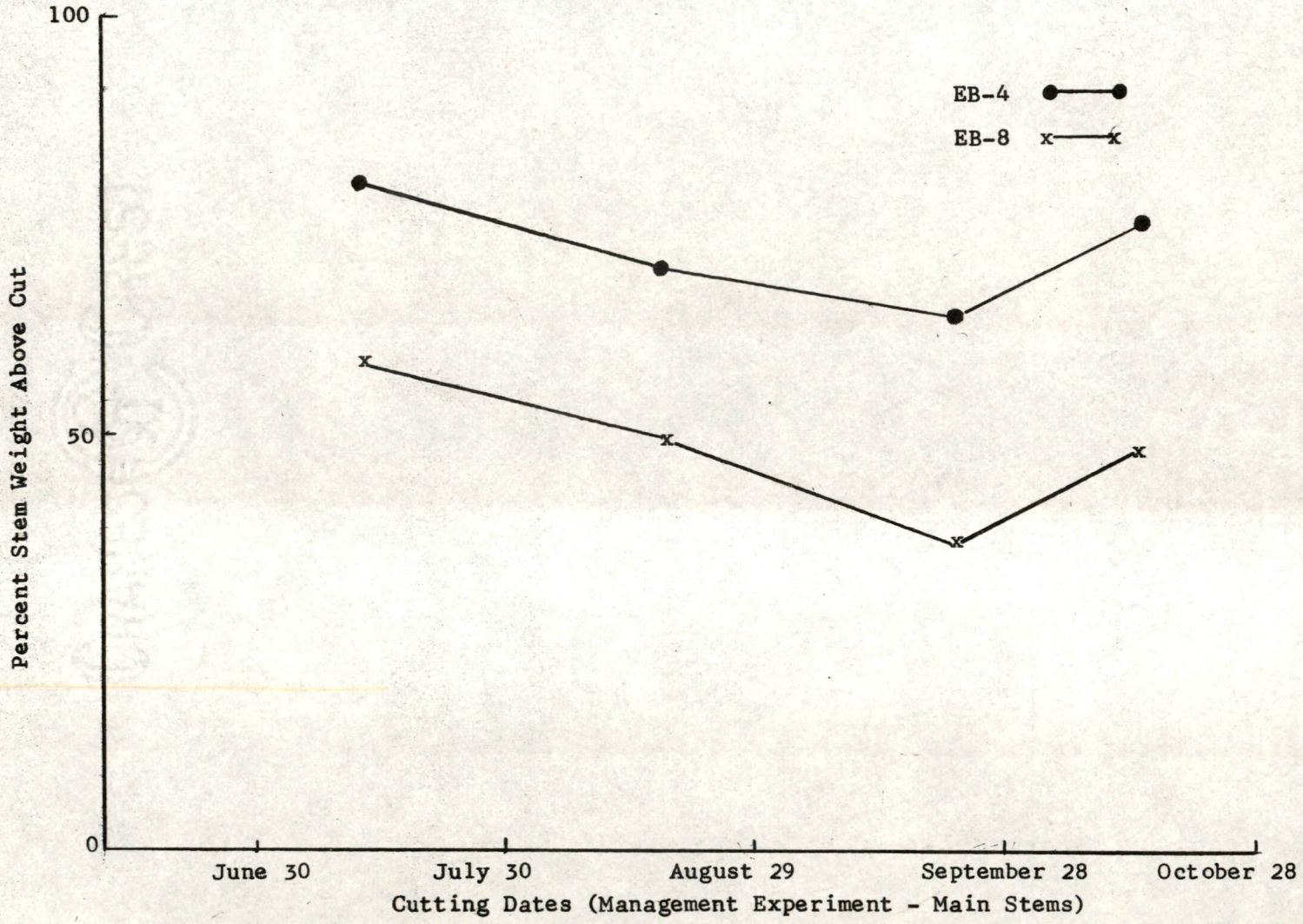


Figure 15--Seasonal distribution of percentages of main stem weights occurring above scheduled cut under E.B.-4 and E.B.-8 cutting intensities.

Percent stem weight occurring above cut remained fairly constant at 70 to 80% under 30-3 cutting intensity, and at 40 to 60% under 30-6 cutting intensity. On the other hand, only 5 to 10% of stem weight occurred above cut under a 30-10 cutting management at the first two harvests and 30 to 40% later in the season. A somewhat different situation took place under the 30-14 cutting intensity; there, 50% of stem weight was above cut at the first two harvests, and only 10 to 20% later. This discrepancy early in the season may have been due to the fact that the 30-14 plots were harvested just a few days later than the 30-10 plots.

The percent stem weight above the scheduled height of cut under E.B.-4 cutting intensity ranged between 75 and 85% and, under E.B.-8, between 45 and 55%. The similarity between the two curves shows that about 20% of the total stem weight occurred throughout the season between 4 and 8 inches above ground.

In tillers also, the same trends of percent stem weight above cut were observed as in the case of main stems (Appendix B). The cutting intensity 30-3 maintained a higher percent stem weight above cut. However, when the frequency of cuttings is taken into consideration the 6, 10 and 14-inch stubble showed a rapid recovery after cutting at each time. The cutting intensity E.B.-4 also showed a higher percent stem weight above the scheduled height of cut, but the recovery of the stubble after each cutting was slow.

Dry weight of live leaves per 100 plants

The seasonal distribution of weight of live leaves from primary

stems per 100 plants is graphically presented in figures 16, 17 and 18.

It is apparent that, under all treatments, the weight of leaves per plant generally decreased from beginning to end of the growing season, this decrease being more marked for those plants allowed to reach an early bloom stage of maturity than for the others. Plants allowed to reach a height of 20 inches before cutting had about 35 to 50 grams of leaf per 100 plants at the first harvest, as compared to 40 to 55 grams for the 30-inch growth. On the other hand, early bloom growth had more than twice that much leaf weight per plant in June. It is remarkable, however, that all treatments finished the seasonal growth with only 10 to 20 grams of leaf dry weight per 100 plants. This gradual but marked decline in leaf weight per plant through the season may in fact explain the decreasing daily forage productions obtained from Gahi-1 pearlmillet at the end of the summer and in early fall. Similar trends in weight of leaves were observed for tillers (Appendix B), except for the fact that they maintained a larger leaf weight over a longer period in the season.

Leaf/stem ratios of primary stems on dry weight basis

The leaf/stem ratios for the different cutting intensities are presented graphically in figures 19, 20 and 21.

Leaf/stem ratios superior to 1.0 and as much as 1.5 were observed for the 20-inch growth at the first two harvests. From then on, a slow decrease to a ratio ranging between 0.5 and 0.9 was observed. Up until the middle of August, there was no appreciable difference between the three stubble-height treatments. After that time, it appeared that 20-3

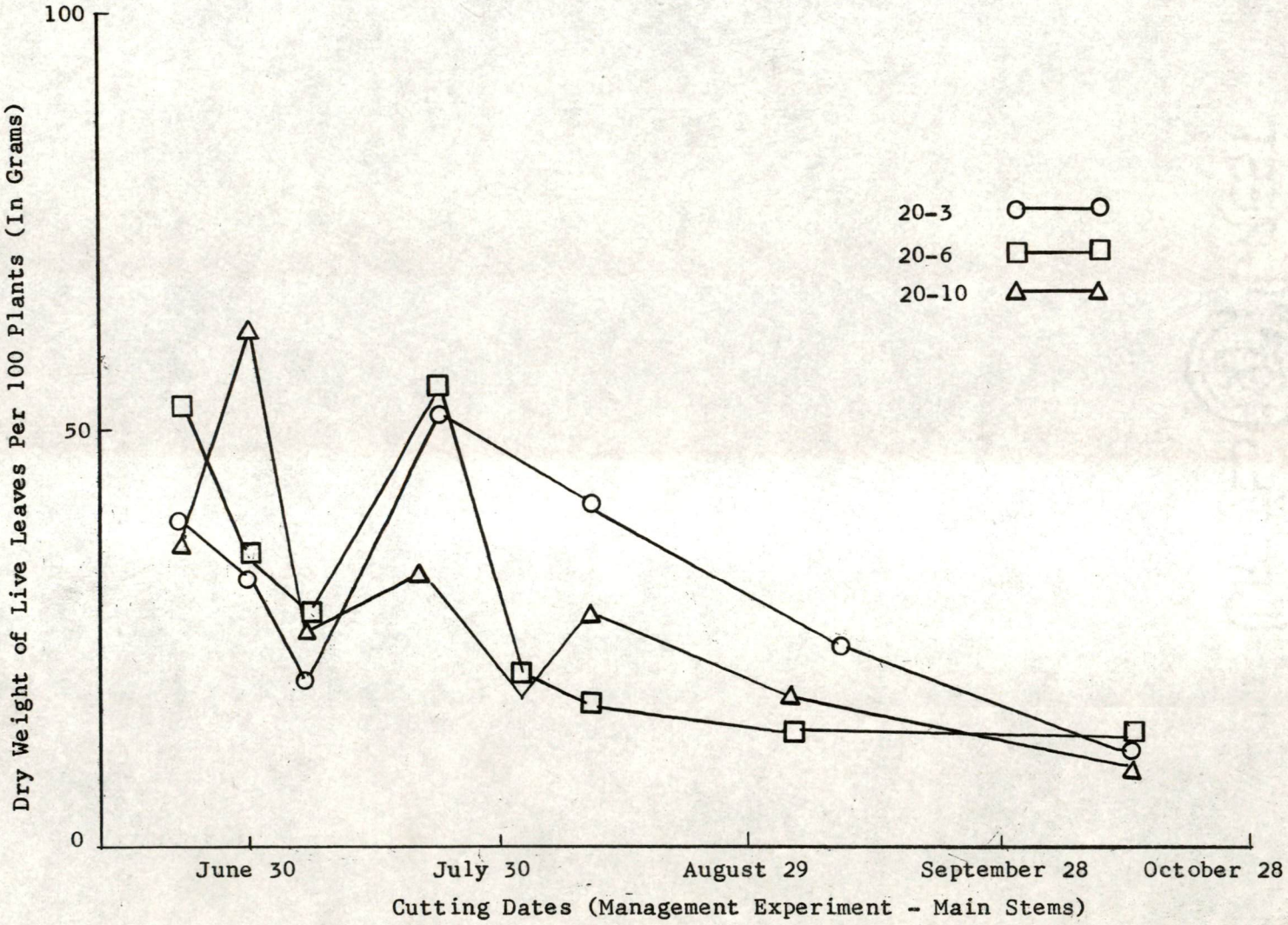


Figure 16--Seasonal distribution of dry weights per 100 plants of live leaves from main stems under 20-3, 20-6 and 20-10 cutting intensities.

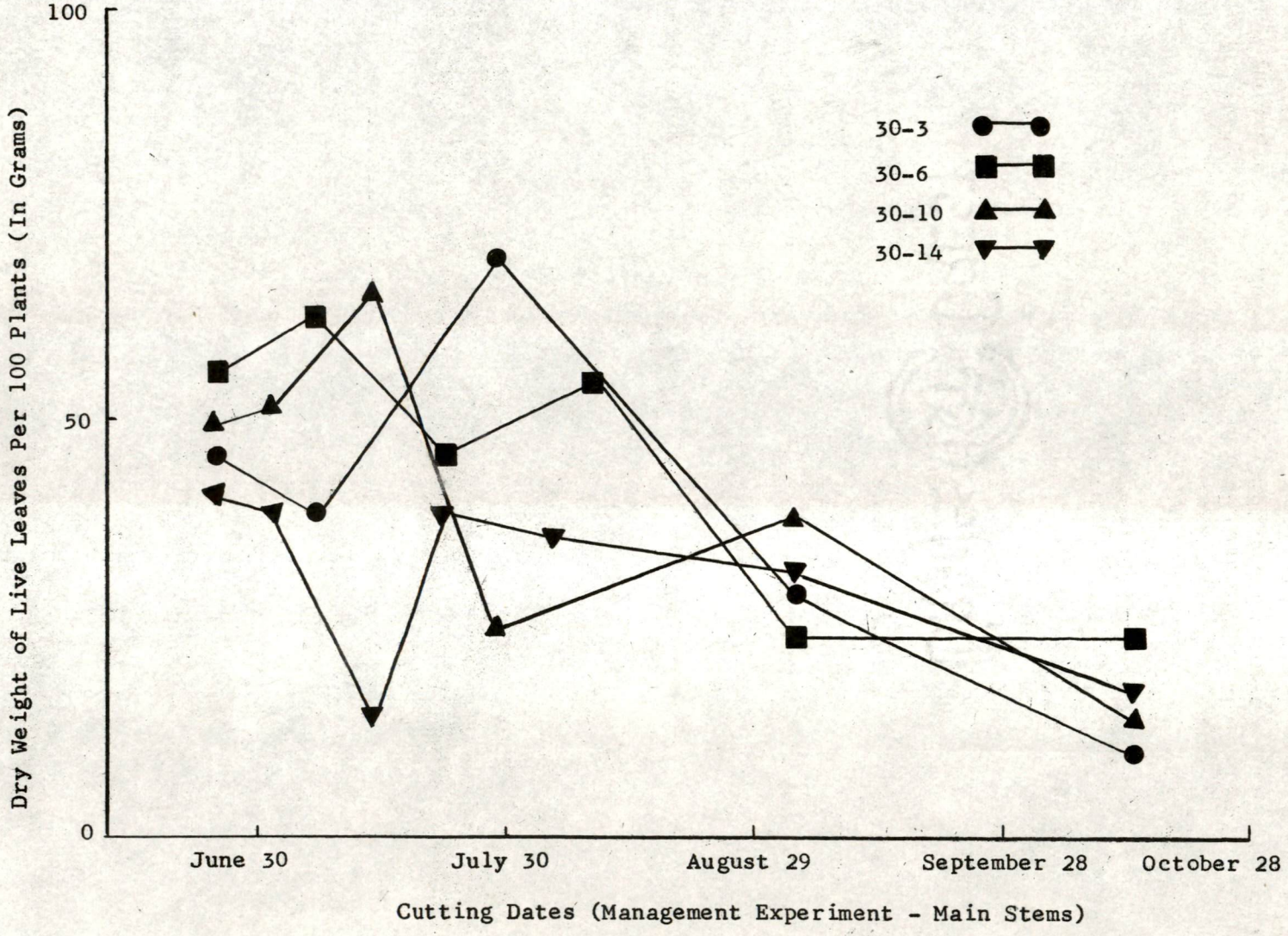


Figure 17--Seasonal distribution of dry weights per 100 plants of live leaves from main stems under 30-3, 30-6, 30-10 and 30-14 cutting intensities.

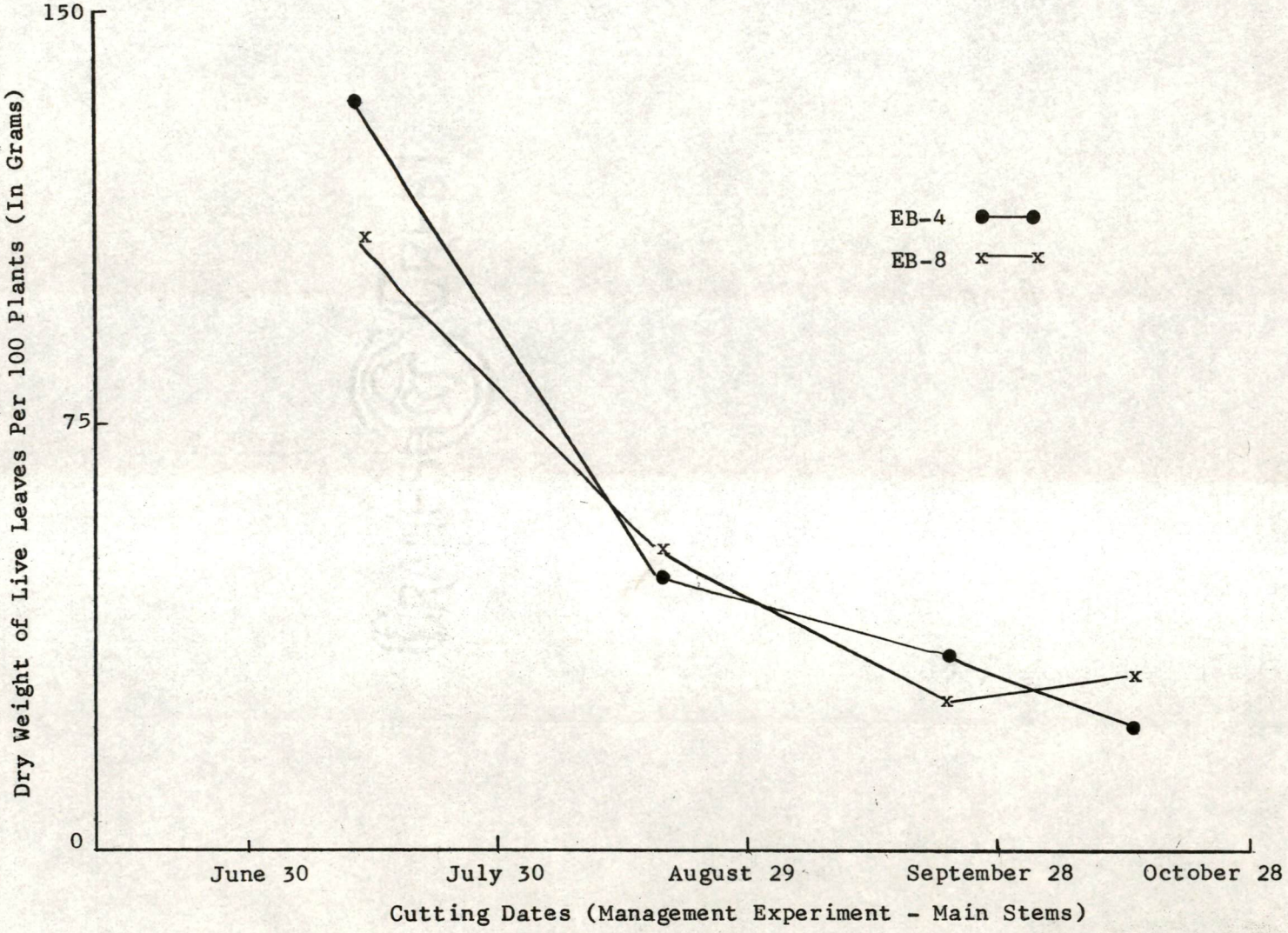


Figure 18--Seasonal distribution of dry weights per 100 plants of live leaves from main stems under E.B.-4 and E.B.-8 cutting intensities.

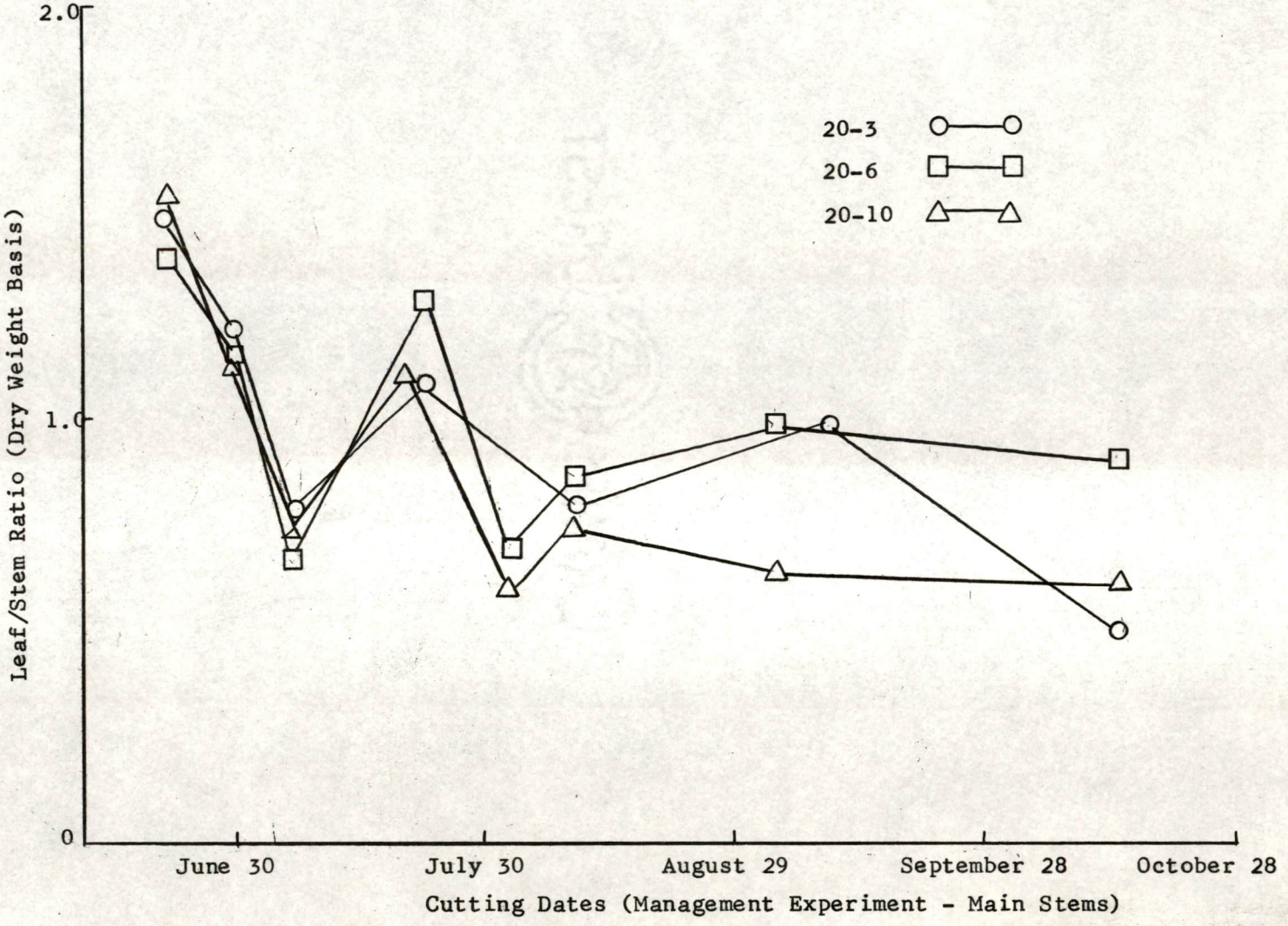


Figure 19--Seasonal distribution of leaf/stem ratios of main stems on a dry weight basis under 20-3, 20-6 and 20-10 cutting intensities.

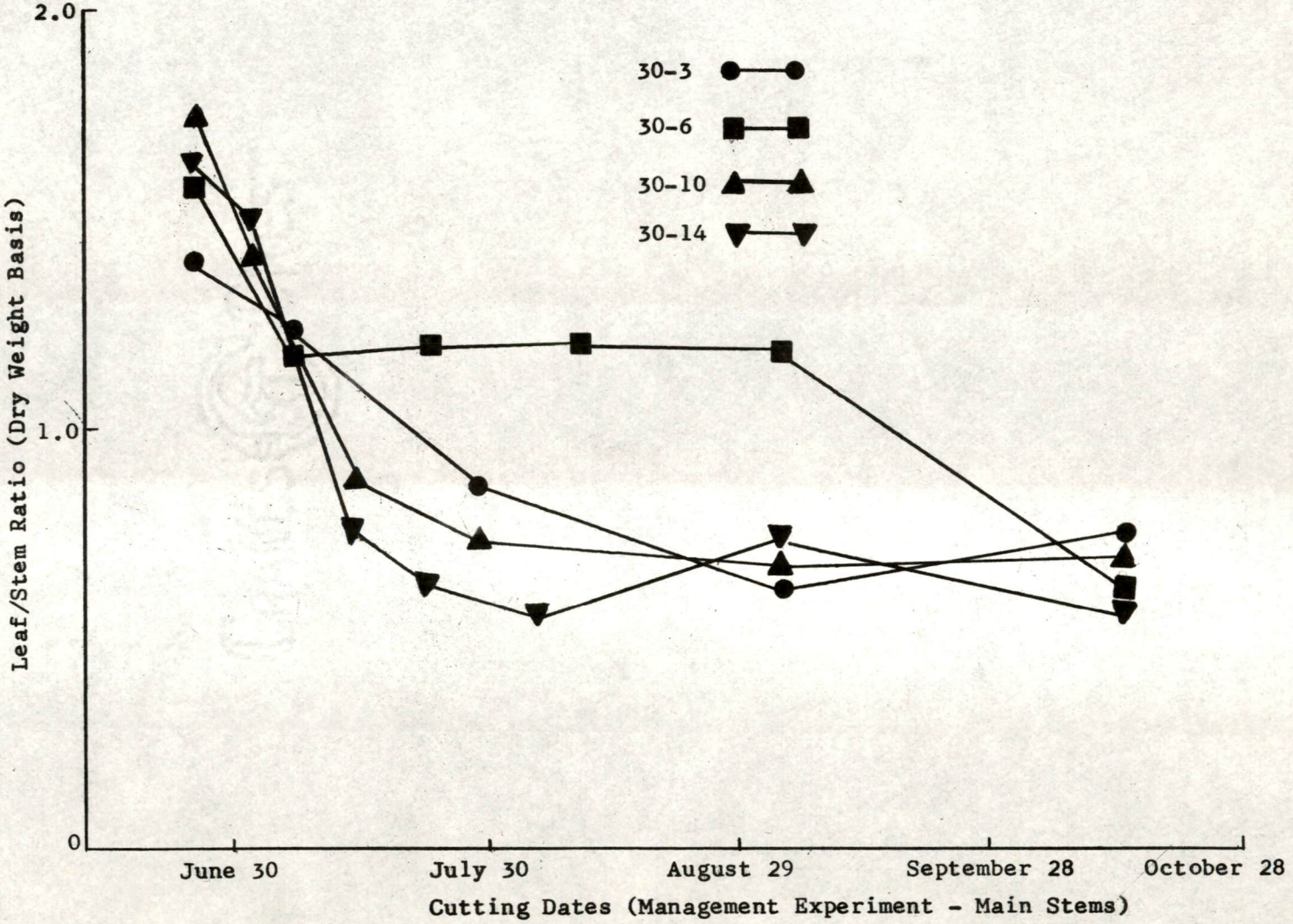


Figure 20--Seasonal distribution of leaf/stem ratios of main stems on a dry weight basis under 30-3, 30-6, 30-10 and 30-14 cutting intensities.

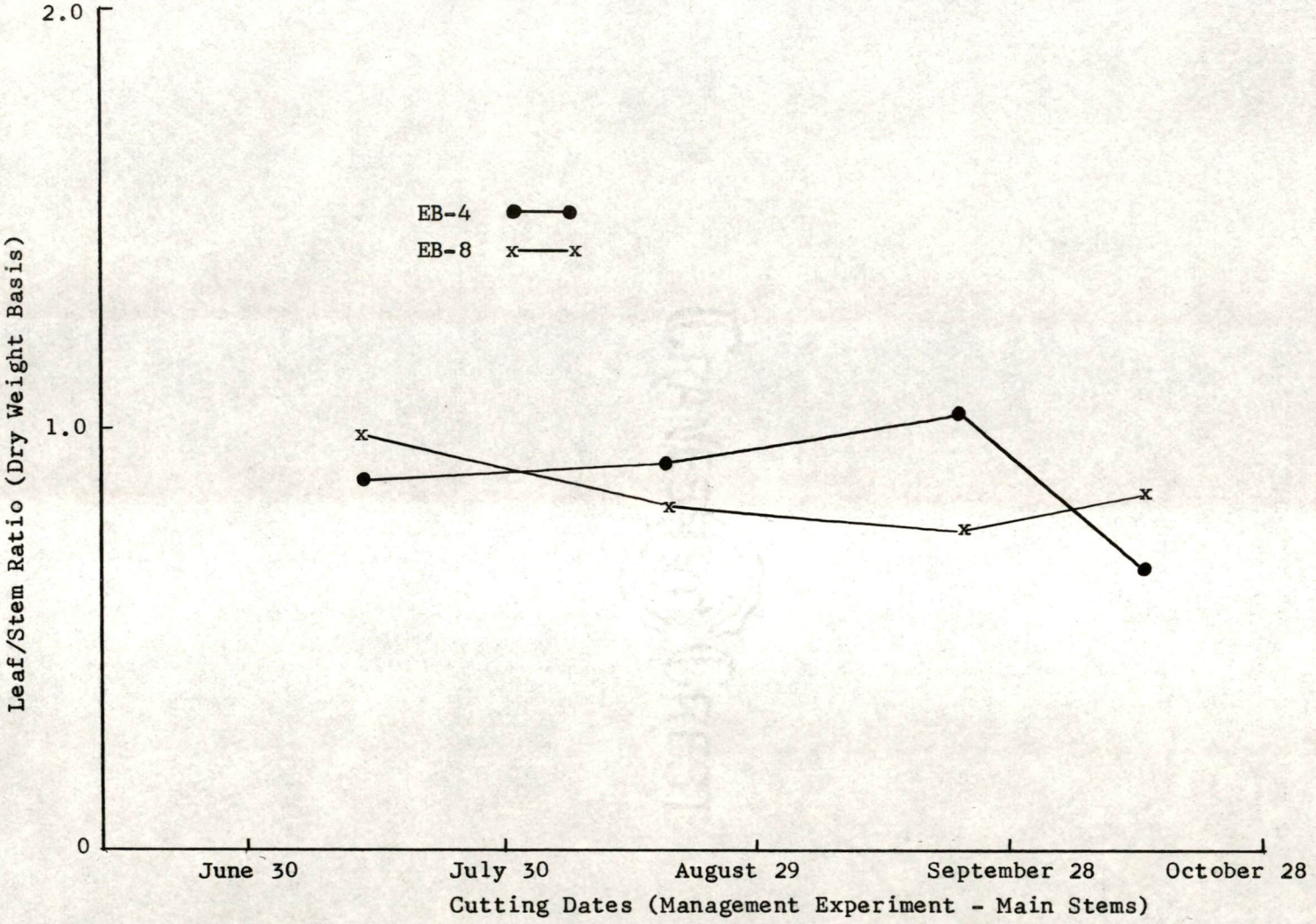


Figure 21--Seasonal distribution of leaf/stem ratios of main stems on a dry weight basis under E.B.-4 and E.B.-8 cutting intensities.

and 20-6 cutting intensities resulted in slightly higher leaf/stem ratios than the 20-10 management, indicating that a larger proportion of the regrowth in the latter treatment was from leaves than in the other two treatments.

There was little difference among the 30-inch growth treatments during the early part of the season as to leaf/stem ratios. At the time of first harvest, leaf/stem ratios of 1.3 to 1.6 indicated a large proportion of leaves on a dry weight basis. After the third harvest, the leaf/stem ratios for the 30-3, 30-6 and 30-10 treatments dropped below 1.0, and remained fairly constant at 0.6 to 0.8. The 30-6 cutting intensity behaved somewhat differently, the leaf/stem ratio remained at 1.1 through August, and dropping to 0.6 only at the last harvest. Reasons for this are not readily apparent.

Both E.B.-4 and E.B.-8 treatments behaved quite differently from the 20-inch and 30-inch growths treatments. The leaf/stem ratios observed for both early-bloom growth treatments remained constantly at 0.9 to 1.0 throughout the season.

In tillers also, the same trend was observed except that 30-14 cutting intensity maintained a slightly higher ratio than the main stems for that treatment (Appendix B).

Average number of tillers per plant

A graphic analysis of the average number of tillers is presented in figures 22, 23 and 24.

There were not many differences between the average number of tillers among the three treatments, 20-3, 20-6 and 20-10, throughout the

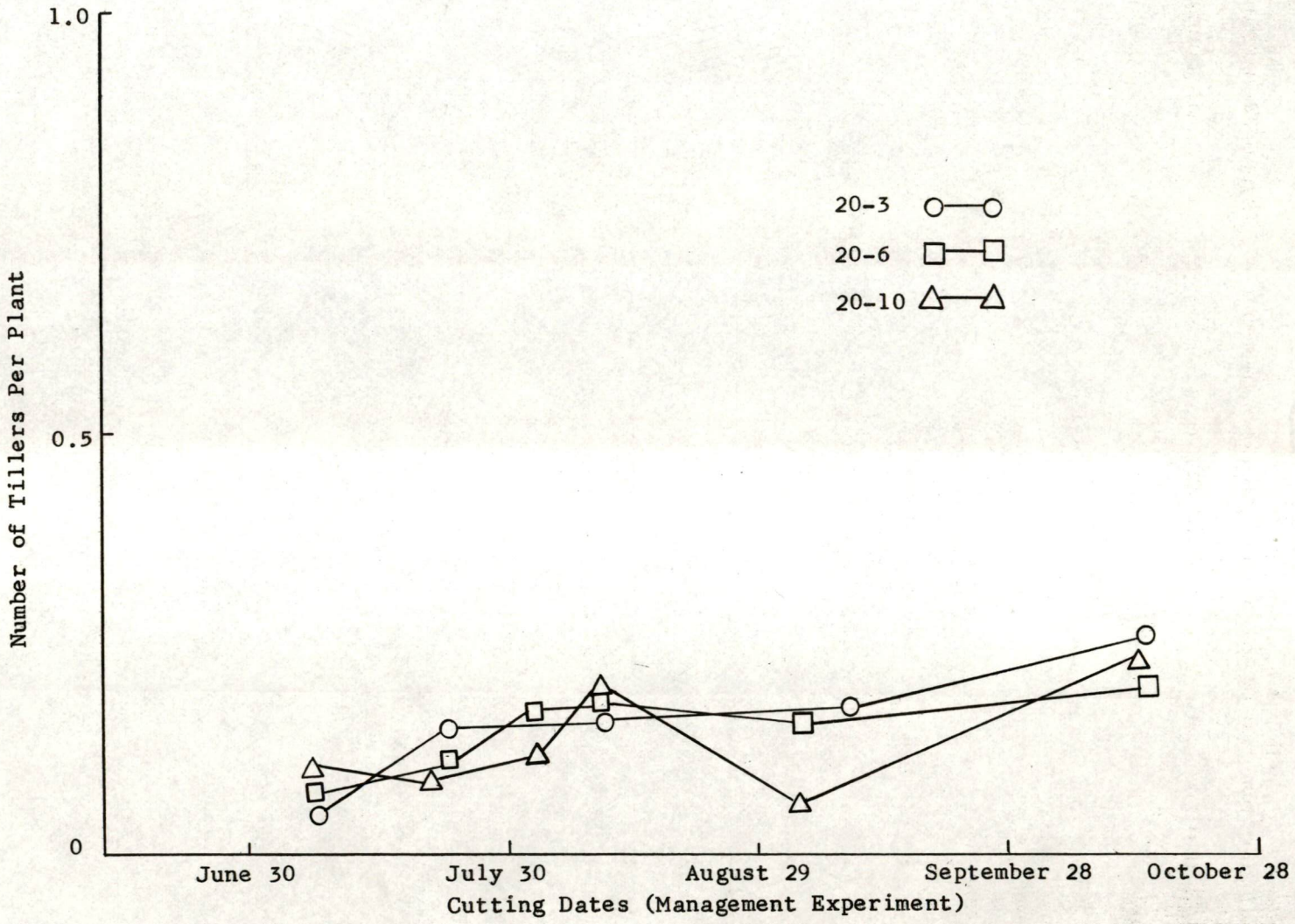


Figure 22--Seasonal distribution of average number of tillers per plant under 20-3, 20-6 and 20-10 cutting intensities.

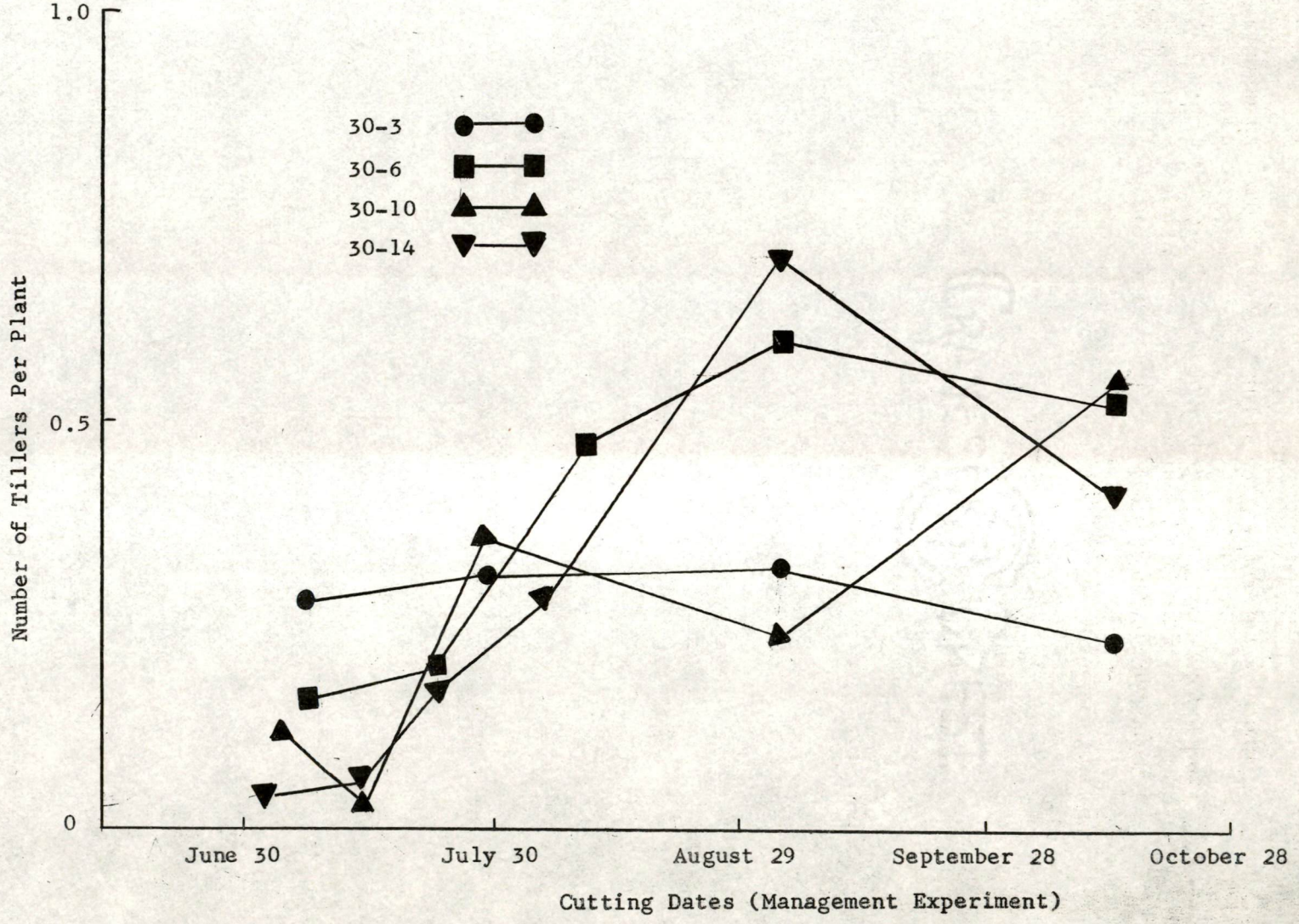


Figure 23--Seasonal distribution of average number of tillers per plant under 30-3, 30-6, 30-10 and 30-14 cutting intensities.

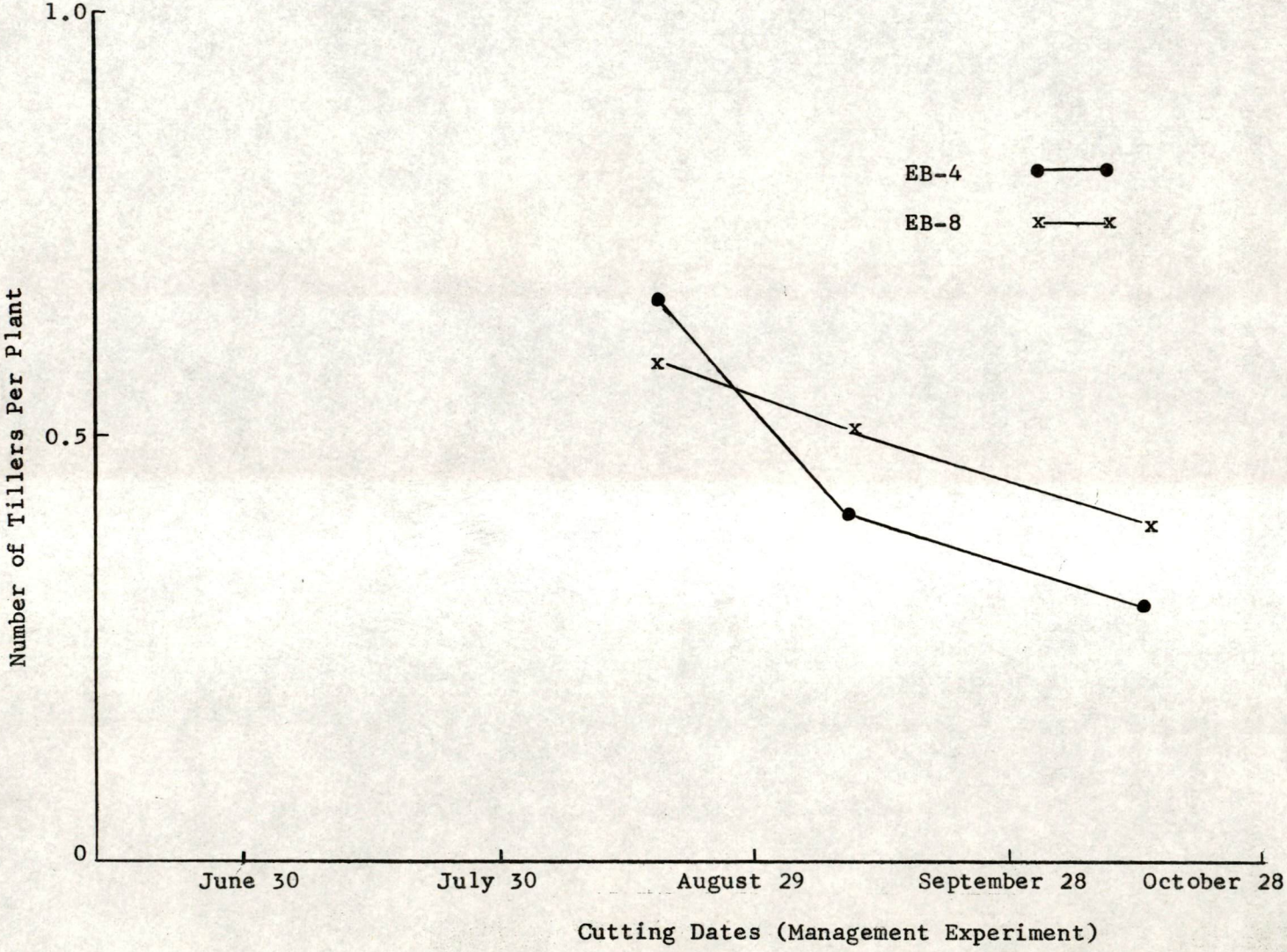


Figure 24--Seasonal distribution of average number of tillers per plant under E.B.-4 and E.B.-8 cutting intensities.

season. At first, about 0.1 tiller per plant was observed, and this number increased gradually to 0.2 to 0.3 in October.

A very different situation was encountered among those treatments allowed to reach a height of 30 inches of growth. The average number of tillers per plant under 30-3 cutting intensity ranged fairly constantly between .2 to .3 throughout the season. On the other hand, 30-6, 30-10 and 30-14 treatments had marked increases in tiller number from June through October. At first, there was only an average of 0.1 to 0.2 tiller per plant. The number increased with almost every harvest through August, up to 0.5 to 0.6 tiller per plant, and then tended to decrease slightly at the last harvest. The one exception to this general trend, for which there is no ready explanation, was a count of about 0.25 tiller per plant at the August harvest of 30-10.

The early bloom treatments behaved very differently from the other seven treatments. There were no tillers at the time of the first harvest, over 0.6 tiller per plant at the second harvest, and fewer later in the season. There appeared to be slightly fewer tillers under an E.B.-4 than an E.B.-8 system of management.

Percentages of dead main stems

The percentages of dead main stems for the various treatments are presented graphically in figures 25, 26 and 27.

When 20-inch growth was cut down to 3, 6 or 10-inch stubble, no main stems were killed until after the third harvest. At the time of fourth harvest, 15% of the main stems under 20-3 and 20-6 cutting intensities were dead. Under 20-10 cutting intensities, on the other hand,

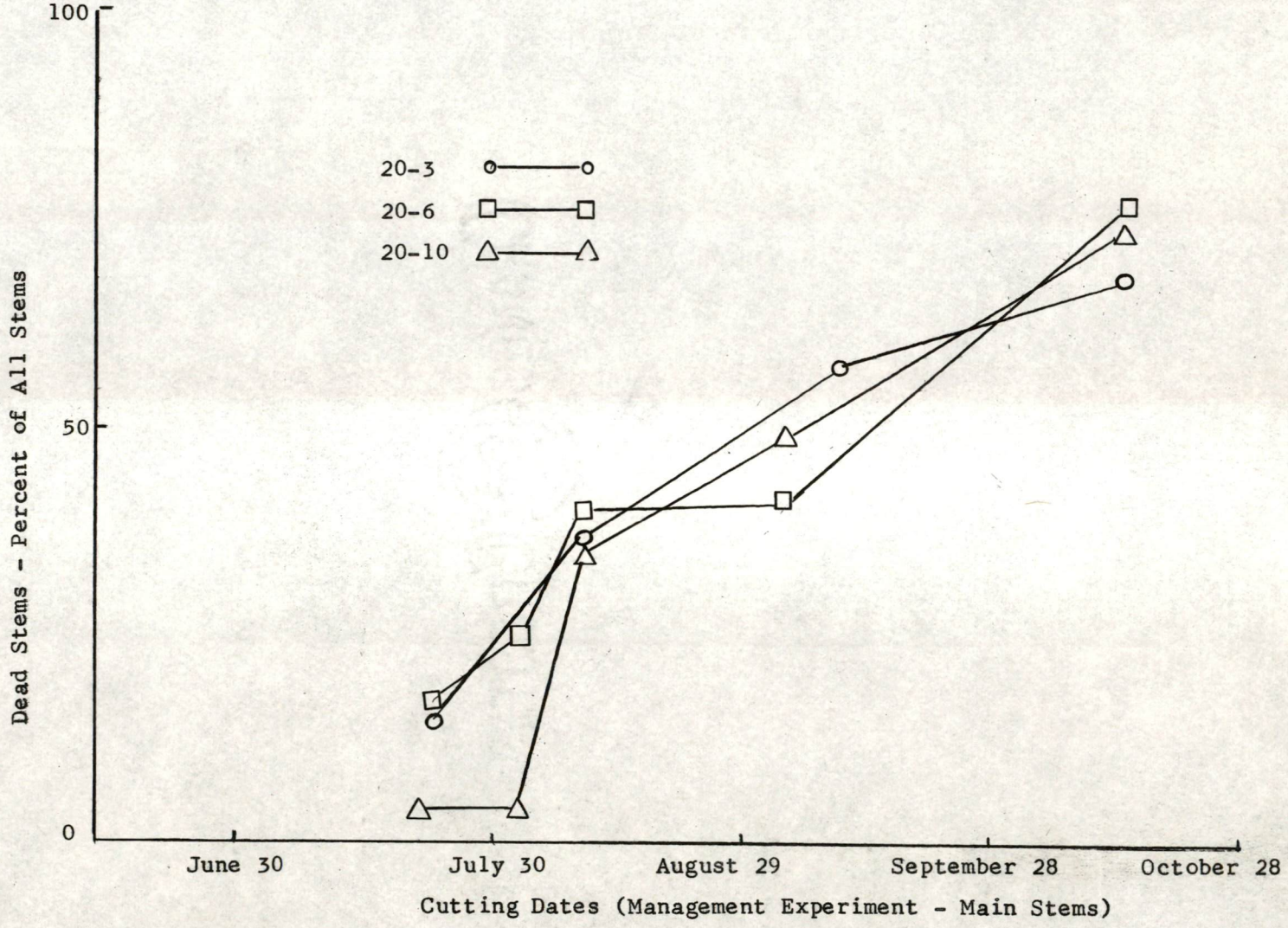


Figure 25--Seasonal distribution of percentages of dead main stems under 20-3, 20-6 and 20-10 cutting intensities.

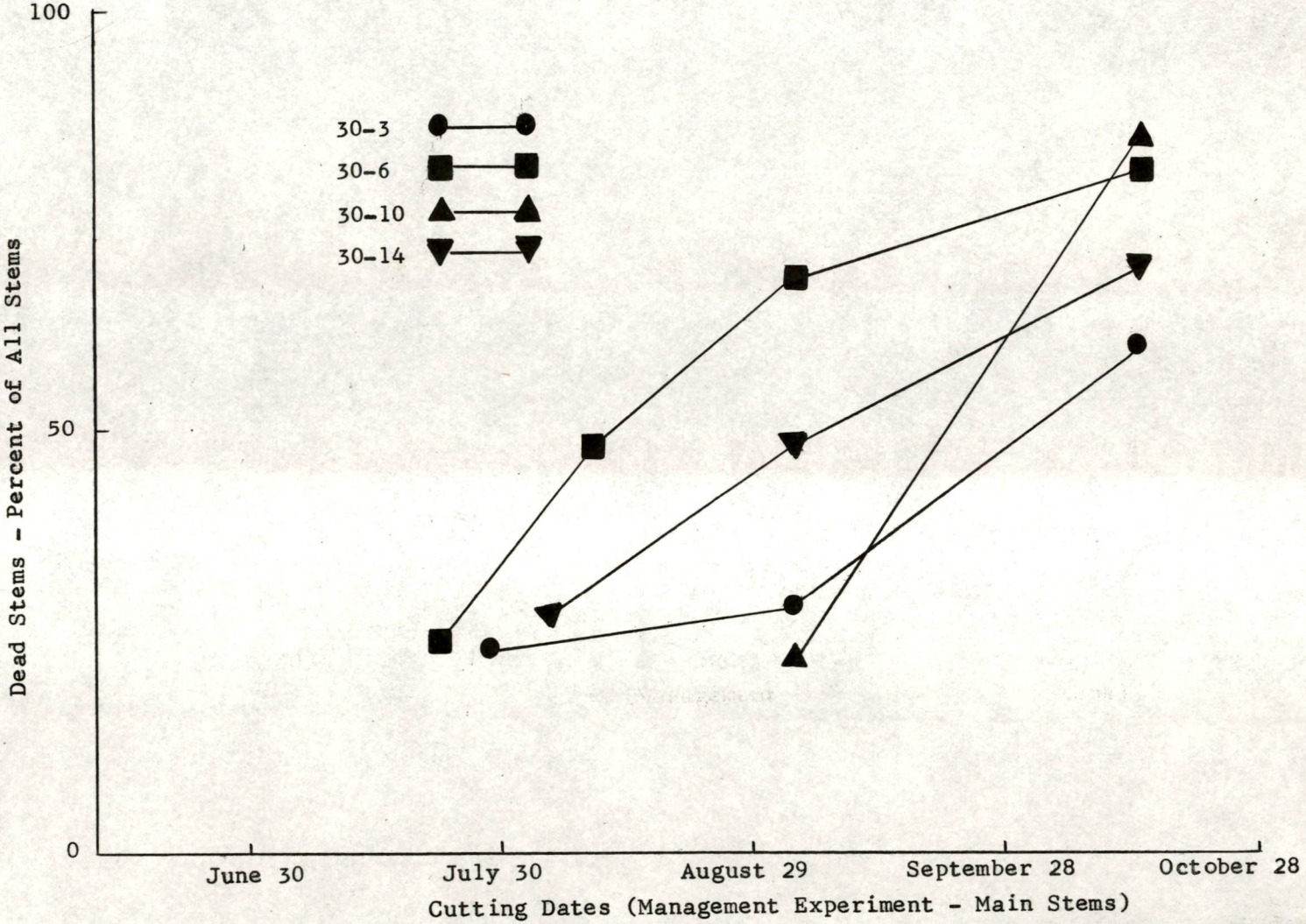


Figure 26--Seasonal distribution of percentages of dead main stems under 30-3, 30-6, 30-10 and 30-14 cutting intensities.

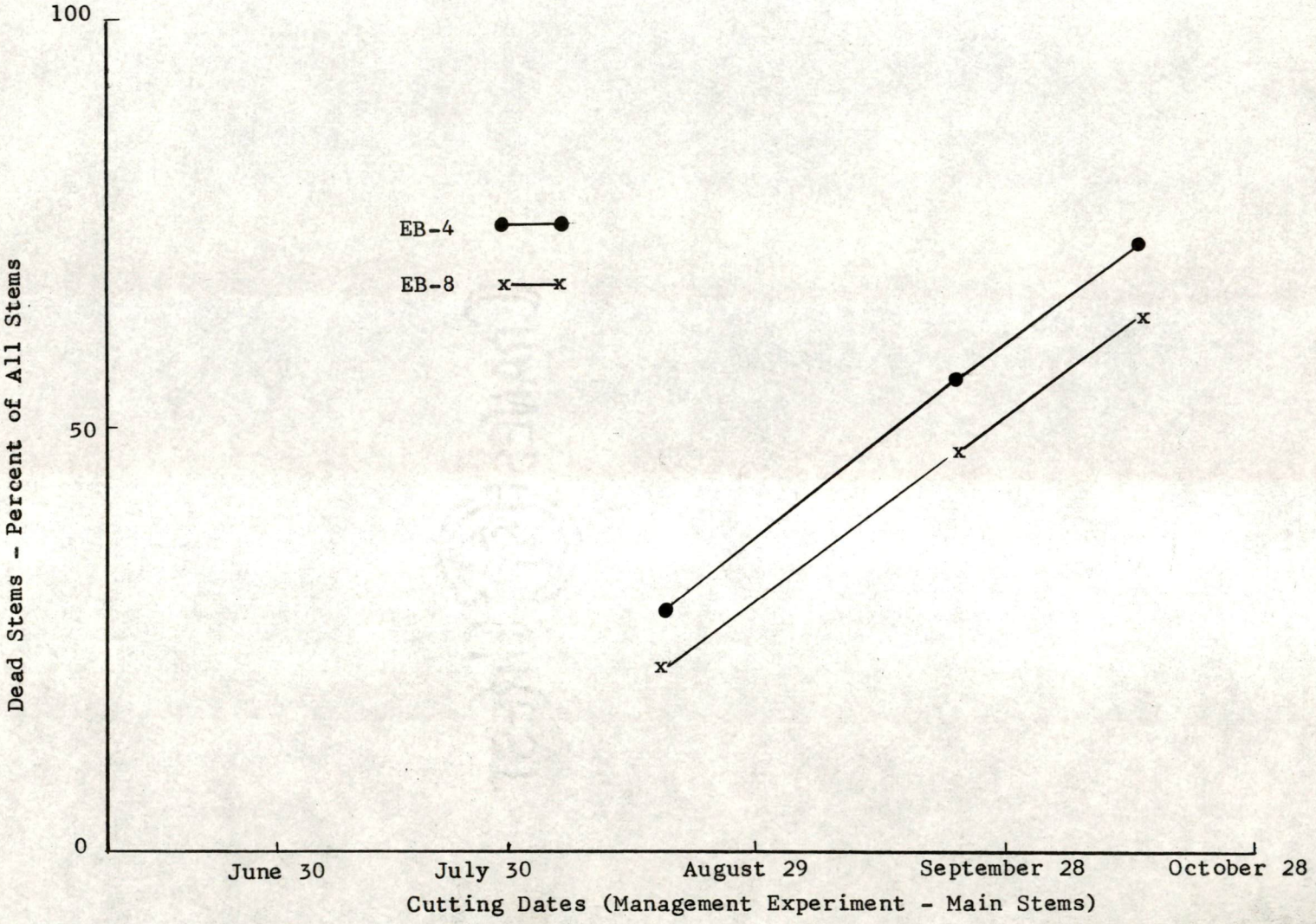


Figure 27--Seasonal distribution of percentages of dead main stems under E.B.-4 and E.B.-8 cutting intensities.

only 5% were dead at the time of fourth and fifth harvests. After that time, all three treatments followed the same pattern, and the percentage of dead stems increased rapidly to over 60% at the end of the season.

Dead stems did not appear until the third harvest under 30-3 and 30-6 cutting intensities, until the fourth under 30-10, and until the sixth under 30-14. However, when dead stems did appear, they accounted for 30% of all stems, and rapidly increased to 55 to 75% of the total in October.

When harvested at early bloom, Gahi-1 pearlmillet suffered 30% main stem mortality as a result of the first harvest, 50% following the second, and over 60% after the third. There were about 5% less dead main stems under the E.B.-8 than the E.B.-4 treatment.

Dry matter yields

The dry matter yields obtained from each treatment at each harvest date are presented in table 3. These are means of the three replications harvested. The average daily dry matter productions for the periods preceding the corresponding harvests are presented in table 4.

Statistical analysis of the total seasonal yields indicate that no treatment yielded significantly more than any other at the .25 level of probability. Therefore, the distribution of production over the season, as well as the leafiness and other factors associated with forage quality, would appear to be more important for distinguishing between the treatments.

The greatest portion of the production from those treatments allowed to reach heights of 20 or 30 inches had been produced by the end

Table 3.--Yield of harvested forage in pounds of dry matter per acre (Mean of three replications), cutting management experiment, Koella Farm, 1959.

Harvest date	Cutting intensities								
	20-3	20-6	20-10	30-3	30-6	30-10	30-14	E.B.-4	E.B.-8
June 23	1120	1032	332						
26				1318	1157	876	313		
July 1	1009	931	807						
3						765	885		
8	369	562	443	1175	1342				
14							1328	1162	1060
15						1157			
22			1577						
24	1175	1419			1263		682		
30				1530		1236			
Aug. 3		429	989						
6							1056		
11	751	299	304		949				
19								2890	2720
Sept. 4		714	1304	2305	1161	1461	1526		
10	691								
23								1134	1291
Oct. 15	240	715	862	493	631	475	525	267	212
Seasonal total	5355	6101	6618	6821	6503	5970	6315	5453	5282

Table 4.--Daily production of dry matter in pounds per acre for the growth periods preceding each harvest date (cutting management experiment, Koella Farm, 1959).

Harvest date	Cutting intensities								
	20-3	20-6	20-10	30-3	30-6	30-10	30-14	E.B.-4	E.B.-8
June 23	37	34	11						
26				40	35	26	9		
July 1	126	116	101						
3						109	126		
8	53	80	63	98	112				
14							121	23	21
15						96			
22			113						
24	73	89			79		68		
30				70		82			
Aug. 3		107	165						
6							151		
11	44	37	38		56				
19								80	76
Sept. 4		30	54	64	48	40	53		
10	23								
23								32	37
Oct. 15	7	17	21	12	15	12	13	12	10

of July. In the case of the early bloom treatments, the first two harvests accounted for three-fourths of the seasonal production.

The daily dry matter production rates reflect these trends. During the early part of the season, the 20-inch and 30-inch growth treatments very rapidly reached a peak of daily production of over 100 pounds of dry matter per acre per day between the first and second harvests. This production rate then decreased to around 70 pounds per day and steadily declined to less than 20 pounds per day in the case of 20-3, 30-3, 30-6 and 30-10. Treatments 20-6, 20-10 and 30-14, however, had a second peak of high daily growth toward the end of July. The slower rate of growth in early July can be further explained by the fact that only two inches of rainfall were recorded between July 6 and July 17. During the second half of July, on the other hand, substantial rainfall occurred. Apparently 20-6, 20-10 and 30-14 plants were in a morphological condition that made it possible for them to grow again at a rapid rate, using the newly-available moisture.

The treatments where growth was allowed to reach an early bloom stage did not differ in their growth rates. These rates were substantially lower than for the other treatments and never exceeded 80 pounds of dry matter per day.

General discussion

Irrespective of the cutting intensities, the percentages of primary stems with buds below the scheduled height of cut decreased in all cutting treatments as the season advanced. However, lower stubble heights resulted in higher percentages of stems which had buds below the

scheduled height of cut. There were no plants with buds below the height of cut under the E.B.-4 cutting intensity during the entire season. In general, as growth and/or stubble heights were allowed to increase from treatment to treatment, the average height of the apical meristems tended to increase also.

The percentages of primary stems which had buds above the cut were generally inversely proportional to the cutting heights.

The tillers (Appendix B) showed the same trends as the main stems. All apical buds under cutting intensities 20-3, 30-3 and E.B.-4 were above the scheduled height of cut after the first or the second harvest.

Percent stem weight above cut was high in the low stubble cutting intensity treatments. This was due to the fact that proportionately more stem and less leaf blade would be removed at a lower stubble height. However, regrowth from 6 and 10-inch stubble was much more rapid than from 3 or 4-inch stubble. This was probably due to both the presence of a larger number of lateral buds and extension of new leaf tissue on high stubble plants, whereas closely clipped plants, having lost more of their growing points, were forced to develop new leaves from lateral buds at fewer of the lower nodes. Nevertheless, as indicated by the yields, the latter did admirably well. This immediately suggests that the productivity might be further enhanced by cutting in such a way that increasing numbers of lateral buds would be left on increasing heights of stubble at intervals throughout the season.

The intensity of defoliation, the effect of which persisted until

the end of the season, accounts for the difference in live leaf weight between 20 and 30-inch growth treatments. In fact, the dry weight of live leaves per 100 plants was higher in both E.B.-4 and E.B.-8, when the crop was cut in those two treatments. The dry weight gradually came down as the season advanced and on the last harvest date, E.B.-8 had higher dry weight of leaves than E.B.-4.

The dry weight of live leaves from plants allowed to reach a height of 30 inches was double that of leaves from the 20-inch growth treatments, but considerably less than the leaf weight from early bloom cutting intensities. This must have been a difference in weight of individual leaves, since the number of leaves was remarkably constant (Appendix A). It was probably due largely to the frequent defoliation of crop when it was cut back from a height of only 20 inches, resulting in a reduction in size of the leaves.

The average number of tillers was lower when the crop was allowed to grow only 20 inches, than when the crop was allowed to reach a height of 30 inches. However, the cutting intensity 30-3 maintained a much lower number of tillers than the 30-6, 30-10 and 30-14 cutting intensities. This may be explained by the fact that when the crop was cut above 3 inches, the apical meristems were higher than those from plants allowed to grow to 20 inches and there were more nodes with lateral buds left. A larger number of meristems thus would be removed from a taller crop than a shorter one. It is conceivable that tillering would be stimulated when the meristems on the primary stem have been removed since cutting, by removal of the apical meristem, would affect apical dominance

and allow initiation of laterals, including tillers. Continued growth of tillers, on the other hand, would depend primarily upon food reserves from the uncut stubble portions, at least until tillers themselves were of a large enough size to contribute appreciably to food synthesis and storage. This was not shown clearly to be the case with E.B.-4 and E.B.-8, because only four cuttings were made for these two treatments. However, E.B.-8 still had more numerous tiller production than E.B.-4. It is apparent that repeated defoliation checked tillering to a certain extent. This is indicated by the smaller tiller number obtained from the 20-3, 20-6 and 20-10 treatments, as compared to the other cutting intensities.

In general, the percentage of dead stems increased as the season advanced, irrespective of cutting intensity. The decline in production of dry matter yields as the season advanced may be attributed in great part to the increase in dead stems, or to the accompanying decrease in the number of live shoots. The increase in the percentage of dead stems was slower under 30-3 and 20-10 cutting intensities than in the other treatments, and no dead stems were found in the tillers from these two treatments. This may be due to the fact that these tillers appeared later on in the season and were not subjected to as many clippings as the main stems.

Cultural Experiment

All the data for the different individual morphological characteristics measured for main stems and tillers in the cultural experiment are

presented in Appendices C and D as means of the two replications measured. Graphical analysis of the important characteristics of main stems is presented in the text.

Average heights of occurrence of apical buds below and above the scheduled heights of cut

The average heights of apical meristems for the various seeding and row spacing treatments are presented in appendices C and D, whereas the percentages of occurrence above and below the scheduled heights of cut are shown in figures 28 and 29.

The average height of the apical meristems in primary stems below the scheduled cut varied between 4.0 and 5.5 inches in all treatments. Since all six treatments in this experiment were managed under a 30-6 cutting intensity, differences in apical meristem height among treatments would not be expected to be very large. However, the data indicate that doubling the seeding rate resulted in slightly higher bud heights below cut, and that increasing spacing from 7 inches to 36 inches had a similar, though small, effect.

During the first half of the season, 7-inch row spacings resulted in a higher percentage of apical buds below the scheduled heights of cut than either 21 or 36-inch row spacings. As the percentage decreased with successive cuttings, the differences disappeared. No effect of plant density was noted.

No consistent difference in height of buds above cut due to row spacing was noted between treatments. However, slightly higher heights were observed under normal seeding rates than at the higher population,

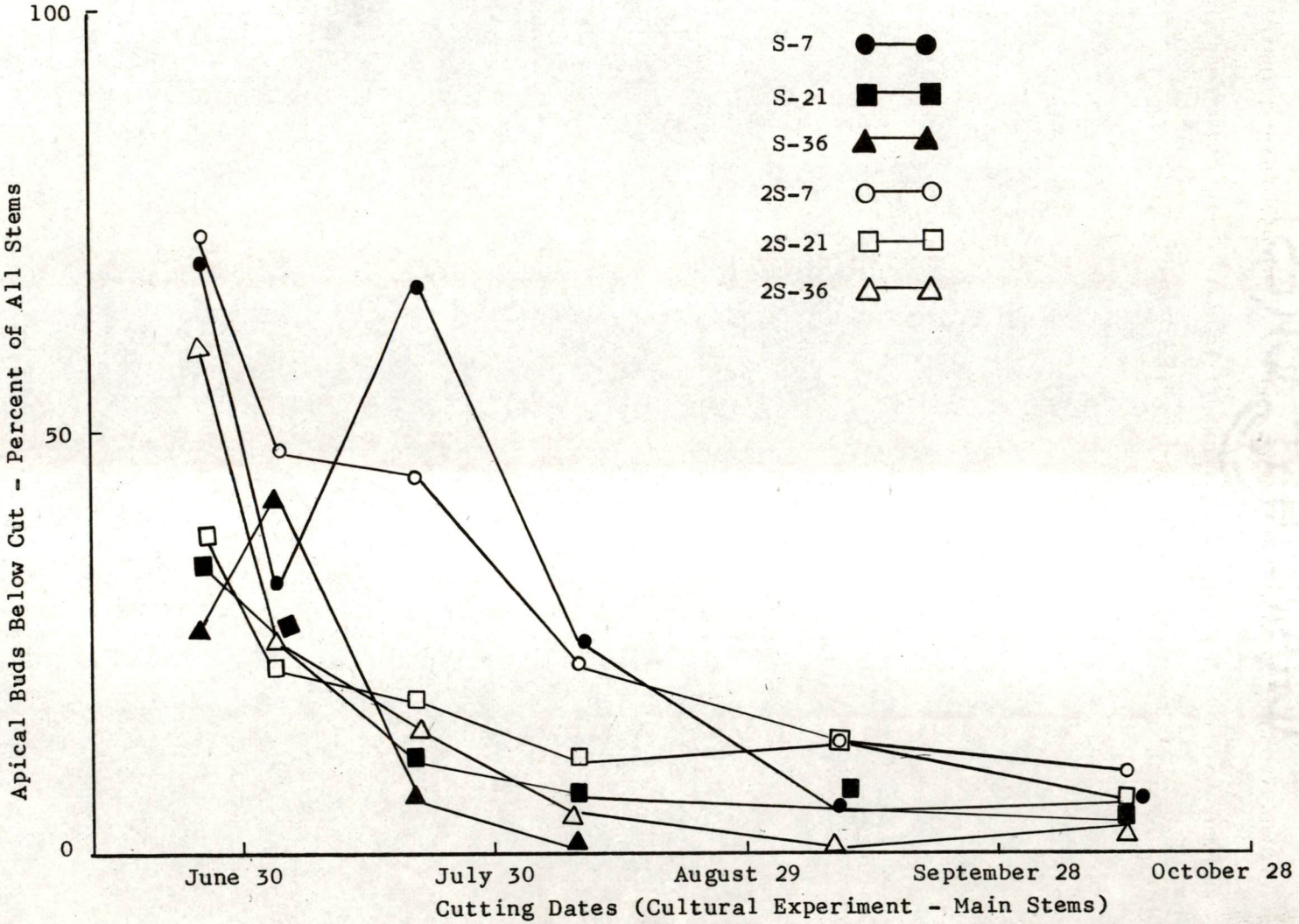


Figure 28--Seasonal distribution of percentages of main stems with apical buds below scheduled cut under a 30-6 cutting intensity with two seeding rates and three row spacings.

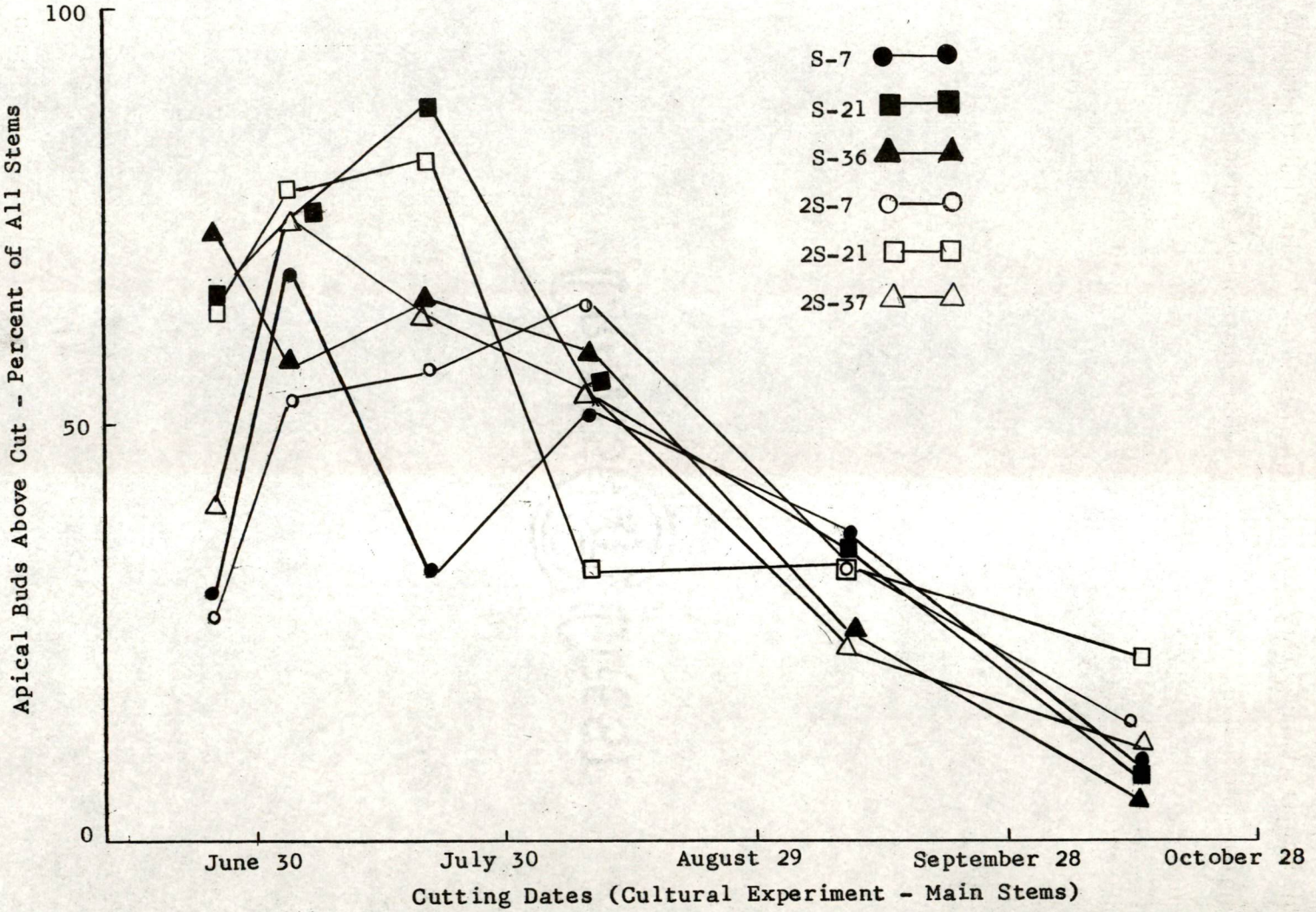


Figure 29--Seasonal distribution of percentages of main stems with apical buds above scheduled cut under a 30-6 cutting intensity with two seeding rates and three row spacings.

especially in the second half of the season.

The percentage of stems which had buds above the scheduled cut was higher through August 1 in 7-inch row spacings than in the other treatments. After that time, as percentages decreased, there was little difference between any of the six treatments.

Wider row spacing with normal seeding rate favored taller plants when compared to 7-inch spacing with double seeding rate. Probably this was due to less competition among the plants for plant nutrients, air and soil moisture.

In tillers, the average height of buds below cut followed the same general trends that were found in primary stems, except that the 7-inch row spacing with normal seeding rate produced plants which had no apical buds below the scheduled height of cut on four harvest dates in the season. The percentages of tiller stems which had apical buds below cut were high in treatments of 21 and 36-inch row spacings at the normal seeding rate, but only on the first harvest date.

The average height of meristems above the scheduled height of cut in tillers for 21 and 36-inch row spacings with normal seeding rate ranged up to 16 inches, whereas the narrower spacing of 7 inches at either seeding rate produced plants which had buds at a comparatively lower average height of 10 to 11 inches as maximum. The percentages of tillers which had buds above the scheduled height of cut were higher in 21 and 36-inch row spacings. However, normal seeding rate with 7-inch spacing produced more plants with apical buds above cut during the season.

Percentages of stem weights occurring above the scheduled height of cut

The percentages of main stem weights occurring above the scheduled heights of cut for the various treatments are presented graphically on figure 30.

A row spacing of 36 inches with double seeding rate resulted in a larger percentage of stem weight above the scheduled cut than other treatments, especially during the second half of the season. No consistent difference among the other treatments was observed for this character, observations fluctuating generally between 30 and 50%. However, substantially larger weights per plant were obtained from 36-inch than from either 21 or 7-inch row spacings.

In tillers, no consistent differences between treatments were observed for percent stem weight above cut. On the other hand, dry weight of tillers per plant above cut increased considerably both with increasing row widths and decreasing seeding rates.

Dry weight of live leaves per 100 plants

Dry weights of live leaves from main stems per 100 plants are presented in figure 31.

Live leaf weight per plant varied considerably with treatment. In general, 1.5 to 2 times more leaf weight per plant was measured in plots seeded at normal seeding rates than in those seeded at twice that rate, regardless of spacing. Secondly, considerably more leaves per plant occurred at wider row spacings than at the narrower spacings. Results similar to those obtained from main stems were obtained with tiller leaves. These trends were not unexpected since the leaves in

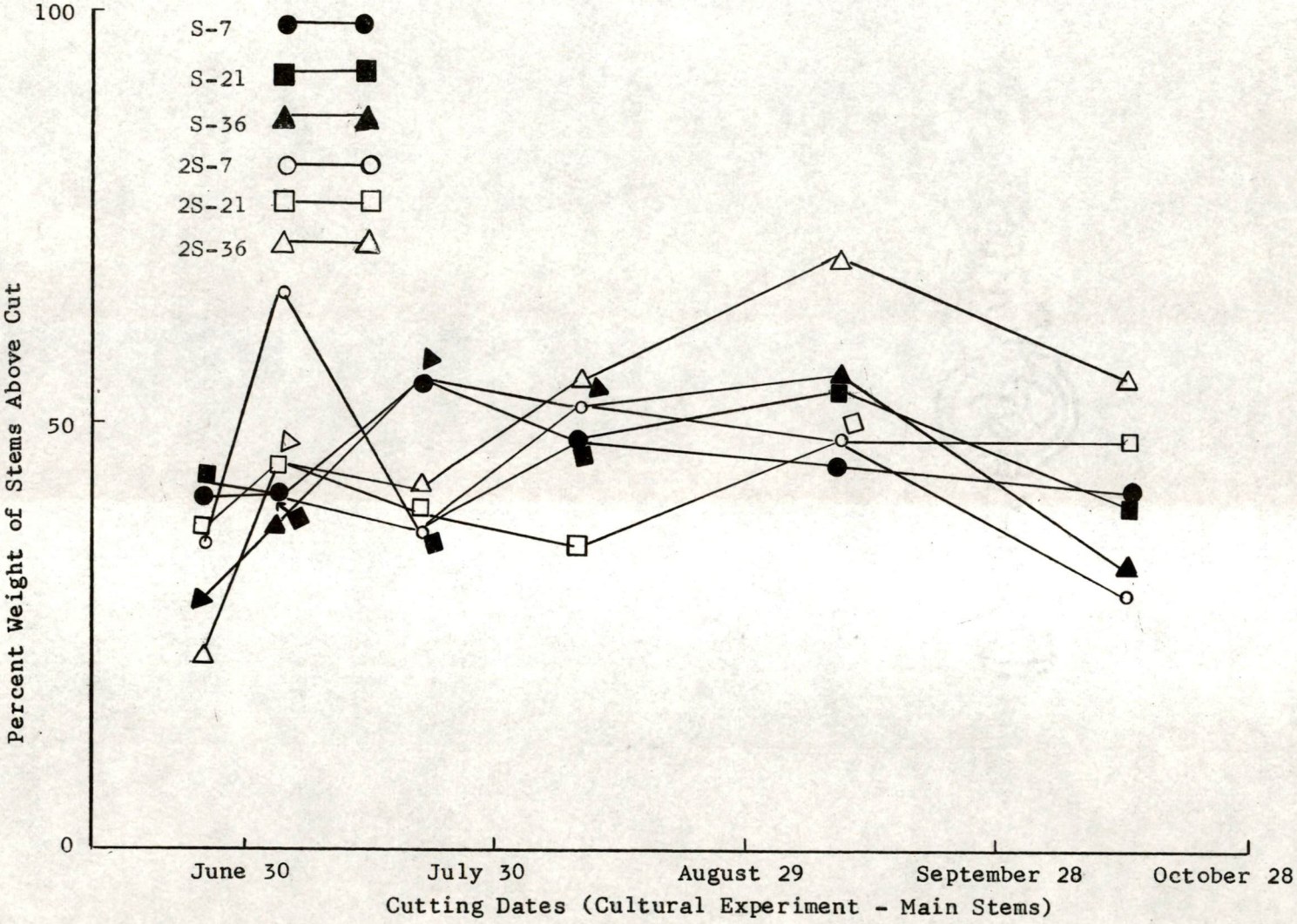


Figure 30--Seasonal distribution of percentages of main stem weights above scheduled cut under a 30-6 cutting intensity with two seeding rates and three row spacings.

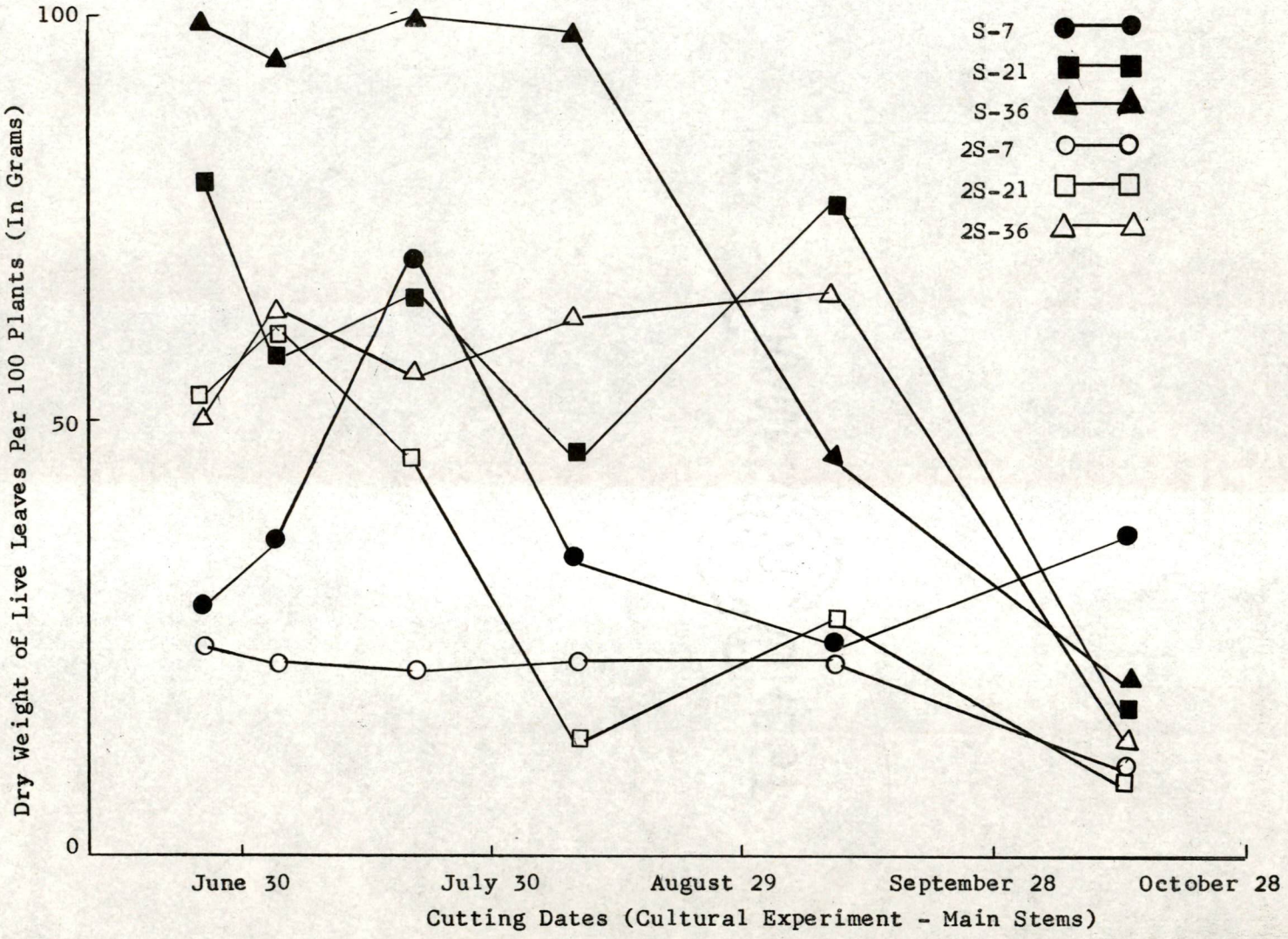


Figure 31--Seasonal distribution of dry weights per 100 plants of live leaves from main stems under a 30-6 cutting intensity with two seeding rates and three row spacings.

36-inch spacing treatment developed fully, whereas the leaves from plants in narrower spacings were less developed due to competition for plant nutrients, light and possibly carbon dioxide and water.

Leaf/stem ratios on dry weight basis

The leaf/stem ratios are graphically presented in figure 32 for primary stems.

Most treatments followed the same trend with a high initial ratio which decreased as the season advanced.

The leaf/stem ratio for the treatment of 36-inch spacing with normal seeding rate ranged between 1.79 and 1.02 during the entire growing season and was 1.22 on the last harvest date. The widest spacing with normal seeding rate maintained the highest ratio on October 15, whereas the lowest ratio was shown by narrowest spacing with double seeding rate on the same date.

Average number of tillers per plant

The average number of tillers per plant is graphically presented in figures 33 and 34.

Tillers appeared generally one cutting earlier on plants grown in 36-inch spacing than on those in narrower spacings. The widest spacing also resulted in substantially larger number of tillers than 21-inch spacing, and 21-inch in slightly larger numbers than 7-inch.

The tiller production, as expected, was higher with normal seeding rate than with the double rate. This might have been for the reason that a smaller number of plants were present in the treatments with

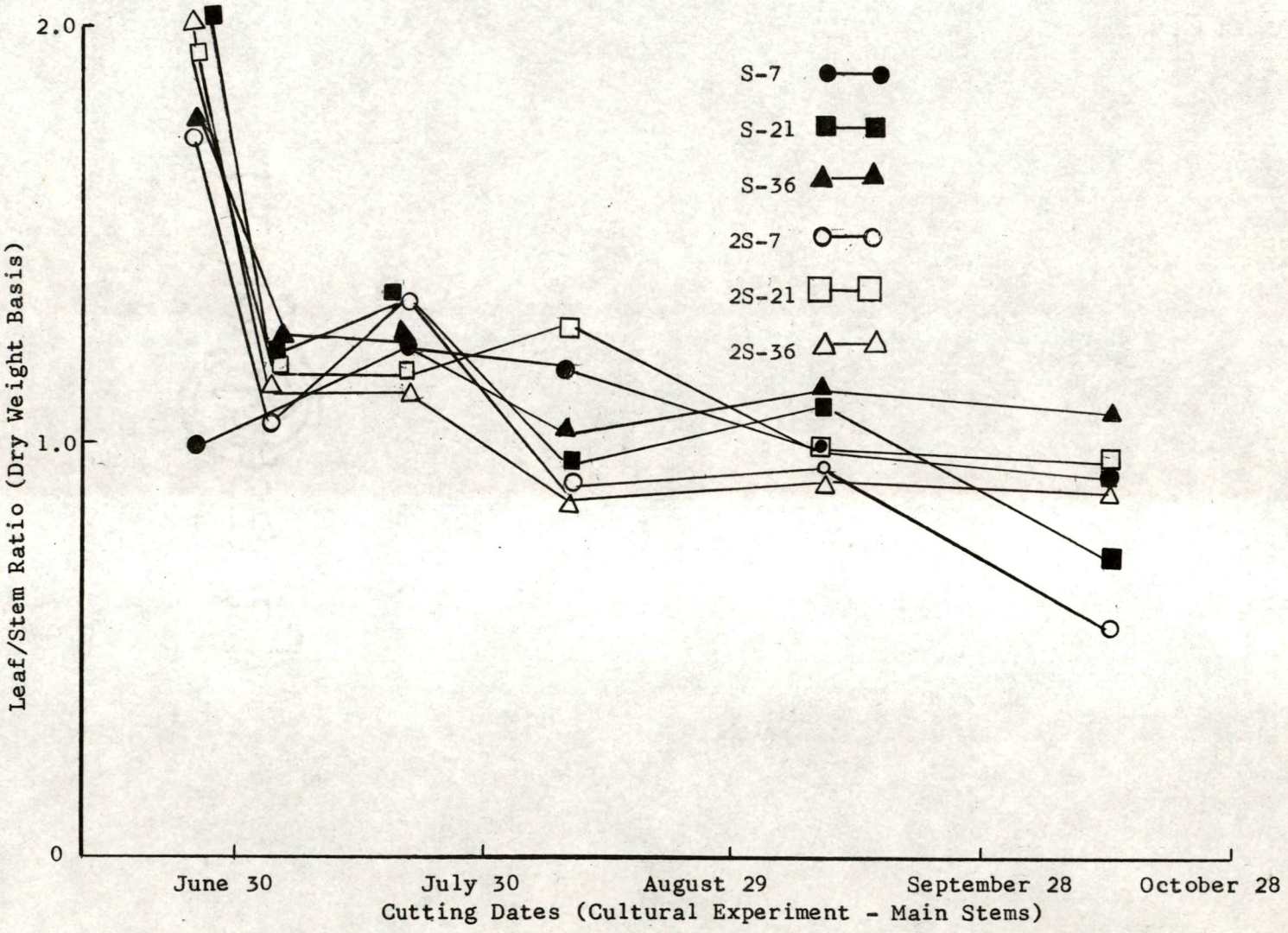


Figure 32--Seasonal distribution of leaf/stem ratios on a dry weight basis from main stems under a 30-6 cutting intensity with two seeding rates and three row spacings.

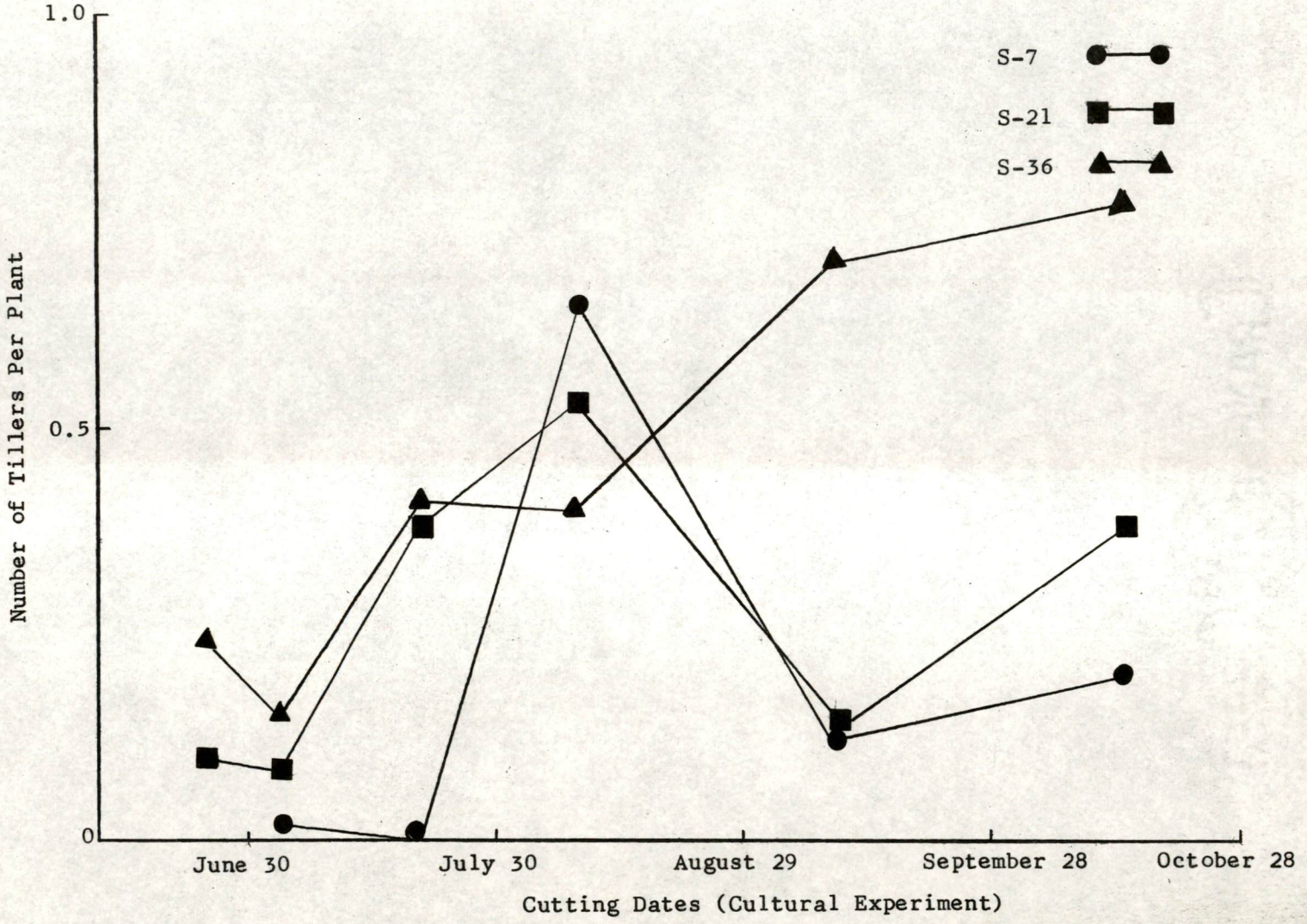


Figure 33--Seasonal distribution of average number of tillers per plant under a 30-6 cutting intensity with normal seeding rate and three row spacings.

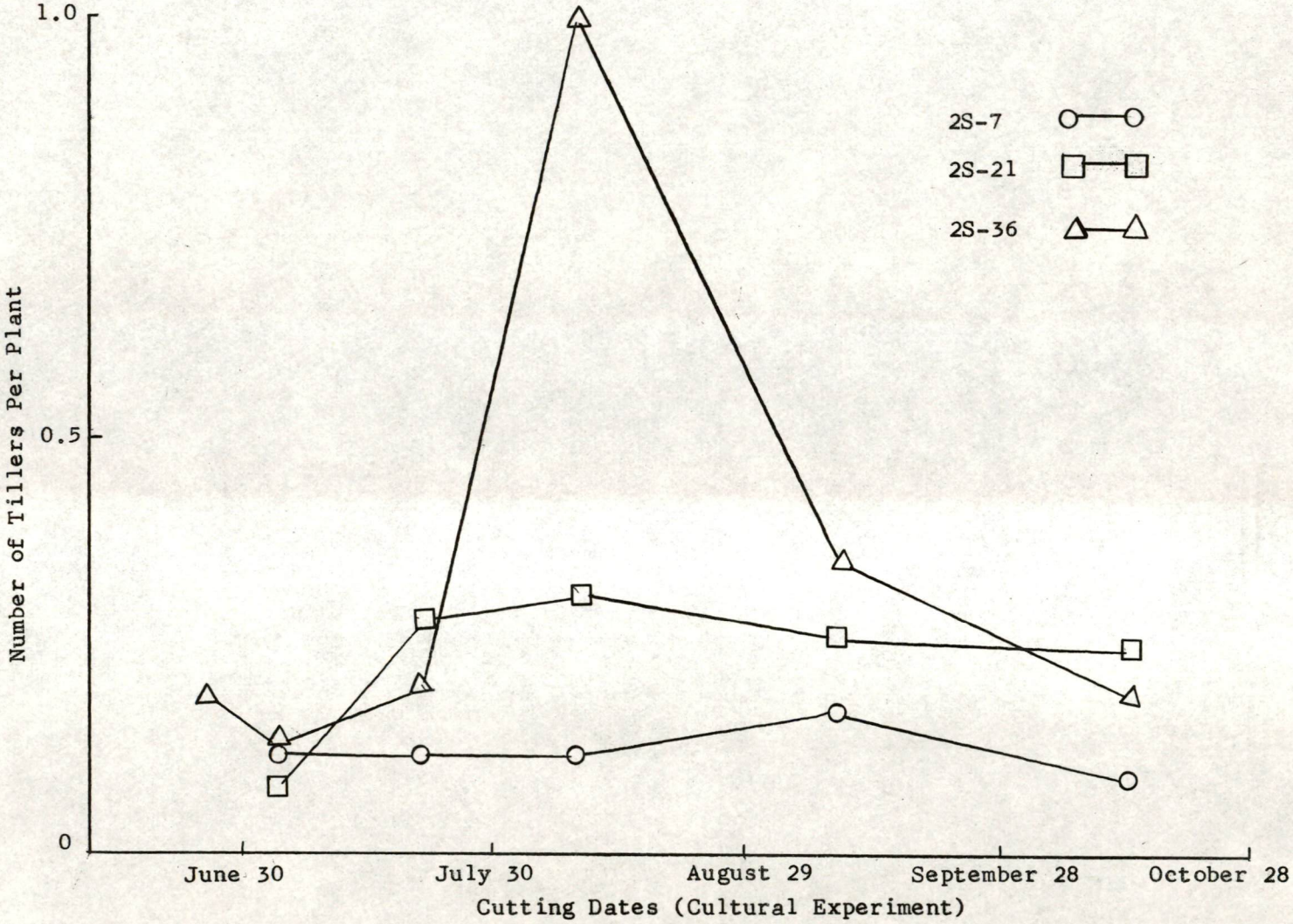


Figure 34--Seasonal distribution of percentages of dead main stems under a 30-6 cutting intensity with double seeding rates and three row spacings.

normal seeding rate than in those with double seeding rate. Spacing of 7 inches, when combined with the double seeding rate, had lower tiller production owing to the competition of more plants for plant nutrients. This trend was reversed when 36-inch row spacing was combined with normal seeding rate.

Percentages of dead main stems

The percentages of dead main stems are graphically presented in figure 35. There was a gradual increase in the percent dead main stems in all treatments as the season advanced. Dead main stems occurred several weeks earlier on plants grown in 36-inch row spacings than at narrower row widths. In addition, percentages of dead main stems were nearly always higher under 36-inch spacing, regardless of seeding rate, than in the other treatments. Since there were fewer plants per acre and less live shoots per plant in 36-inch row spacings than in closer spacings, there were considerably less productive plants per acre in the 36-inch rows. Fewer dead stems were observed under 7-inch than under 21-inch row spacings. Seeding rate seemed to have little effect on dead stems, though doubling the seeding rate slightly reduced their number.

Dry matter yields

The dry matter yields obtained are presented in table 5. At only two of the six harvests did the treatments produce significantly different yields. However, differences at all times were consistently in the same direction, and the seasonal totals mirror well the harvest by harvest differences. Therefore, only the seasonal total yields will be

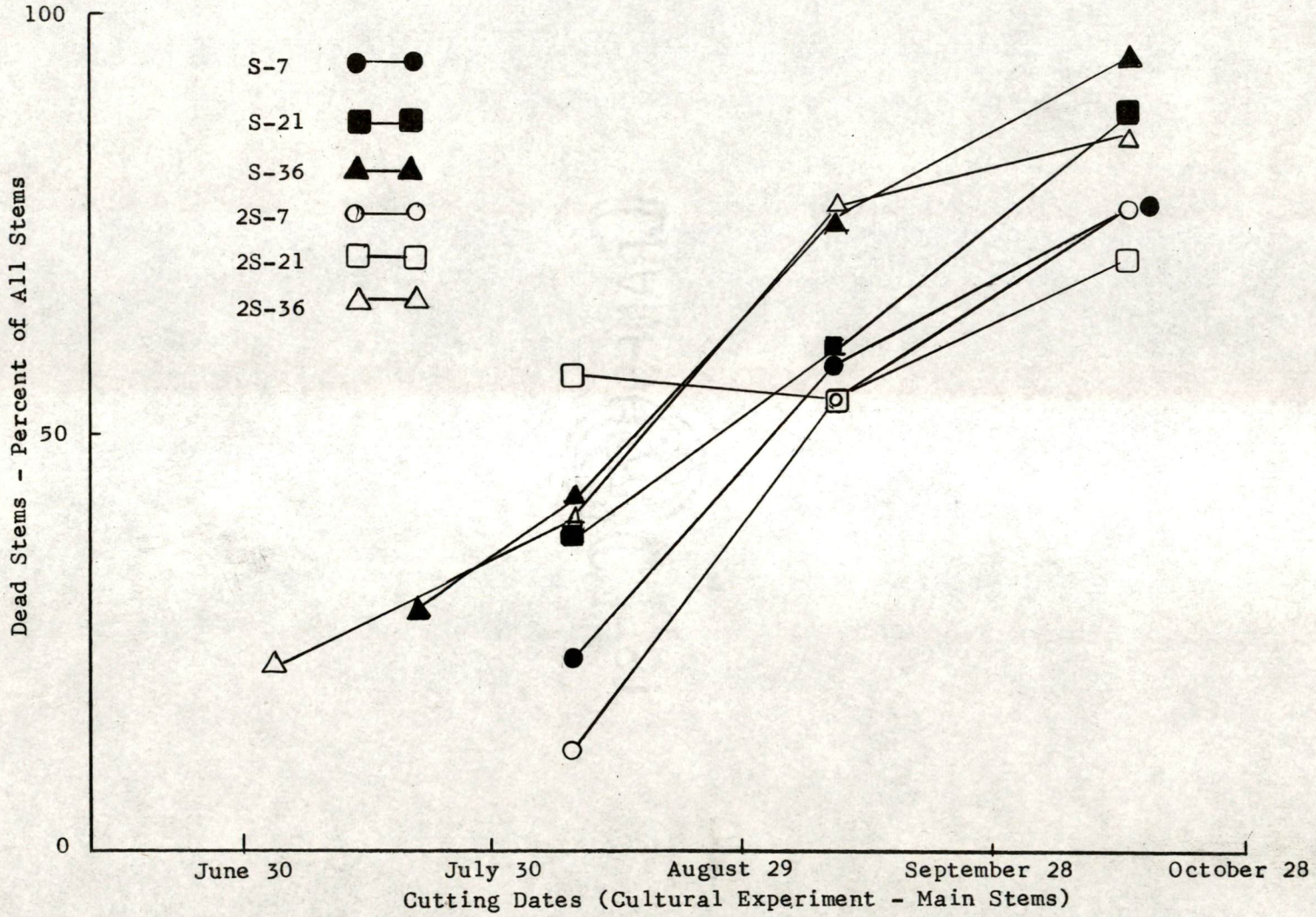


Figure 35--Seasonal distribution of percentages of dead main stems under a 30-6 cutting intensity with two seeding rates and three row spacings.

Table 5.--Yield in pounds of dry matter per acre of harvested forage on different cutting dates and for the season (Mean of four replications), cultural experiment, Koella Farm, 1959.

Harvest date	Treatment						L.S.D. at .05	C.V.%
	2S-36	S-36	2S-21	S-21	S-7	2S-7		
June 26	978	895	1295	1712	1649	1845	N.S.	15.3
July 5	823	990	1206	1186	1784	1597	482	25.3
July 22	951	1176	1255	1289	1680	1442	N.S.	8.5
Aug. 10	976	867	1065	1193	1701	2220	N.S.	28.9
Sept.10	1043	986	1238	1442	2279	2023	710	31.5
Oct. 15	355	343	428	528	373	394	N.S.	7.1
Seasonal total	5126	5257	6489	7350	9459	9521	2192	20.1
Multiple range groups (P=.05)								

discussed.

The differences due to seasonal total yields are significant at the .05 probability level. Plants grown in 36-inch row spacings yielded less than those grown in 21-inch row, which in turn yielded less than those under 7-inch row widths. Within each row spacing, there was no yield difference as a result of doubling the seeding rate.

Total seasonal dry matter yields were ranked in the increasing order: 2S-36; S-36; 2S-21; S-21; S-7 and 2S-7. It is interesting to note that the highest yields per acre were obtained from 7-inch spacings, whereas highest yields per plant undoubtedly occurred under 36-inch row spacings.

General discussion

Wider row spacing of 36 inches with normal seeding rate favored taller plants when compared to 7-inch spacing with double seeding rate. This was shown by the higher average height of the apical buds above the scheduled height of cut in the 36-inch spacing with normal seeding rate. This was due to rapid extension of the growing point when the plants competed less for light, air, water and plant nutrients in wider spacings when compared to the 7-inch rows, where plants were more crowded. Doubling the seeding rate resulted in double the initial stand obtained with normal seeding, a fact that was verified by stand counts one week after emergence.

The percent stem weight above cut was lower with closer row spacings. The 7-inch row spacing with double seeding rate produced the lowest percent stem weight above cut from among the treatments. Thus,

regrowth of individual plants was slowed by closer row spacing. Apparently closer row spacing resulted in more total forage per acre but less forage being produced per plant. The regrowth of individual plants was faster with wider row spacings. This might have been due to the growth of fewer, but more erect and stemmy plants in wider row spacings.

Spacing of 21 and 36 inches with normal seeding rate favored quick regrowth from stubble. This might be expected since the plants growing in plots seeded at the normal rate and with wider spacing probably had a more abundant supply of nutrients, carbon dioxide, soil moisture and sunlight than those plants growing under more crowded conditions.

For similar reasons, wider row spacings resulted in higher dry weight of live leaves per 100 plants.

Spacings of 36 inches with normal seeding rate produced the highest number of tillers, on an average, over the season. The lowest average number of tillers in the season was produced under 7-inch, double seeding rate conditions. The 21-inch spacing with double seeding rate tillered more than the 7-inch spacing at the same seeding rate. Tillering varied in proportion with the different spacings. This trend was not unexpected since, as spacing decreased and seeding rate increased, there were more plants in a given area, resulting in more competition among plants and reducing the possibility for more tillering.

Seven-inch row spacings were definitely superior to 21 or 36-inch spacings, regardless of seeding rate in terms of total dry matter yields.

This might well be expected, in view of the erect growth habit of this species. How this information can be used in terms of a practical grazing program remains to be investigated. It would be easy to apply this information to a silage or soilage harvest, but the problems of trampling and droppings by grazing animals may render the use of a broadcast or 7-inch spacing impractical.

CHAPTER V

SUMMARY AND CONCLUSIONS

Two field studies were conducted at the Tennessee Agricultural Experiment Station, Blount County, during the summer of 1959. The objective of these studies was to investigate the behavior and morphological development of Gahi-1 pearlmillet (Pennisetum glaucum L.) under different cutting intensities, row spacings and seeding rates.

In the cutting management experiment, the plants were harvested when 20 inches tall and cut at a 3, 6 or 10-inch stubble; or when 30 inches tall at a 3, 6, 10 or 14-inch stubble; or at the early bloom stage at a 4 or 8-inch stubble.

In the cultural experiment, spacings of 7, 21 and 36 inches between rows, each at either normal or double seeding rate, were used under a uniform cutting management of 30-6.

From these studies, the following general conclusions may be drawn:

1. Percentages of primary stems with apical buds below the scheduled height of cut decreased under all cutting intensities as the season advanced; they also decreased with decreasing stubble heights.

2. Percentages of primary stems with apical buds above the scheduled cut were generally inversely proportional to cutting heights.

3. Percent stem weight above cut was high in low stubble cutting intensity treatments.

4. Regrowth from 6 and 10-inch stubble was more rapid than from

3 or 4 inch stubble.

5. Dry weight of live leaves from plants allowed to grow to 30 inches was double that of leaves from 20-inch growth, but much less than the weight from early bloom cutting intensities.

6. Tiller production was less under 20-inch growth and under 30-inch growth cut down to low stubble heights than when either 30-inch growth was cut to higher stubble heights or when the plants were allowed to reach early bloom. Early bloom growth cut down to 8-inch stubble resulted in more tillers than that cut down to 4-inch stubble.

7. Percentages of dead stems increased to 30 and even 75% in some treatments as the season advanced. Mortality was generally inversely proportional to severity of management.

8. No significant differences in total seasonal dry matter production were measured between the 9 cutting intensities studied. Daily dry matter production was dependent upon cutting intensity and number of previous harvests, and exceeded 100 pounds per acre per day during peak periods of growth.

9. Wider row spacing of 36 inches with normal seeding rate favored taller plants when compared to 7-inch row spacing with double seeding rate.

10. Percent stem weight above cut was lower with closer row spacings.

11. Regrowth of individual plants was slowed by closer row spacing.

12. Wider row spacings resulted in higher leaf dry weights than narrower spacings.

13. Tiller numbers were highest in 36-inch rows seeded at normal

seeding rate and lowest under 7-inch, double seeding rate conditions; other treatments varied between these extremes and in proportion to plant density.

14. Highest dry matter yields were produced from 7-inch spacings with double seeding rate. Seven-inch row spacings yielded significantly more than 21 or 36-inch spacings.

Although Gahi-1 pearlmillet dry matter yields were higher in 7-inch than in 21-inch row spacings, and higher in the latter than in 36-inch rows, stage of growth at harvest and stubble height did not affect total seasonal dry matter production. However, spacing, plant density, stage of growth at harvest and stubble heights were important factors in determining regrowth after harvest, leafiness, and combined productivity of the plants over the whole season. The effects of harvest and plant density on stubble food reserves, and the combined effects of food reserves and morphological changes on the regrowth of pearlmillet, still remain to be investigated. Productivity might be maintained at a higher level for a longer period of time if harvesting could be regulated in such a way that increasing numbers of lateral buds would be left on increasing heights of stubble at intervals throughout the season. Such a management could be followed without great difficulty in a silage or soilage program, but present management skills would render it impractical in a pasture program. Similarly, though drill seeding produces more per acre than wide rows, and could be used easily for silage or soilage production, grazing animals might use plants grown in wider spacings to greater advantage.

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LITERATURE CITED

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APPENDICES

APPENDIX A

Cutting management experiment

Morphological characteristics of main stems
(Mean of two replications)

Cutting intensity	Cutting date	Apical buds below cut		Apical buds above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
		Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
20-3	Jun 23	2.3	15.6	6.0	84.4	15.1	14.5	49.0
	Jul 1	2.6	19.0	5.8	81.0	15.4	16.5	51.7
	8	---	---	6.4	100.0	15.2	19.3	55.9
	24	---	---	9.2	85.2	17.5	39.2	69.1
	Aug 11	---	---	8.6	63.0	18.0	46.9	72.3
	Sep 10	---	---	7.4	43.3	16.5	23.7	62.0
	Oct 15	---	---	8.7	31.7	15.9	38.6	71.8
20-6	Jun 23	4.8	56.6	6.8	43.4	32.7	9.0	21.6
	Jul 1	3.8	32.4	8.2	67.6	25.9	16.8	39.4
	8	4.6	26.2	8.4	73.8	28.5	22.4	66.0
	24	4.2	13.5	9.1	71.5	29.4	21.2	41.9
	Aug 3	4.9	18.1	8.7	57.0	28.7	19.4	40.3
	11	4.4	17.7	8.2	45.0	25.9	13.5	34.3
	Sep 4	4.4	19.1	8.5	39.7	19.4	8.6	30.7
	Oct 15	4.2	7.3	8.7	15.7	23.7	20.2	46.0
20.10	Jun 23	4.5	100.0	---	---	27.9	---	---
	Jul 1	5.2	76.5	11.3	23.5	50.2	12.1	19.9
	8	6.2	82.0	11.3	18.0	45.3	4.7	9.9
	22	7.0	70.3	11.5	26.1	31.9	4.7	12.8
	Aug 3	7.0	32.0	11.3	64.0	46.0	7.9	14.7
	11	7.2	44.6	11.4	29.6	46.0	7.8	14.4
	Sep 4	7.3	20.4	12.5	31.0	39.5	15.9	28.7
	Oct 15	7.8	14.1	11.3	10.0	9.2	8.1	46.8

APPENDIX A (Continued)

Cutting management experiment

Morphological characteristics of main stems
(Mean of two replications)

Cutting intensity	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)	% Dead stems of all stems
		Live	Dead	Live	Dead		
20-3	Jun 23	4.7	2.1	39.0	5.0	1.51	---
	Jul 1	4.4	1.3	31.8	7.0	1.23	---
	8	3.8	1.9	20.1	7.8	.82	---
	24	3.7	1.7	52.3	10.0	1.10	14.8
	Aug 11	3.6	3.2	41.0	14.5	.78	37.0
	Sep 10	2.7	3.4	23.9	13.5	.96	56.7
	Oct 15	2.6	3.6	11.3	13.7	.46	68.3
20-6	Jun 23	5.1	2.9	53.4	7.8	1.42	---
	Jul 1	4.2	1.2	33.6	18.9	1.20	---
	8	3.9	1.9	28.2	25.3	.68	---
	24	3.5	2.2	52.4	11.6	1.30	15.8
	Aug 3	3.4	2.9	21.3	13.2	.70	24.9
	11	3.3	3.9	16.9	18.0	.88	37.3
	Sep 4	2.8	4.1	14.1	13.9	1.00	41.2
	Oct 15	2.6	5.5	11.5	28.1	.91	77.0
20-10	Jun 23	4.2	2.5	35.8	6.7	1.54	---
	Jul 1	6.6	2.0	62.3	12.9	1.19	---
	8	5.1	2.5	27.9	7.6	.72	---
	22	4.9	2.2	32.7	8.8	1.12	3.6
	Aug 3	3.6	2.2	19.4	12.5	.60	4.0
	11	3.1	3.3	27.9	15.3	.81	35.8
	Sep 4	2.9	4.1	17.5	18.1	.65	48.6
	Oct 15	2.7	4.9	11.8	13.7	.62	75.9

APPENDIX A (Continued)

Cutting management experiment

Morphological characteristics of main stems
(Mean of two replications)

Cutting intensity	Cutting date	Apical buds below cut		Apical buds above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
		Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
30-3	Jun 26	2.4	9.8	5.7	90.2	12.5	22.9	66.7
	Jul 8	---	---	6.2	100.0	17.6	28.2	61.6
	30	---	---	10.6	75.6	18.3	57.9	76.0
	Sep 4	---	---	11.1	70.8	15.6	64.8	80.6
	Oct 15	2.5	2.5	9.7	37.6	9.8	30.9	75.9
30-6	Jun 26	4.4	29.5	8.8	70.6	24.8	16.0	39.2
	Jul 8	4.4	21.1	11.1	78.9	36.4	31.4	46.3
	24	4.7	18.8	9.9	56.0	27.3	20.7	43.1
	Aug 11	4.6	5.7	9.7	46.8	33.0	36.3	52.4
	Sep 4	3.8	6.2	9.3	26.1	14.4	14.4	50.0
	Oct 15	5.1	3.1	10.5	15.7	26.8	46.9	63.7
30-10	Jun 26	6.5	98.2	10.3	1.8	32.9	2.5	7.1
	Jul 3	6.6	70.9	16.9	20.1	36.9	7.0	15.9
	15	6.5	31.8	14.4	68.2	60.5	31.3	34.1
	30	6.8	31.1	12.7	68.9	42.6	16.3	27.7
	Sep 4	7.4	23.2	16.1	53.6	49.9	43.5	46.6
	Oct 15	7.7	8.1	16.0	9.0	36.7	17.5	32.3

APPENDIX A (Continued)

Cutting management experiment

Morphological characteristics of main stems
(Mean of two replications)

Cutting intensity	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)	% Dead stems of all stems
		Live	Dead	Live	Dead		
30-3	Jun 26	4.8	1.6	46.3	8.1	1.40	---
	Jul 8	3.7	1.9	39.0	7.6	1.24	---
	30	4.9	3.2	70.1	13.9	.87	24.4
	Sep 4	3.2	3.7	29.3	15.6	.62	29.2
	Oct 15	3.0	4.2	9.9	19.7	.75	59.9
30-6	Jun 26	4.6	1.7	56.3	8.5	1.58	---
	Jul 8	4.7	1.8	62.6	12.8	1.20	---
	24	3.5	2.4	46.3	12.7	1.20	25.3
	Aug 11	3.5	4.2	55.8	32.6	1.21	47.5
	Sep 4	3.0	3.7	23.8	9.8	1.19	67.7
	Oct 15	2.9	3.9	24.2	17.0	.62	81.2
30-10	Jun 26	5.4	2.0	49.6	9.9	1.75	---
	Jul 3	4.5	2.1	52.4	8.5	1.42	---
	15	4.9	2.2	66.4	12.9	.89	---
	30	3.8	2.4	24.8	17.8	.74	---
	Sep 4	3.7	3.8	38.7	23.8	.67	23.2
	Oct 15	2.1	4.5	14.1	40.0	.70	82.9

APPENDIX A (Continued)

Cutting management experiment

Morphological characteristics of main stems
(Mean of two replications)

Cutting intensity	Cutting date	Apical buds below cut		Apical buds above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
		Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
30-14	Jun 26	6.4	100.0	---	---	32.1	---	---
	Jul 3	8.5	75.7	15.8	24.3	49.9	43.5	46.6
	15	8.6	50.5	18.2	49.5	60.3	61.4	50.5
	24	10.3	63.7	16.3	36.3	84.8	15.4	15.4
	Aug 6	11.0	48.7	16.7	23.8	88.4	14.7	14.3
	Sep 4	10.4	18.2	17.7	33.9	65.5	33.7	29.4
	Oct 15	9.4	18.6	17.7	12.8	58.2	10.1	14.8
E.B.-4	Jul 14	---	---	16.2	100.0	35.2	136.8	80.2
	Aug 19	---	---	9.2	85.6	20.8	47.7	69.7
	Sep 23	---	---	8.9	42.6	21.2	38.4	64.4
	Oct 15	---	---	8.8	27.0	17.3	51.2	74.7
E.B.-8	Jul 14	5.5	41.1	17.0	58.9	57.8	79.4	57.9
	Aug 19	6.0	31.3	12.8	46.9	40.8	40.9	50.0
	Sep 23	5.5	20.3	15.7	32.2	41.9	24.6	37.0
	Oct 15	5.5	16.9	14.1	18.7	26.2	23.9	47.7

APPENDIX A (Continued)

Cutting management experiment

Morphological characteristics of main stems
(Mean of two replications)

Cutting intensity	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)	% Dead stems of all stems
		Live	Dead	Live	Dead		
30-14	Jun 26	4.5	2.2	40.6	11.2	1.63	---
	Jul 3	6.0	2.1	38.7	23.8	1.47	---
	15	5.3	2.1	13.9	13.5	.76	---
	24	3.5	2.4	38.9	16.8	.63	---
	Aug 6	3.2	3.4	35.8	11.8	.56	27.5
	Sep 4	3.8	4.1	30.9	33.4	.69	47.9
	Oct 15	3.6	5.5	17.1	27.9	.59	68.6
E.B.-4	Jul 14	5.7	2.7	133.7	21.0	.88	---
	Aug 19	4.0	4.1	49.7	37.0	.92	28.8
	Sep 23	3.9	5.1	34.9	25.6	1.04	57.6
	Oct 15	3.5	5.5	21.4	23.2	.67	73.0
E.B.-8	Jul 14	5.3	2.7	103.6	20.4	.99	---
	Aug 19	3.9	3.8	53.4	13.6	.82	21.8
	Sep 23	3.4	4.2	27.2	22.5	.76	47.5
	Oct 15	3.3	5.0	30.9	23.9	.84	64.4

APPENDIX B

Cutting management experiment

Morphological characteristics of tillers
(Mean of two replications)

Cutting intensity	Cutting date	No. of tillers per plant	Apical bud below cut: Ave. ht. in.	Apical bud below cut: % of all stems	Apical bud above cut: Ave. ht. in.	Apical bud above cut: % of all stems	Stem dry weight per 100 plants(g.): Below cut	Stem dry weight per 100 plants(g.): Above cut	% Stem weight above cut
20-3	Jun 23	---	---	---	---	---	---	---	---
	Jul 1	---	---	---	---	---	---	---	---
	8	.05	2.5	100.	---	---	37.5	25.0	40.0
	24	.15	---	---	7.9	100.0	45.0	55.0	55.0
	Aug 11	.16	---	---	8.4	100.0	20.0	37.5	34.8
	Sep 10	.17	---	---	7.8	100.0	35.4	54.9	60.8
	Oct 15	.26	---	---	11.0	100.0	28.6	71.4	71.4
20-6	Jun 23	---	---	---	---	---	---	---	---
	Jul 1	---	---	---	---	---	---	---	---
	8	.06	4.5	62.5	6.8	37.5	50.0	50.0	50.0
	24	.11	5.5	11.5	7.4	88.5	56.5	19.9	26.1
	Aug 3	.16	3.7	39.3	8.5	60.7	63.5	15.5	26.3
	11	.18	---	---	7.8	100.0	59.0	22.9	28.0
	Sep 4	.16	4.5	23.1	8.3	76.9	45.4	17.7	28.1
	Oct 15	.20	---	30.7	12.5	69.3	65.4	84.6	56.4
20-10	Jun 23	---	---	---	---	---	---	---	---
	Jul 1	---	---	---	---	---	---	---	---
	8	.10	6.2	95.9	16.5	4.1	54.2	8.3	13.3
	22	.09	5.7	91.7	10.7	16.7	41.7	8.3	16.6
	Aug 3	.12	4.9	100.0	---	---	34.2	---	---
	11	.20	9.4	33.3	10.6	66.7	75.0	8.3	10.0
	Sep 4	.51	7.2	32.2	13.9	67.8	33.0	29.1	46.9
	Oct 15	.25	7.4	46.7	14.3	53.4	56.7	36.7	39.3

APPENDIX B (Continued)

Cutting management experiment

Morphological characteristics of tillers
(Mean of two replications)

Cutting intensity	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)
		Live	Dead	Live	Dead	
20-3	Jun 23	---	---	---	---	---
	Jul 1	---	---	---	---	---
	8	4.1	2.0	37.5	12.5	.80
	24	3.5	2.1	50.0	20.0	.65
	Aug 11	2.9	2.2	27.5	12.5	.71
	Sep 10	3.9	2.9	52.8	17.4	.78
	Oct 15	4.1	3.6	26.2	20.1	.47
20-6	Jun 23	---	---	---	---	---
	Jul 1	---	---	---	---	---
	8	5.0	1.5	50.0	18.8	.72
	24	3.3	1.8	39.8	16.0	.79
	Aug 3	3.3	2.4	26.8	15.5	.78
	11	3.0	2.9	22.9	19.9	.57
	Sep 4	4.2	2.9	45.0	17.7	1.00
	Oct 15	3.7	4.2	42.4	23.1	.45
20-10	Jun 23	---	---	---	---	---
	Jul 1	---	---	---	---	---
	8	6.3	1.8	58.3	31.3	1.60
	22	5.7	1.7	41.7	10.9	1.60
	Aug 3	4.4	1.0	27.1	13.6	1.50
	11	2.9	2.9	16.6	25.0	.50
	Sep 4	4.1	2.5	39.6	18.6	.51
	Oct 15	4.0	3.3	20.0	13.3	.37

APPENDIX B (Continued)

Cutting management experiment

Morphological characteristics of tillers
(Mean of two replications)

Cutting intensity	Cutting date	No. of tillers per plant	Apical bud below cut		Apical bud above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
			Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
30-3	Jun 26	---	---	---	---	---	---	---	---
	Jul 8	.28	---	---	5.8	100.0	30.6	59.3	66.0
	30	.31	---	---	8.2	100.0	26.1	42.9	62.2
	Sep 4	.32	---	---	9.4	100.0	35.7	71.5	66.7
	Oct 15	.23	---	---	13.0	100.0	28.7	115.0	80.0
30-6	Jun 26	---	---	---	---	---	---	---	---
	Jul 8	.16	4.5	45.9	8.9	54.1	72.2	36.1	33.3
	24	.20	4.6	32.9	7.8	67.1	34.3	15.2	30.7
	Aug 11	.47	4.3	22.2	10.1	87.7	59.1	55.8	48.6
	Sep 4	.60	4.6	16.8	8.5	83.2	47.8	16.1	25.2
	Oct 15	.52	6.6	10.0	9.8	90.0	62.8	40.8	39.4
30-10	Jun 26	---	---	---	---	---	---	---	---
	Jul 3	.12	4.0	92.9	11.0	7.1	13.4	9.0	40.2
	15	.03	5.0	100.0	---	---	50.0	---	---
	30	.36	7.9	12.5	11.8	87.5	95.0	17.5	15.6
	Sep 4	.24	8.0	3.3	15.6	96.7	126.7	83.4	39.7
	Oct 15	.54	7.4	36.9	12.4	63.1	98.8	27.4	21.7

APPENDIX B (Continued)

Cutting management experiment

Morphological characteristics of tillers
(Mean of two replications)

Cutting intensity	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)
		Live	Dead	Live	Dead	
30-3	Jun 26	---	---	---	---	---
	Jul 8	3.6	1.7	39.8	33.5	1.23
	30	4.4	2.0	42.0	16.8	.91
	Sep 4	4.5	3.6	50.7	17.2	.59
	Oct 15	3.6	4.0	31.4	23.7	.39
30-6	Jun 26	---	---	---	---	---
	Jul 8	4.0	1.3	101.4	33.6	1.30
	24	3.5	1.5	32.9	15.2	.99
	Aug 11	4.1	2.4	61.1	31.5	.71
	Sep 4	3.3	3.0	14.5	13.1	.43
	Oct 15	3.1	3.2	23.9	23.1	.47
30-10	Jun 26	---	---	---	---	---
	Jul 3	3.9	1.3	27.7	9.8	2.06
	15	5.5	2.0	50.0	25.0	.97
	30	4.0	2.3	27.5	12.5	.46
	Sep 4	4.7	3.9	60.0	43.3	.51
	Oct 15	3.1	4.0	18.8	19.3	.32

APPENDIX B (Continued)

Cutting management experiment

Morphological characteristics of tillers
(Mean of two replications)

Cutting intensity	Cutting date	No. of tillers per plant	Apical buds below cut: Ave. ht. in.	Apical buds below cut: % of all stems	Apical buds above cut: Ave. ht. in.	Apical buds above cut: % of all stems	Stem dry weight per 100 plants(g.): Below cut	Stem dry weight per 100 plants(g.): Above cut	% Stem weight above cut
30-14	Jun 26	---	---	---	---	---	---	---	---
	Jul 3	.04	4.5	100.0	---	---	25.0	---	---
	15	.06	4.8	100.0	---	---	54.2	---	---
	24	.18	12.9	50.0	16.3	50.0	100.0	20.0	16.7
	Aug 6	.28	8.6	37.0	15.9	63.0	110.0	37.7	25.6
	Sep 4	.70	8.2	28.4	19.3	71.6	49.5	57.0	53.5
	Oct 15	.41	12.2	13.9	17.7	86.1	122.2	36.0	22.8
E.B.-4	Jul 14	---	---	---	---	---	---	---	---
	Aug 19	.66	---	---	9.9	100.0	40.8	73.7	64.4
	Sep 23	.41	---	---	8.7	100.0	42.3	47.4	52.8
	Oct 15	.30	---	---	9.1	100.0	38.4	41.5	51.9
E.B.-8	Jul 14	---	---	---	---	---	---	---	---
	Aug 19	.59	5.6	59.0	12.4	40.0	46.7	20.7	30.6
	Sep 23	.51	6.3	33.3	10.2	66.7	72.4	18.8	20.6
	Oct 15	.40	6.3	12.5	15.7	87.6	63.4	77.6	55.0

APPENDIX B (Continued)

Cutting management experiment

Morphological characteristics of tillers
(Mean of two replications)

Cutting intensity	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)
		Live	Dead	Live	Dead	
30-14	Jun 26	---	---	---	---	---
	Jul 3	3.9	---	33.2	---	---
	15	2.8	1.6	37.5	33.2	1.51
	24	3.1	---	35.0	14.6	1.25
	Aug 6	3.6	2.8	48.1	29.1	1.25
	Sep 4	4.0	3.1	45.9	32.6	.54
	Oct 15	3.8	6.0	25.0	38.9	.41
E.B.-4	Jul 14	---	---	---	---	---
	Aug 19	5.1	3.6	60.5	22.4	.80
	Sep 23	3.6	2.0	30.5	12.2	.48
	Oct 15	3.5	3.8	23.9	18.5	.55
E.B.-8	Jul 14	---	---	---	---	---
	Aug 19	6.2	3.0	42.4	14.1	.84
	Sep 23	3.8	2.6	31.1	17.4	.54
	Oct 15	3.8	5.3	32.6	30.5	.46

APPENDIX C

Cultural experiment

Morphological characteristics of main stems
(Mean of two replications)

Treatment[a]	Cutting date	Apical buds below cut		Apical buds above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
		Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
2S-7"	Jun 26	4.0	73.1	7.2	26.9	13.4	7.7	35.5
	Jul 5	4.0	46.9	9.2	53.1	18.5	39.1	67.9
	22	4.3	44.5	9.7	55.5	14.2	8.8	38.3
	Aug 10	4.1	22.4	10.1	65.4	17.7	19.7	52.7
	Sep 10	4.7	12.7	9.4	33.3	20.5	19.7	49.0
	Oct 15	4.2	10.0	7.8	13.3	14.3	6.0	29.6
2S-21"	Jun 26	4.3	37.5	7.4	62.5	20.5	12.1	37.1
	Jul 5	4.6	21.8	10.2	78.2	33.4	28.3	45.9
	22	5.1	17.9	9.9	82.1	29.0	18.8	39.3
	Aug 10	4.6	10.6	9.9	31.8	17.6	9.9	36.0
	Sep 10	4.4	12.9	9.6	33.0	29.0	27.6	48.8
	Oct 15	4.2	6.2	8.8	22.4	19.4	18.4	48.7
2S-36"	Jun 26	4.4	59.9	6.8	40.1	23.3	6.8	22.6
	Jul 5	4.2	25.3	10.8	74.7	34.6	29.4	45.9
	22	4.8	14.8	9.2	63.1	33.4	24.7	42.5
	Aug 10	4.2	5.4	11.2	54.3	40.6	51.6	56.0
	Sep 10	---	---	10.6	23.4	18.7	45.6	70.9
	Oct 15	5.1	3.1	9.2	10.6	16.3	20.8	56.1

APPENDIX C (Continued)

Cultural experiment

Morphological characteristics of main stems
(Mean of two replications)

Treatment[a]	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)	% Dead stems of all stems
		Live	Dead	Live	Dead		
2S-7"	Jun 26	4.3	1.9	24.5	5.3	1.73	---
	Jul 5	4.0	1.8	22.6	5.8	1.05	---
	22	3.3	2.8	21.6	8.1	1.34	---
	Aug 10	3.3	3.4	22.5	9.3	.89	12.2
	Sep 10	3.0	3.8	23.4	15.4	.94	54.0
	Oct 15	2.5	4.8	9.7	11.9	.54	76.7
2S-21"	Jun 26	4.3	1.4	53.5	8.5	1.93	---
	Jul 5	3.0	1.6	63.0	8.0	1.16	---
	22	3.5	2.2	46.7	15.6	1.29	---
	Aug 10	3.3	3.7	13.3	11.5	.95	57.6
	Sep 10	2.8	4.0	28.2	17.7	.95	54.1
	Oct 15	3.3	4.1	9.2	15.3	.69	71.4
2S-36"	Jun 26	4.7	1.5	51.8	9.8	2.05	---
	Jul 5	4.8	1.8	63.8	8.3	1.11	---
	22	3.8	2.1	56.8	7.4	1.12	22.1
	Aug 10	4.2	3.1	64.3	19.9	.88	46.3
	Sep 10	3.8	4.5	66.7	24.4	.92	76.6
	Oct 15	2.4	5.6	12.7	20.8	.88	86.3

APPENDIX C (Continued)

Cultural experiment

Morphological characteristics of main stems
(Mean of two replications)

Treatment[a]	Cutting date	Apical buds below cut		Apical buds above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
		Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
S-7"	Jun 26	4.4	72.4	7.3	27.6	18.1	13.2	42.3
	Jul 5	4.5	31.3	9.4	68.7	20.1	14.8	42.4
	22	4.9	68.0	12.1	32.0	36.2	46.3	56.1
	Aug 10	4.8	25.0	10.1	52.1	29.6	28.2	48.8
	Sep 10	4.7	5.1	10.5	36.7	25.3	21.9	46.4
	Oct 15	5.1	4.5	9.2	9.4	50.0	37.5	42.9
S-21"	Jun 26	4.5	35.3	7.6	64.7	28.9	15.4	42.8
	Jul 5	4.8	24.9	9.5	75.1	34.0	24.7	42.1
	22	5.3	11.2	9.1	88.8	38.5	23.5	37.9
	Aug 10	5.2	7.3	9.9	52.8	37.0	35.2	48.8
	Sep 10	4.6	4.9	10.3	34.9	44.6	53.9	54.7
	Oct 15	5.5	4.0	9.5	7.9	29.2	20.8	41.6
S-36"	Jun 26	4.8	27.1	7.8	72.9	43.5	18.3	29.6
	Jul 5	4.5	42.9	9.4	57.1	52.3	32.8	38.5
	22	5.2	7.1	11.2	63.8	59.8	75.4	55.8
	Aug 10	---	---	9.9	58.5	52.3	59.0	53.0
	Sep 10	---	---	12.0	23.7	39.3	51.8	56.9
	Oct 15	---	---	8.7	5.3	40.0	20.0	33.3

APPENDIX C (Continued)

Cultural experiment

Morphological characteristics of main stems
(Mean of two replications)

Treatment[a]	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)	% Dead stems of all stems
		Live	Dead	Live	Dead		
S-7"	Jun 26	3.8	1.6	29.2	36.5	.98	---
	Jul 5	4.3	1.9	36.6	29.4	1.23	---
	22	4.9	2.2	71.6	18.1	1.18	---
	Aug 10	3.8	3.3	34.9	18.8	.97	22.9
	Sep 10	3.7	4.9	25.3	16.9	.89	58.2
	Oct 15	3.9	7.5	37.5	37.5	.90	86.1
S-21"	Jun 26	5.3	1.4	80.8	8.7	2.08	---
	Jul 5	4.7	1.8	58.9	6.8	1.14	---
	22	4.1	2.0	66.9	15.2	1.33	---
	Aug 10	3.1	4.2	46.9	20.5	.92	39.9
	Sep 10	4.2	4.0	78.0	30.6	1.09	60.2
	Oct 15	3.3	4.4	14.6	20.9	.71	88.1
S-36"	Jun 26	6.0	2.3	98.8	10.7	1.79	---
	Jul 5	5.3	2.2	94.8	7.7	1.21	---
	22	5.0	1.6	120.3	16.7	1.02	29.1
	Aug 10	4.1	3.4	97.5	12.9	1.12	41.5
	Sep 10	4.0	5.1	46.5	48.2	1.07	76.3
	Oct 15	2.2	3.2	20.0	20.0	1.22	94.7

[a]S refers to a normal seeding rate, equivalent to 41.6 lbs/A, 13.9 lbs/A and 7.7 lbs/A for 7", 21" and 36" row spacings, respectively. 2S refers to a seeding rate double that of the corresponding S treatment.

APPENDIX D

Cultural experiment

Morphological characteristics of tillers
(Mean of two replications)

Treatment[a]	Cutting date	No. of tillers per plant	Apical buds below cut		Apical bud above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
			Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
2S-7"	Jun 26	---	---	---	---	---	---	---	---
	Jul 5	.12	4.1	66.7	8.0	33.3	22.2	5.5	19.9
	22	.12	4.1	77.8	7.1	22.2	36.8	8.8	19.3
	Aug 10	.12	2.5	44.4	7.9	55.6	11.1	11.1	50.0
	Sep 10	.17	3.5	9.5	8.8	90.5	39.1	41.9	51.7
	Oct 15	.09	3.5	20.0	7.5	80.0	22.5	16.3	42.0
2S-21"	Jun 26	---	---	---	---	---	---	---	---
	Jul 5	.08	4.2	70.9	11.7	29.1	20.8	14.6	41.3
	22	.28	4.7	29.0	8.1	71.0	18.0	14.0	43.8
	Aug 10	.31	---	---	9.4	100.0	48.4	18.4	36.3
	Sep 10	.26	4.6	12.1	8.6	87.9	69.3	64.8	48.3
	Oct 15	.24	4.1	11.8	9.5	88.2	37.7	32.2	46.1
2S-36"	Jun 26	.19	3.7	84.6	6.2	15.4	30.8	3.9	11.2
	Jul 5	.13	4.2	61.2	8.2	38.8	44.9	22.2	33.1
	22	.20	4.6	36.8	7.9	63.2	63.5	24.3	27.7
	Aug 10	1.03	3.9	76.7	13.9	23.3	82.4	132.6	61.7
	Sep 10	.35	---	---	14.5	100.0	100.0	163.6	62.1
	Oct 15	.19	5.0	9.1	12.5	90.9	82.1	77.0	48.4

APPENDIX D (Continued)

Cultural experiment

Morphological characteristics of tillers
(Mean of two replications)

Treatment[a]	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)
		Live	Dead	Live	Dead	
2S-7"	Jun 26	---	---	---	---	---
	Jul 5	4.0	1.9	33.5	5.5	1.40
	22	3.1	1.8	18.1	11.8	.92
	Aug 10	3.5	2.1	11.1	11.1	1.00
	Sep 10	3.4	2.4	43.8	17.2	.71
	Oct 15	3.9	2.9	13.2	11.3	.63
2S-21"	Jun 26	---	---	---	---	---
	Jul 5	3.6	1.4	16.6	20.8	1.00
	22	4.2	2.3	30.0	14.0	1.50
	Aug 10	3.8	2.7	42.5	13.8	.76
	Sep 10	4.3	3.2	47.5	14.3	.51
	Oct 15	3.3	3.3	21.8	15.9	.54
2S-36"	Jun 26	3.6	1.8	38.5	15.4	1.56
	Jul 5	4.1	2.0	94.5	22.2	1.84
	22	3.7	1.7	73.7	18.7	1.30
	Aug 10	4.9	2.5	135.4	31.5	.80
	Sep 10	4.6	3.2	148.1	23.4	.68
	Oct 15	3.8	4.0	26.8	20.9	.30

APPENDIX D (Continued)

Cultural experiment

Morphological characteristics of tillers
(Mean of two replications)

Treatment[a]	Cutting date	No. of tillers per plant	Apical bud below cut		Apical bud above cut		Stem dry weight per 100 plants(g.)		% Stem weight above cut
			Ave. ht. in.	% of all stems	Ave. ht. in.	% of all stems	Below cut	Above cut	
S-7"	Jun 26	---	---	---	---	---	---	---	---
	Jul 5	.02	---	---	7.0	100.0	100.0	50.0	33.3
	22	---	---	---	---	---	---	---	---
	Aug 10	.65	5.3	13.3	11.3	86.7	66.7	66.7	50.0
	Sep 10	.12	---	---	10.6	100.0	50.0	54.2	52.0
	Oct 15	.20	---	---	9.9	100.0	55.7	58.6	51.3
S-21"	Jun 26	.10	4.2	100.0	---	---	25.0	---	---
	Jul 5	.09	4.3	45.2	8.3	54.8	38.1	22.7	37.3
	22	.38	5.2	34.8	8.2	65.2	42.7	22.1	34.1
	Aug 10	.53	4.7	25.9	9.4	74.1	60.5	38.4	38.8
	Sep 10	.13	---	---	15.9	100.0	100.0	39.5	28.3
	Oct 15	.38	4.5	11.1	11.9	88.9	67.5	53.6	44.3
S-36"	Jun 26	.24	4.1	100.0	---	---	16.7	---	---
	Jul 5	.15	3.7	73.4	7.1	26.6	36.7	13.3	26.6
	22	.41	5.0	20.0	8.6	80.0	56.5	30.0	34.7
	Aug 10	.40	4.3	13.3	10.6	86.7	90.0	37.5	29.4
	Sep 10	.70	---	10.0	15.0	90.0	105.0	160.0	60.4
	Oct 15	.77	5.2	12.5	11.2	87.5	76.2	68.4	47.3

APPENDIX D (Continued)

Cultural experiment

Morphological characteristics of tillers
(Mean of two replications)

Treatment[a]	Cutting date	Ave. no. leaves per plant		Dry wt. leaves per 100 plants(g.)		Leaf/stem ratio (dry wt. basis)
		Live	Dead	Live	Dead	
S-7"	Jun 26	---	---	---	---	---
	Jul 5	7.0	2.0	200.0	20.0	2.7
	22	---	---	---	---	---
	Aug 10	3.0	2.1	46.7	26.7	.55
	Sep 10	4.2	3.6	66.7	25.0	.85
	Oct 15	4.2	3.1	19.3	12.2	.27
S-21"	Jun 26	4.2	1.0	16.7	8.3	1.00
	Jul 5	5.2	1.4	36.8	11.9	1.39
	22	4.4	1.3	64.7	21.4	1.35
	Aug 10	5.2	3.1	74.9	22.9	.96
	Sep 10	3.9	3.2	80.6	44.5	.57
	Oct 15	5.2	2.7	33.8	13.4	.39
S-36"	Jun 26	3.6	0.5	79.2	31.8	2.12
	Jul 5	4.3	1.0	52.5	12.5	1.19
	22	3.7	1.1	48.7	19.4	.96
	Aug 10	5.4	3.4	132.2	24.1	.70
	Sep 10	4.8	3.7	112.5	32.5	.54
	Oct 15	4.5	2.5	35.7	14.2	.35

[a]S refers to normal seeding rate, equivalent to 41.6 lbs/A, 13.9 lbs/A and 7.7 lbs/A for 7", 21" and 36" row spacings, respectively. 2S refers to a seeding rate double that of the corresponding S treatment.

Daily temperature in degrees fahrenheit reported at the Knoxville Airport, U. S. Weather Bureau, 1959.

Day	May		June		July		Aug.		Sep.		Oct.	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	58	77	68	83	71	95	73	93	71	88	62	82
2	56	87	67	79	71	83	69	94	70	85	57	86
3	60	87	63	80	65	90	70	89	67	89	59	85
4	60	90	57	83	68	89	73	87	68	90	61	88
5	59	93	62	82	68	85	71	87	68	90	63	89
6	65	88	62	82	70	88	71	83	67	87	64	83
7	64	88	60	87	66	91	71	80	72	79	64	79
8	59	83	60	88	64	92	71	83	68	85	67	79
9	60	81	63	88	65	94	66	85	68	89	66	79
10	60	83	65	85	66	86	64	85	67	81	63	78
11	70	85	66	87	67	86	64	90	62	71	57	78
12	65	84	68	85	63	88	63	93	59	82	48	76
13	63	78	66	88	67	88	67	92	60	76	57	68
14	49	64	58	78	65	90	65	92	59	76	51	61
15	43	63	55	85	67	88	69	90	56	77	49	65
16	48	69	60	87	67	91	65	86	54	84	44	72
17	45	77	59	85	68	86	69	87	59	85	55	68
18	60	85	57	81	68	85	71	84	61	78	51	70
19	64	90	58	82	70	85	67	91	56	80	43	71
20	67	77	57	87	69	87	70	94	57	83	41	74
21	66	82	59	90	70	85	72	94	55	82	50	66
22	63	86	67	89	69	86	70	94	55	83	55	77
23	64	82	69	89	67	87	70	93	57	87	57	65
24	67	85	67	78	72	85	69	95	59	89	48	63
25	65	77	69	82	69	87	67	93	59	84	42	49
26	65	85	69	91	69	89	71	93	59	84	36	70
27	65	84	71	92	70	90	71	89	71	85	44	57
28	64	86	70	94	69	91	70	88	64	91	37	57
29	66	82	71	96	73	90	70	89	66	88	46	55
30	67	75	73	96	72	93	71	92	67	79	50	71
31	67	83	--	--	74	96	69	89	--	--	56	65
Average	61.1	81.8	63.9	86.0	68.4	88.6	69.0	89.5	62.7	83.6	52.9	71.8

Daily precipitation in inches reported at the Knoxville Airport, U. S. Weather Bureau, 1959.

Day	May	June	July	Aug.	Sept.	Oct.
1	0.07	0.74	.07	.03	.04	
2		.23	.19		.04	
3				.13		
4			T	T		
5		.44		.71	.01	
6		T	T	.06	T	.75
7				.18	.10	.31
8					T	.07
9	.04				T	1.07
10			.45		.65	T
11		T	.04			.05
12	.28	T				
13	.28					.93
14			.01			.28
15						T
16				T		
17			.61			.03
18	T		.42	.14		
19	T		.44	.05		
20	.93		.01	T		
21	T		.06			
22	.04		.12	.01		T
23		.01				.49
24		.77	T	3.25		.56
25	.03	.59	.08			.02
26	T		T	.01	T	.20
27	.75		.47	T	T	.12
28				.32		
29	T			.02	.07	.10
30	.68			T	.02	.01
31	.43	---		T	---	.01
1959 Total	3.53	2.78	2.97	4.91	.93	5.00
Long term mean	3.58	3.47	4.72	3.63	2.53	2.63