# DEFOLIATION OF OATS AND PEARLMILLET AS RELATED TO HERBAGE YIELD

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# INTRODUCTION

Forage plants differ from most other crop plants in that they are commonly subjected to frequent drastic defoliation of leaves and stems. Too often in the past, the consequences of defoliation of pasture plants have been ignored as animals practiced uncontrolled grazing. In recent years rotational and strip grazing have been increasingly used to augment productivity per acre. The problems facing the grazier using more intensive pasture system have been outlined by Myers (62) in Australia.

> Two questions must be decided in rotational grazing or close folding: (1) the height of the pasture at the beginning of grazing which depends on the frequency of grazing and (2) the height of the pasture at the finish of grazing (i.e., the severity of grazing).

The above mentioned questions have been answered to a large degree for cool season perennial grasses and to a more limited extent for warm season perennial grasses. Annual forage grasses have received little attention insofar as plant management is concerned. Consequently, oats (Avena sativa L.) and pearlmillet (Pennisetum glaucum (L.)) have been selected for this study, the former being a cool season plant and the latter a warm season species. Both have been cited in Florida work (56, 55) as being the most productive dairy pasture species during their respective growing seasons.

The questions raised at the inception of this inquiry concerned the consequences of defoliation on total yields and seasonal distribution of forage and to a lesser extent the effects on crude protein content and root production. This series of experiments attempted to evaluate the effects of plant height when defoliated and the stubble height on forage and root production of oats and pearlmillet. The effects of varieties, row spacings, irrigation, and nitrogen levels on forage yields were studied to a more limited extent.

## REVIEW OF LITERATURE

### Perennial Grasses

Effect of plant height at time of cutting or grazing

The literature is replete with references to various frequency of clipping experiments with cool season perennial grasses. One of the earliest studies was made by Crozier (21) with timothy and reported in 1897. He found that frequent mowing reduced total yield to one-fourth of the yield under hay conditions. Although the percentage of crude protein was highest in forage from frequently cut plots, Crozier did not feel that it made up for the loss in yields. Cotton (18) in 1910 ascribed the deterioration of pastures in New York and New England to overgrazing, causing less food storage in perennial plants. Several years later Carrier and Oakley (16) and Hutcheson and Wolfe (42) reported that heavy grazing of Kentucky bluegrass resulted in larger gains per acre than light grazing. Somewhat different conclusions were made by Ellett and Carrier (27) in 1915 from their work with Kentucky bluegrass sod. They found that the total yield of forage varied inversely with the number of times the plants were cut but that the decrease in protein content at the mature stage more than counterbalanced the increase in dry matter. Early work by

Waters (87) pointed out the importance of maturity of top-growth on subsequent yields and permanence of stands of timothy.

Stapledon and Beddows (74) in England reported in 1926 that repeated cutting of orchardgrass reduced the number of new shoots. Another English worker, Fagan (28), compared orchardgrass and Italian ryegrass cut monthly and every fourteen days, finding that the crude protein content was highest from plants cut most frequently but the total protein quantity secured during April and May was greater from plants cut at monthly intervals. Work by Hudson (41) in New Zealand also points out the decrease in yields from frequent clipping of ryegrass and clover.

Graber (30) in 1931 at the University of Wisconsin found that the amount of root and top growth of bluegrass, red top, fescue, and timothy varied inversely with the frequency of defoliation. Similar results were reported by Robertson (68) in 1933. In contrast, Ahlgren (1) obtained increased productivity from cutting bluegrass when four to five inches tall instead of at heading time. Mott (61) in Indiana found that bluegrass-white clover clipped when the herbage reached four to six inches produced three times more forage than when clipped weekly. Dibbern (26), working with bromegrass, substantiated previous investigations in that dry weights of tops and roots were in inverse proportion to frequency of clipping. Tincker (81) noted that a plant produces more additional dry weight in a month by adding to its old growth than when it is clipped and produces new leaves.

Wagner (84) subjected mixtures of orchard-ladino, brome-ladino, orchard-alfalfa, and brome-alfalfa to various cutting intervals and stubble heights of six and twelve inches. He concluded that frequency of cutting had the greatest over-all effect on total yield and distribution of production.

The adverse effect of frequent defoliation on forage production of native range grasses is well known. Studies with native grasses of mostly cool season species in the western United States by Sarvis (72), Sampson and Malmsten (71), Biswell and Weaver (8), and Gernert (29) all point out the decline in forage production under frequent clipping or grazing.

The time of the year when frequent defoliation occurs may be important. Blaisdell and Pechanec (9) found that the greatest reduction in yield of bluebunch wheatgrass the following year occurred from clippings made in late May and early June. Stoddart (77) reported that _Agropyron spicatum_ in Utah was most severely damaged by clipping in midsummer due to drouth conditions normally existing at that time. This same grass was also found to be most vulnerable to clipping damage at the middle of its vegetative stage and that cutting intensified maximum vulnerability and prolonged its duration (58).

Cutting or grazing management may alter the seasonal distribution of forage. English workers (75) found that when cutting does not begin until late May, the May to November growth curve is much more level than when cutting begins earlier in the year. Bird (7) emphasized that stage of plant growth at the time of the first cutting determines the period of aftergrowth.

Frequency of clipping studies with warm season grasses were reported by Leukel, Camp, and Coleman (52) at the Florida Experiment Station in 1934. Bahia, carpet, and centipede grasses cut frequently maintained more vegetative growth and made a better sod. In 1935 Leukel and Barnette (51) reported that although Bahiagrass cut when mature produced the most dry matter, the largest quantity of nitrogen was produced by frequently cut plants. Studies with napiergrass in Trinidad (65) and Hawaii (89) also indicate decreased dry matter production with frequent cutting. The Hawaii workers found that the greatest amount of palatable forage was produced by cutting every eight weeks.

Lovvorn (53, 54) in North Carolina studied the effects of clipping on Dallis, carpet, Bermuda, and Kentucky bluegrass, concluding that although Dallis was most seriously injured by frequent cutting, all the species required more careful management under high fertility. He also found that frequent cutting was more deleterious at high temperature. Prine and Burton (67) studied the effect of nitrogen rate and clipping frequency on Coastal Bermudagrass in Georgia. They found that increasing the clipping interval from one to eight weeks increased hay yield, stem and leaf length, plant height, seed head frequency, and internode length and number. This had little effect on protein yield and percentage nitrogen recovery and decreased the protein percentage and leaf percentage of this grass.

To recapitulate then, forage grass yields are generally in inverse proportion to the frequency of defoliation; the response to clipping being influenced by the species, time of year when clipping is practiced, and soil fertility. Protein yields, on the other hand, may be as high or higher under more frequent defoliation.

Unfortunately, most clipping studies have been based on a chronological schedule rather than on the height of the plant. Kohler (47) points out in his studies on the chemistry of grasses that cutting treatments in variety and fertilizer tests should be on the basis of physiological age rather than on a time interval.

The problem immediately arises as to what is meant by plant height. Heady (37) defines the height of a plant as "the perpendicular distance from the soil at its base to the highest point reached with all parts in their natural position." In clipping studies with plant varieties having different growth habits, it is difficult to use this definition and remove an equivalent amount of forage from each of the plants. In the case of decumbent and upright oat varieties, too often clipping experiments have disregarded the amount of forage left on the decumbent plants. Cattle grazing, however, tend to remove much more of the basal growth on the decumbent plants. For this reason it would seem highly desirable to lift decumbent forage into an erect position to determine its true "height" or length before cutting.

Effect of stubble height

The influence of stubble height on top and root growth of perennial grasses has been investigated by a number of workers. Stapledon and Milton (76) reported in 1930 that orchardgrass plants cut to leave a six-inch stubble considerably outyielded those cut to the ground level. Graber and Ream (32) found that closely clipped bluegrass did not respond to additional nitrogen but that leaving a one and one-half-inch stubble greatly increased production both with and without additional nitrogen fertilizer. A number of other studies point out that bluegrass can be clipped or grazed closely without ill effect (31, 60, 5, 12). Bromegrass, on the other hand, requires that higher stubble be left if forage production is to remain high (90, 2). Quite obviously, the growth habit of a forage species determines the response to close clipping. Lang and Barnes (49) and Newell and Keim (63) noted that native short grasses produced greater yields when cut frequently to ground level than when cut only once at the end of the season.

Harrison (35) and Harrison and Hodgson (36) deduced from clipping studies with several cool season grasses that the shorter the stubble, the less top growth and roots were produced. Harrison (35) concluded that the deleterious effect of frequent cutting may be offset partially by cutting the plants at a greater height above the soil. Dexter (25) and Johnson and Dexter (44) found that quackgrass could be severely injured and often killed by close clipping.

Aldous (3) found in clipping studies with big and little bluestem that a four-inch stubble height gave 25 percent more forage than a two-inch stubble. Holscher (38) reported that with bluestem, wheatgrass, and blue grama even a stubble height of four centimeters was not sufficient to maintain yields and prevent killing of the plants.

Research on tropical grasses by Paterson (66) in Trinidad showed that close clipping sharply reduced yields of para, elephant, Guinea, and Guatemala grasses. He recommended that a cutting height of six to ten inches should be used for these tropical grass species.

Torstensson (82) in Sweden found that meadow fescue and Italian ryegrass grown in the greenhouse were most productive when cut to leave a five-centimeter stubble every 15 days. Jantti and Heinonen (43) in Finland reported that a mixed sward of fescue-orchard-timothy-red and white clover showed a striking reduction in yield when clipped closely. Defoliation to leave a stubble of one centimeter, while the soil moisture was at or near permanent wilting percent down to a depth of 40 centimeters, arrested growth almost completely but the growth rate of plants with a four- or 12-centimeter stubble was 70 to 90 percent of the corresponding rate on moist soil. They concluded that defoliation alone causes heavy reductions in forage yield even in moist soil, and these reductions are more important quantitatively than those resulting from the interaction with soil moisture. Similar results were noted by Canfield (15) with black grama and tobosa grasses where close clipping nullified the value of high rainfall years under range conditions. Tobosa grass clipped to leave a four-inch stubble yielded 110 percent more forage than two-inch stubble over an 11-year period.

Robinson and Sprague (70) found that clipping bluegrass-white clover sod to a height of two inches produced a more dense sod of grass with less clover than when shorter stubble heights were used. Brougham (10, 11) found that a perennial ryegrass, white, and red clover mixture in New Zealand defoliated to five inches yielded 20 percent more herbage than pasture cut to one inch during a 32-day period. During the first 14 days of regrowth the yield difference was 100 percent. He inferred that excess light changed the growth habit. The more intense the defoliation, the lower the initial leaf efficiency.

In contrast to the preceding papers which point out the advantages of higher stubble, Cooper (17) found that the yield of Nevada bluegrass and sedges from a native mountain meadow in Oregon decreased as the cutting height was increased from two to four or six inches. Protein percent of the forage showed only a slight increase with higher stubble height. The lack of response to higher stubble heights here may probably be attributed to the low quality forage plants and unfavorable wet environment.

Root growth as affected by defoliation

Forage plant roots are often decreased in size and number by frequent defoliation of the top growth. Dibbern (26) concluded that clipping of smooth bromegrass was more adverse in its effects on root growth than top growth. Sturckie (78) reported that any cutting of Johnsongrass reduced rootstalk development and the more frequent the cutting, the greater was the reduction. Similar results have been reported for orchardgrass (76), Kentucky bluegrass (46), and wheatgrass (33). Parker and Sampson (64) noted that frequent removal of aerial growth of purple needlegrass and soft chess caused poorly developed roots with a reduction in the diameter of the stele and entire root.

Baker (6) in England found that cutting of top growth reduced the number of roots and tillers per ryegrass plant but increased the number of roots per tiller. The root weight of cut plants was found to be lower than on uncut plants a few weeks after defoliation.

Crider (2), in a detailed study of 13 cool and warm season grasses including bunch, rhizomatous, and stoloniferous types, showed that root growth stopped for a time after each removal of aerial growth. He concluded that the growing top cannot be reduced more than half without adversely affecting the functioning of the root system and the plant as a whole. At variance with this work, Laird (48) concluded that mowing of centipede and Bermudagrasses increased the root growth. The difference of opinion as expressed by the latter paper can probably be attributed to poor control of environmental factors in root investigations. This fact is stressed by Williams and Baker (88) who point out that root studies should be conducted on plants grown in their natural habitat, or on field experimental plots, rather than in the artificial environment provided by containers.

## Annual Grasses

Clipping studies with annual forage plants have been limited in number. Many of these experiments were concerned with grain production of oats, rye, and wheat. Field studies in Pennsylvania by Washko, Edge, and Haskins (86) showed that fall clipping of oats did not affect grain yields but that spring clipping decreased grain yields. Robinson (69) in England found that if grazing of winter wheat is continued into mid or late April the loss of grain will be 20 to 25 percent of the potential crop. Applying 100 to 150 pounds per acre of ammonium sulfate immediately after the last grazing reduced the loss of grain by one-half. Morris and Gardner (59) in north Georgia found that clipping to March 15 resulted in 75 percent or more reduction in grain yields of oats, wheat, and rye. Research work in north Florida (58) indicated that clipping oats until February 15 reduced grain yields 25 percent while an additional two weeks of clipping resulted in 50 percent yield reduction. High nitrogen fertilization was effective in maintaining yields of oats and rye clipped to mid

February. Cutler, Pavez, and Mulvey (22) in Indiana found that clipping wheat during early April increased the yield and quality of grain. Clipping reduced plant height by shortening the lower internodes and thus decreased lodging of the grain.

Davies (23) in England reported that winter grazing of oats caused a much sharper decrease in grain yields than did spring grazing. His results indicate that the reduced yields of grain are probably due to the height of the plants grazed and the stubble heights used but he attributes the difference to season of the year. In this experiment, the plants were two to three inches tall and grazed to leave a three-quarter-inch stubble on the winter grazed paddocks while in the spring grazed paddocks the plants were six to seven inches tall and grazed to leave a one to one and one-half-inch stubble.

Washko (85) found in Tennessee sheep grazing trials on erect and prostrate types of oats, wheat, barley, and rye that the habit of growth had no effect on forage production. Grazing was found to be detrimental to grain production on all species. Thurman (79) reports that upright varieties of oats produce more forage in the fall than prostrate types but that the total production for the season is about the same.

Hubbard and Harper (40) in Oklahoma found that severe clipping of small grain produced slightly less forage and appreciably lower grain yields than did moderate clipping. Yields were affected most by severe clipping in unfavorable growing seasons. The chemical composition of forage from severe and moderately clipped plots was similar.

Thurman and Grissom (80) in Arkansas reported that clipping very young oat plants reduced root growth and forage yields as compared to delayed clipping. The regrowth of oats was reduced when the growing point of the short stems was clipped along with the leaves. Clipping above the terminal growing point and after the plants had a good start more than doubled forage yields. Laude (50) in a greenhouse experiment with soft chess noted that growth was faster from a cut shoot when the terminal bud was retained and the culm continued elongation, than when the bud was removed and regrowth was by tillering. In addition, the tiller was smaller and lighter than the main shoot. Justus and Thurman (45) also report decreased yields of oats by frequent clipping. Burton and Prine (14) found that forage yields of Abruzzi rye, Southland oats, and ryegrass were greatly increased by cutting at bi-monthly instead of monthly intervals late in the season. Early in the season this had little effect on yields.

Hoveland (39) in Texas found that oats clipped back to one inch whenever they reached three to four inches in height produced 83 percent less forage than where the plants were permitted to grow 10 to 12 inches tall before clipping. Marshall (55), in a Florida trial with dairy heifers on oats, concluded that increasing the height of forage to about eight to ten inches before grazing as compared to six to eight inches was responsible for obtaining a higher yield of total digestible nutrients. Verbeek (83) in South Africa also stated the desirability of having oat plants at that height for grazing. He also cautioned that oat and wheat plants should not be allowed to get much higher than 12 inches because the recovery power of the plants is reduced with consequent fewer grazings being obtained per season.

The effect of cutting sudangrass at two- and six-inch stubble heights was studied by DePeralta (24) in Nebraska. Yields of forage and roots were markedly reduced by close clipping. Seeding rate was also studied but this factor had little effect on yield response under the two cutting treatments. Burger, Jackobs, and Hittle (13), in an Illinois study, found that herbage yields of four sudangrass varieties were much lower when cut at 18 to 20 inches tall than when harvested at hay stage. Little difference existed between varieties when cut at the shorter height.

Row spacings may influence the response to cutting of oats (73) and pearlmillet (19). In general, narrower row spacings favor higher forage yields but defoliation systems may alter this pattern.

## OATS

### Materials and Methods

All of the experiments in this study were established on Arredondo loamy fine sand located at the Agronomy Farm, University of Florida, Gainesville, during the winters of 1955-56 and 1956-57.

<u>Effect of cutting treatments, varieties, and irrigation, winter, 1955-56</u>

A split plot design was employed, consisting of three varieties as main plots, subplots of three dates when clipping stopped in order to produce grain, and sub-subplots of six defoliation or cutting treatments. All combinations of these were used. Oat varieties were selected on the basis of representative growth habit: decumbent-Arlington; intermediate-Floriland; and upright-Seminole. The dates to stop clipping on each variety were based on the usual time of heading at Gainesville. The average heading dates at Gainesville are: Arlington-April 1, Floriland-March 1, and Seminole-February 20. Six cutting heights were selected to obtain a range from very intensive to light defoliation. The treatments were replicated six times.

The entire experiment was grown under both irrigated and non-irrigated conditions, making a total of 648 plots. The irrigation schedule was determined from mercury tensiometers, placed at depths of three and nine inches. A tensiometer location is shown in Figure 1. After the plants had become established, irrigation water was applied by sprinklers whenever the soil moisture tension reached 500 centimeters at the nine-inch level. Due to the low water-holding capacity of this soil, only one inch of water was applied per irrigation. During the winter, a total of 18 inches of water was applied in order to maintain adequate soil moisture. One-half of this water was applied from February 25 to April 20. Very hard winds and blowing sand during the last two weeks of March and the first week of April made it difficult to supply sufficient moisture for plant growth.

All oat varieties were planted October 18 at the rate of four bushels per acre in nine-inch rows using a Planet Jr. 300A planter. The fertilization at planting consisted of: 800 pounds per acre 8-8-8, 100 pounds calcium sulfate, 40 pounds magnesium sulfate, 10 pounds copper sulfate, 10 pounds manganese sulfate, 10 pounds zinc sulfate, one pound fertilizer borax, and one-fourth pound sodium molybdate. Additional applications of 100 pounds per acre ammonium nitrate were made on November 28, January 3, February 3, and March 9, making a total of 196 pounds of actual nitrogen per acre for the season. Subsequent nitrogen applications were made on the basis of plant tissue tests. Both irrigated and unirrigated portions of the experiment received the same fertilization.

Each plot consisted of three rows seven feet long; the two outer rows serving as borders and being cut the same as the inner yield row. A 5.8-foot strip of the center row, 0.0001 acre in area, was harvested and weighed for yield.

Cutting was done by hand using paring knives. The proper height of cut (two, five, or nine inches) was maintained by using as a knife guide a plywood board of the proper height. Nails 5.8 feet apart on top of the board indicated the exact length of row. Bamboo stakes driven into the ground at one end of each yield row indicated the height to which the plants were to be grown before cutting. The heights of stubble were color coded on both stakes and the wooden cutting boards (red = two inch, white = five inch, blue = nine inch). This feature eliminated much of the potential chance for error in the field. Views of the field experiment and the cutting technique are shown in Figures 2 to 4.

The question of when to cut a particular treatment was determined by visual inspection of the plots. Decumbent oat forage was lifted to an erect position to determine its true height and also for the cutting operation itself. Green forage was not weighed but only oven dry weights were recorded in grams. Plot yields were converted to pounds per acre and then subjected to statistical analysis.

Forage was collected in December, January, and March from two replications of each treatment, dried and ground for nitrogen analysis by the Kjeldahl method (4).

Grain yields were obtained by harvesting a .0001 acre strip, drying, and threshing with a Vogel machine. Weight of grain per plot was recorded in grams and later converted to pounds per acre.

Fig. 1.--Mercury tensiometers located in oats.

Fig. 2.--Hand cutting of oats using a two-inch red board.

Fig. 3.--Hand cutting of oats using a nine-inch blue board.

Fig. 4.--The irrigated portion of the 648 plots in the 1955-56 oat clipping study. Bamboo stakes with colored tips indicate the height at which plants are cut.

Effect of cutting treatments, varieties, and irrigation, winter 1956-57

In continuation of the clipping studies with oats, a split plot experiment was planted October 18, 1956 using Arlington, Floriland, and Seminole oat varieties as main plots. Subplots consisted of eight clipping treatments as follows:

(1) Clipped all winter when six inches tall to leave a two-inch stubble.

(2) Clipped all winter when 12 inches tall to leave a two-inch stubble.

(3) Clipped all winter when 12 inches tall to leave a five-inch stubble.

(4) Clipped all winter when 18 inches tall to leave a two-inch stubble.

(5) Clipped all winter when 18 inches tall to leave a five-inch stubble.

(6) Clipped the first time at six inches to leave a two-inch stubble. Clipped remainder of winter when 12 inches tall to leave a two-inch stubble.

(7) Clipped the first time when six inches tall to leave a two-inch stubble. Clipped remainder of winter when 12 inches tall to leave a five-inch stubble.

(8) Clipped the first time when 12 inches tall to leave a two-inch stubble. Clipped remainder of the winter when six inches tall to leave a two-inch stubble.

The experiment was replicated five times and grown under both irrigated and unirrigated conditions, making a total of 240 plots. Fertilization at the October 18 planting date on both irrigated and unirrigated areas consisted of 800 pounds per acre of 6-8-8, 100 pounds calcium sulfate, 50 pounds magnesium sulfate, and 50 pounds fritted trace elements. In addition, the irrigated experiment received 200 pounds per acre sodium nitrate on November 6, November 26, December 20, January 9, January 30, and March 11 making a total of 240 pounds of actual nitrogen per acre for the season. The unirrigated experiment received additional applications of 200 pounds per acre sodium nitrate on November 6, December 20, and January 30 making a total for the season of 144 pounds of actual nitrogen.

A total of 11 one-inch applications of water were made to the irrigated plots; the irrigation schedule being determined as in the 1955-56 experiment. Planting and harvesting operations were carried out as in the previous year. An over-all view of the experiment is shown in Figure 5.

In order to obtain information on root production under the various regimes of cutting, two cores six inches deep and four inches in diameter were collected from each plot of the irrigated experiment on January 15. Cores were obtained directly from the row, the top growth being clipped off to the ground level. Each plot sample was washed on a screen to remove soil and the root material, was dried and then weighed.

It was noted early in the winter that freezing injury appeared to be dependent on the stubble height at the time of the freeze. The question was posed as to temperature differences within plots. Consequently, minimum thermometers were mounted between the rows of two- and five-inch stubble height plots of Floriland oats at heights of three and six inches as shown in Figures 6 and 7. Unfortunately, only two moderate freezes occurred after mounting the thermometers on January 17 so that only limited information was obtained.

Fig. 5.--A portion of the irrigated 1956-57 oat clipping experiment.

Fig. 6.--Minimum thermometer with shields mounted on pole at five-foot level.

Fig. 7.--Minimum thermometers mounted at heights of three and six inches in oat plots.

Effect of sheep grazing treatments, winter 1956-57

In order to ascertain yields of forage and effects on the plants under different intensities of grazing, a small paddock sheep grazing study was initiated where the animals were used only as a tool in removing the forage. Animal gains were not considered in this study.

Arlington oats were seeded with a grain drill on a one-fourth acre area after fertilizing with 800 pounds per acre 8-8-8, 100 pounds calcium sulfate, 50 pounds magnesium sulfate, and 500 pounds per acre fritted trace elements. Additional nitrogen applications of 200 pounds per acre of sodium nitrate were made on November 6, November 26, and December 28, making a total of 160 pounds of actual nitrogen for the season. Eight inches of irrigation water were applied during the winter.

A randomized block design was employed with five grazing treatments and four replications, thus dividing the area into 20 paddocks. The treatments were as follows:

(1) Grazed when the plants reached six inches, leaving a two-inch stubble.

(2) Grazed when the plants reached 12 inches, leaving a two-inch stubble.

(3) Grazed when the plants reached 12 inches, leaving a five-inch stubble.

(4) Grazed the first time when plants were six inches tall

with a two-inch stubble, thereafter when plants were 12 inches tall, leaving a two-inch stubble.

(5) Grazed the first time when plants were 12 inches tall leaving a two-inch stubble, thereafter when plants were six inches tall leaving a two-inch stubble.

The estimated yields of forage were calculated for each of the treatments using data from the clipping experiment of the previous year and the size of the paddock adjusted so that it could be grazed down within a day by one sheep. It was later discovered that one sheep would not stay and graze well alone, so two animals per paddock were used, making it possible to graze down the area to the desired height in about two hours.

Woven wire fence three feet high and creosoted posts were used in construction of the paddocks. The one-half acre reserve area of oats near the paddocks was fenced with woven wire four feet high to discourage fence jumping. In one corner of this area was constructed a small shelter of sheet metal closed on the north and west as protection against inclement weather. The eight native breed sheep were shut up in the shelter each night as protection against dogs. Figures 8 and 9 show views of the experiment.

Before grazing, yields were taken by cutting to the desired stubble height three quadrats (0.0001 acre each) at random in each paddock. The three quadrat yields were averaged together and the statistical analysis determined on the four replications for each treatment. After clipping, the sheep were turned into the paddock and allowed to graze it down to the stubble height of the clipped quadrats. It was found that the sheep grazed the two-inch stubble paddocks somewhat closer than desired, usually one to two inches, while the five-inch stubble paddocks were grazed to leave a stubble of four to six inches.

Fig. 8.--Sheep grazing in the holding area of oat management study.

Fig. 9.--Paddocks of oat management study. Two sheep were used in each of the four replications of a particular grazing treatment.

## Results

**Effect of cutting treatments, varieties, and irrigation, winter 1955-56**

In Tables 1 and 2 are shown the average yields per treatment combination. The statistical analysis summary in Table 3 was calculated from the original plot yields in grams oven dry forage per 0.0001 acre. Results of the over-all statistical analysis shown in Table 4 indicate that the highest forage yield for the winter was obtained with the Arlington variety, followed by Floriland, and then Seminole. All three varieties generally responded much the same to irrigation, the yield increases ranging from 44 to 48 percent.

As shown by Figure 10, there was little difference in the earliness of forage production by the three varieties. The Seminole variety is usually classed as an early forage producer but this is probably due to its upright habit of growth, giving an appearance of greater forage production than the more decumbent types. Tables 1 and 2 indicate that Seminole made most of its production late in the growing season. Continued high production throughout the winter was found to be better with Arlington and Floriland than with the Seminole variety, regardless of the cutting treatment used.

The comparison of dates when clipping was stopped

TABLE 1

SEASON TOTAL FORAGE YIELDS OF IRRIGATED OATS AS INFLUENCED BY DATE WHEN CLIPPING CEASED, VARIETY, AND CLIPPING TREATMENT, WINTER, 1955-56

| | Pounds per Acre Oven Dry Forage per Clipping Treatments[a] | | | | | |
|---|---|---|---|---|---|---|
| | 6-2 | 12-2 | 12-5 | 18-2 | 18-5 | 18-9 |
| Clipping until six weeks before average heading date: | | | | | | |
| Arlington | 2,310 | 2,650 | 2,620 | 3,480 | 3,210 | 1,890 |
| Floriland | 1,360 | 2,640 | 1,090 | 1,890 | 1,090 | 590 |
| Seminole | 780 | 890 | 850 | 1,610 | 1,290 | 640 |
| Clipping until two weeks before average heading dates: | | | | | | |
| Arlington | 3,050 | 4,080 | 3,730 | 5,160 | 5,630 | 3,580 |
| Floriland | 2,640 | 2,860 | 3,630 | 3,050 | 3,110 | 2,680 |
| Seminole | 1,170 | 1,410 | 1,970 | 2,910 | 2,260 | 1,360 |
| Clipped all season: | | | | | | |
| Arlington | 4,090 | 4,830 | 5,060 | 4,580 | 5,550 | 4,530 |
| Floriland | 2,800 | 4,180 | 4,600 | 3,410 | 3,920 | 3,390 |
| Seminole | 2,820 | 3,400 | 3,220 | 4,370 | 3,010 | 2,670 |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 2

SEASON TOTAL FORAGE YIELDS OF UNIRRIGATED OATS AS INFLUENCED BY DATE WHEN CLIPPING CEASED, VARIETY, AND CLIPPING TREATMENT, WINTER 1955-56

| | Pounds per Acre Oven Dry Forage per Clipping Treatment[a] | | | | | |
|---|---|---|---|---|---|---|
| | 6-2 | 12-2 | 12-5 | 18-2 | 18-5 | 18-9 |
| Clipped until six weeks before average heading date: | | | | | | |
| Arlington | 1,920 | 2,480 | 1,500 | 2,220 | 1,300 | 650 |
| Floriland | 1,090 | 1,640 | 1,400 | - | - | - |
| Seminole | 610 | 1,130 | 610 | - | - | - |
| Clipped until two weeks before average heading date: | | | | | | |
| Arlington | 2,580 | 3,040 | 2,990 | 3,180 | 3,130 | 2,590 |
| Floriland | 2,080 | 2,420 | 2,510 | 2,240 | 2,600 | 1,190 |
| Seminole | 1,190 | 1,550 | 1,300 | 1,890 | 1,680 | 950 |
| Clipped all season: | | | | | | |
| Arlington | 2,800 | 4,140 | 3,170 | 3,850 | 3,150 | 3,000 |
| Floriland | 2,900 | 2,930 | 2,690 | 2,860 | 2,710 | 2,310 |
| Seminole | 2,040 | 2,950 | 2,610 | 3,130 | 2,090 | 1,670 |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 3

ANALYSIS OF VARIANCE: FORAGE YIELDS OF OATS AS INFLUENCED BY IRRIGATION, VARIETY, DATE WHEN CLIPPING CEASED, AND CLIPPING TREATMENT, WINTER 1955-56

| Source | D.F. | Irrigated | | Unirrigated | |
|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Main Plots: | | | | | |
| Replications | 5 | 8,062 | 1,612.4 | 1,324 | 264.8 |
| Varieties | 2 | 392,192 | 196,095.8** | 176,676 | 88,338.0** |
| Error (a) | 10 | 18,772 | 1,877.2 | 2,626 | 262.6 |
| Subplots: | | | | | |
| Date when clipping ceased | 2 | 542,676 | 271,337.8** | 418,216 | 209,108.0** |
| D x V | 4 | 18,275 | 4,568.6** | 9,056 | 2,264.0** |
| Error (b) | 30 | 22,825 | 760.8** | 10,504 | 350.1 |
| Sub-subplots: | | | | | |
| Cutting treatments | 5 | 106,210 | 21,242.0** | 75,575 | 15,115.0** |
| CT x V | 10 | 47,552 | 4,755.2** | 14,875 | 1,487.5** |
| CT x D | 10 | 30,501 | 3,050.1** | 35,491 | 3,549.1** |
| CT x D x V | 20 | 37,217 | 1,860.8** | 22,551 | 1,127.6** |
| Error (c) | 225 | 129,983 | 577.7 | 94,573 | 420.3 |
| Total | 323 | 1,354,265 | | 861,467 | |

**Significant at one percent level.

TABLE 4

SUMMARY OF OAT FORAGE YIELDS AS INFLUENCED BY IRRIGATION, VARIETY, DATE WHEN CLIPPING CEASED, AND CLIPPING TREATMENT, WINTER 1955-56

| | Pounds per Acre Oven Dry Forage | |
|---|---|---|
| | Irrigated | Unirrigated |
| Varieties: | | |
| Arlington | 3,890 | 2,660 |
| Floriland | 2,720 | 1,870 |
| Seminole | 2,040 | 1,410 |
| L.S.D. at 5% | 290 | 110 |
| Date when clipping ceased in order to produce grain: | | |
| Clipped all season | 3,910 | 2,830 |
| Clipped until 2 weeks before average heading date[a] | 3,020 | 2,170 |
| Clipped until 6 weeks before average heading date | 1,720 | 930 |
| L.S.D. at 5% | 170 | 110 |
| Clipping treatments: | | |
| 6 in. tall, 2 in. stubble | 2,340 | 1,910 |
| 12 in. tall, 2 in. stubble | 2,990 | 2,480 |
| 12 in. tall, 5 in. stubble | 2,980 | 2,090 |
| 18 in. tall, 2 in. stubble | 3,380 | 2,160 |
| 18 in. tall, 5 in. stubble | 3,230 | 1,850 |
| 18 in. tall, 9 in. stubble | 2,370 | 1,370 |
| L.S.D. at 5% | 200 | 170 |

[a]Average heading dates at Gainesville:

Arlington - April 1
Floriland - March 10
Seminole - February 20

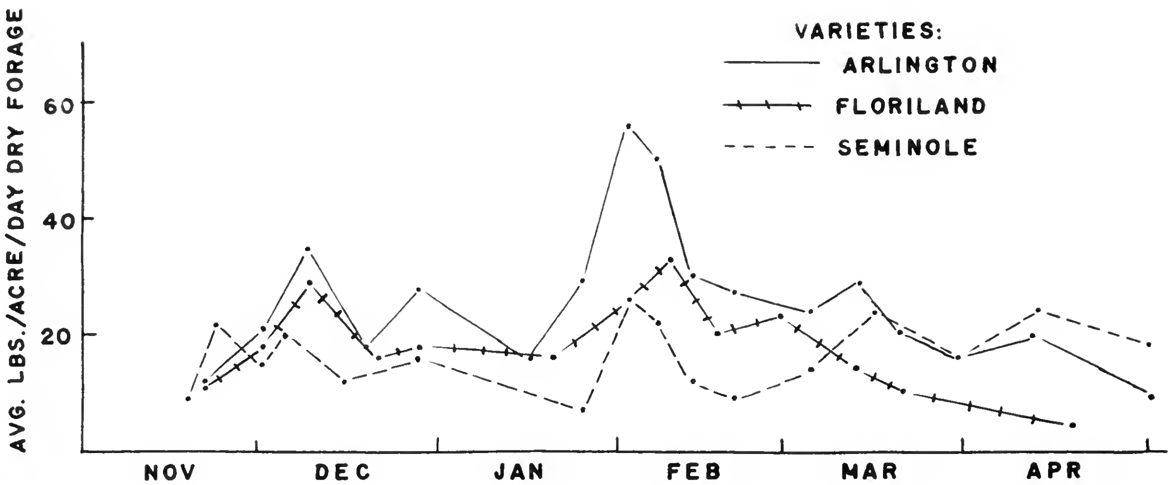


Fig. 10.--Seasonal distribution of forage for three irrigated oat varieties cut when six inches tall to leave a two-inch stubble, winter 1955-56.

to produce grain gives an indication as to the amount of forage produced late in the growing season. Approximately 23 percent less forage was obtained when the removal of forage was stopped two weeks before the average heading date. When clipping ceased six weeks prior to heading, forage yields were reduced 56 percent in the irrigated and 67 percent in the unirrigated plots.

Clipping treatments did not have as much effect on oat forage yields as expected. Low temperatures during the winter months limited the growth of oats and thus probably masked much of the response to clipping encountered in summer forage crops such as pearlmillet. Growth in the unirrigated plots was very slow until spring due to drouth and only one clipping was obtained from the 18-inch plants. As would be expected, the 18-inch plants with two- or five-inch stubble produced the most forage under irrigation. Yields were sharply reduced with a nine-inch stubble.

Forage yields were generally reduced by clipping plants when six inches tall. Under irrigation this decline in yield was most pronounced with the Floriland variety as shown by the data for the total season forage production in Table 1. Under conditions of inadequate moisture, close clipping of this variety decreased the yield early in the growing season but was not detrimental later in the season as shown in Table 2. It is possible that close and frequent clipping may have stimulated increased tillering of this variety. However, intensive clipping under unirrigated conditions reduced the yield of the Seminole and Arlington varieties, indicating that varieties differ in response to defoliation, depending on the moisture available.

The effect of clipping treatments on seasonal distribution of forage is typified by the results for Floriland oats shown in Figure 11. Generally, plants allowed to grow 12 inches tall before clipping produced a greater quantity of forage in midwinter than did the other treatments.

Since there was a highly significant interaction between varieties and clipping treatments under irrigation, it was desirable to ascertain how each variety responded to clipping. Separate analyses of variance (Table 5) were calculated for each variety. As shown in Table 6, the three varieties responded somewhat differently to clipping. Arlington, a decumbent type, gave increased yield with the higher stubble height on 18-inch plants. Seminole, an upright type oat, was quite different in that highest yields were obtained when 18-inch plants were cut with a two-inch stubble. This was also true under unirrigated conditions (Table 2). The reason for this is somewhat difficult to understand since Seminole has an erect habit of growth and close clipping results in loss of the growing point.

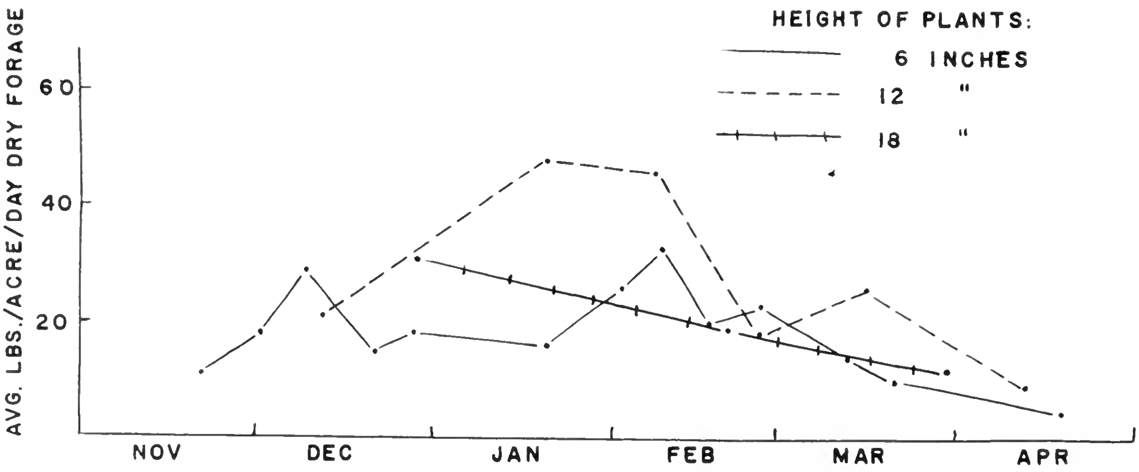


Fig. 11.--Seasonal distribution of irrigated Floriland oats as affected by height of plants when cut, winter 1955-56. All plants were cut to leave a two-inch stubble.

TABLE 5

ANALYSIS OF VARIANCE: FORAGE YIELDS OF THREE IRRIGATED OAT VARIETIES AS AFFECTED BY CLIPPING, WINTER 1955-56

| Source | D.F. | Arlington | | Floriland | | Seminole | |
|---|---|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Replications | 5 | 16,370 | 3,274** | 11,276 | 2,255** | 1,837 | 367 |
| Cutting Treatments | 5 | 15,511 | 3,102** | 25,666 | 5,133** | 22,875 | 4,575** |
| Error | 25 | 16,032 | 641 | 20,445 | 818 | 22,917 | 917 |
| Total | 35 | 47,913 | | 57,387 | | 47,629 | |

**Significant at one percent level.

TABLE 6

EFFECT OF CLIPPING TREATMENTS ON FORAGE YIELDS OF THREE IRRIGATED OAT VARIETIES, WINTER 1955-56

| Cutting Treatment | Pounds per Acre Oven Dry Forage | | |
|---|---|---|---|
| | Arlington | Floriland | Seminole |
| 12 inches tall, 5-inch stubble | 5,060 | 4,600 | 3,220 |
| 12 inches tall, 2-inch stubble | 4,830 | 4,180 | 3,400 |
| 18 inches tall, 5-inch stubble | 5,550 | 3,920 | 3,010 |
| 18 inches tall, 2-inch stubble | 4,580 | 3,410 | 4,370 |
| 18 inches tall, 9-inch stubble | 4,530 | 3,390 | 2,820 |
| 6 inches tall, 2-inch stubble | 4,090 | 2,800 | 2,870 |
| L.S.D. at 5% level | 660 | 750 | 790 |

With 12-inch plants, leaving a five-inch stubble did not significantly increase the forage yield of any variety.

The efficacy of irrigation is shown in Figure 12 where the distribution of forage throughout the season is graphed for the Arlington variety when cut at 12 inches to leave a five-inch stubble. The major contribution of irrigation was in furnishing early forage during December and January. The value of irrigation was erased by improper defoliation management. Figure 13 illustrated this fact in the case of Seminole oats but similar results occurred with the other two varieties. Close and frequent cutting resulted in low production despite adequate moisture being present. The sharp production dips during January on all of these graphs are due to freezes which seriously limited forage growth.

The crude protein content of forage from most of the clipping treatments was high, as shown in Table 7. The protein content remained highest throughout the season with six-inch plants clipped back to two inches. Plants 18 inches tall with a two-inch stubble were lowest in protein. In the case of 12-inch plants, those having a five-inch stubble were somewhat higher in crude protein during the month of March than plants with a two-inch stubble.

Grain yield data are summarized in Table 8. Very low grain yields were obtained as shown in Tables 9, 10, and 11, particularly with the Arlington and Floriland varieties where losses due to bird damage were appreciable. Irrigation increased the yield of Seminole oats by 50 percent but even so, the yield was low. As expected, grain yields decreased when the forage was removed as late as two weeks before the average heading date. However, the yield reduction was much less pronounced where moisture was not limiting.

Under unirrigated conditions, clipping treatments had little effect on the yield of grain except in the case of closely defoliated plants six inches tall with two-inch stubble where the yield was reduced. With adequate moisture, grain yields were greatly affected by defoliation. Plants clipped when 12 inches tall to leave a five-inch stubble produced considerably more grain than any other treatment.

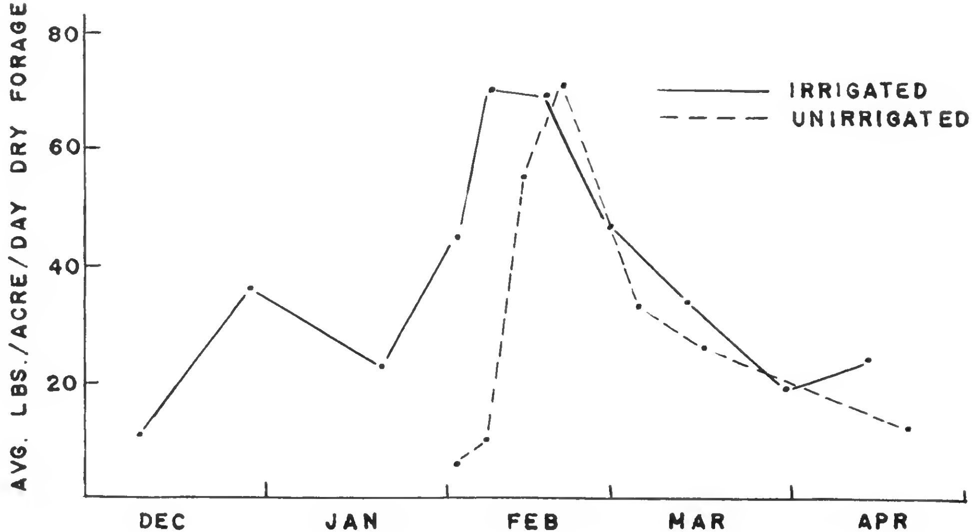


Fig. 12.--Effect of irrigation on the seasonal forage distribution of Arlington oats when cut at 12 inches to leave a five-inch stubble, winter 1955-56.

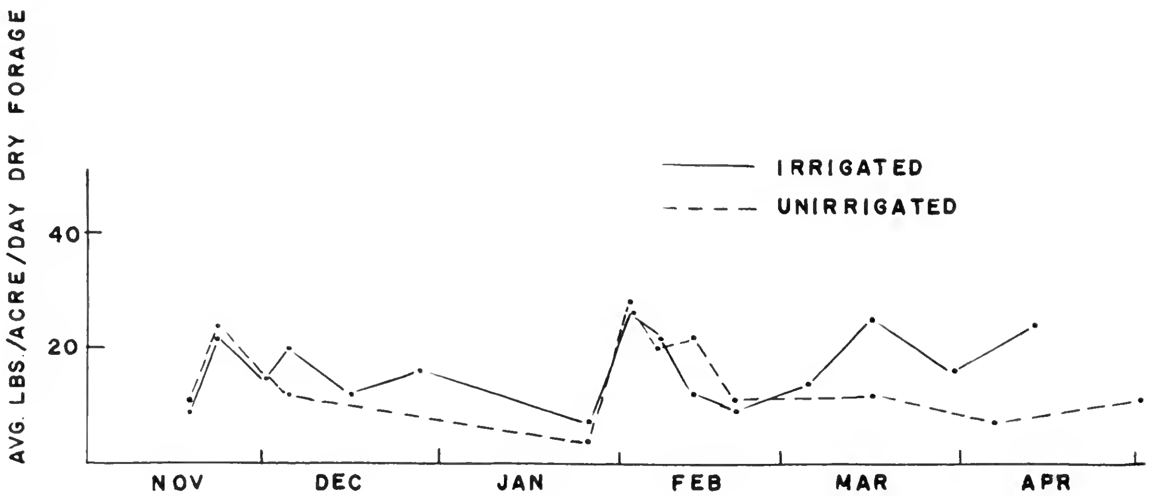


Fig. 13.--The effect of irrigation on the seasonal forage production of Seminole oats when cut at six inches to leave a two-inch stubble, winter 1955-56.

TABLE 7

CRUDE PROTEIN CONTENT OF OAT FORAGE AS AFFECTED BY CLIPPING MANAGEMENT, WINTER 1955-56

| Variety | Height of Plants When Cut | Height of Stubble | Percent Crude Protein in Forage[a] | | | Mean |
|---|---|---|---|---|---|---|
| | | | December | January | March | |
| Arlington | 6 | 2 | 34.6 | 31.2 | 31.6 | 32.5 |
| | 12 | 2 | 32.8 | 31.8 | 24.7 | 29.8 |
| | 12 | 5 | 29.3 | 26.8 | 27.8 | 28.0 |
| | 18 | 2 | 22.9 | 27.2 | 21.4 | 23.8 |
| | 18 | 5 | 28.9 | 26.3 | 22.4 | 25.9 |
| | 18 | 9 | 30.9 | 25.2 | 25.2 | 27.1 |
| Floriland | 6 | 2 | 32.0 | 28.2 | 26.4 | 28.9 |
| | 12 | 2 | -- | 23.5 | 22.0 | -- |
| | 12 | 5 | 31.0 | 26.6 | 24.8 | 27.5 |
| | 18 | 2 | 25.7 | 23.4 | 18.2 | 22.4 |
| | 18 | 5 | 29.0 | 28.0 | 17.6 | 24.9 |
| | 18 | 9 | 28.7 | 24.2 | 24.1 | 25.7 |
| Seminole | 6 | 2 | 32.7 | 30.6 | 31.7 | 31.7 |
| | 12 | 2 | 34.3 | 30.3 | 17.7 | 27.4 |
| | 12 | 5 | 32.4 | 30.6 | 26.8 | 29.9 |
| | 18 | 2 | 25.1 | 26.2 | 18.3 | 23.2 |
| | 18 | 5 | 28.1 | 27.7 | 17.9 | 24.6 |
| | 18 | 9 | 31.8 | 26.7 | 22.0 | 26.8 |

[a]Each figure is an average of the analyses of two replications and expressed on the basis of oven dry forage.

TABLE 8

POUNDS PER ACRE GRAIN OF IRRIGATED OATS AS INFLUENCED BY DATE WHEN CLIPPING CEASED, VARIETY, AND CLIPPING TREATMENTS, WINTER 1955-56

| | Clipping Treatments[a] | | | | | |
|---|---|---|---|---|---|---|
| | 6-2 | 12-2 | 12-5 | 18-2 | 18-5 | 18-9 |
| Clipped until six weeks before average heading date: | | | | | | |
| Arlington | 617 | 742 | 668 | 742 | 786 | 484 |
| Floriland | 760 | 749 | 804 | -- | 742 | 613 |
| Seminole | 1160 | 1110 | 1710 | 1540 | -- | 1020 |
| Clipped until two weeks before average heading date: | | | | | | |
| Arlington | 360 | 140 | 470 | -- | 310 | 569 |
| Floriland | 782 | 540 | 602 | 290 | 609 | 426 |
| Seminole | 852 | 925 | 1440 | 650 | 921 | 1182 |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 9

POUNDS PER ACRE GRAIN OF UNIRRIGATED OATS AS INFLUENCED BY DATE WHEN CLIPPING CEASED, VARIETY, AND CLIPPING TREATMENTS, WINTER 1955-56

| | Clipping Treatments[a] | | | | | |
|---|---|---|---|---|---|---|
| | 6-2 | 12-2 | 12-5 | 18-2 | 18-5 | 18-9 |
| Clipped until six weeks before average heading date: | | | | | | |
| Arlington | 280 | 452 | 400 | 240 | 180 | 290 |
| Floriland | 340 | 374 | 742 | 863 | 818 | 863 |
| Seminole | 609 | 631 | 771 | 1110 | 980 | 921 |
| Clipped until two weeks before average heading date: | | | | | | |
| Arlington | 55 | 66 | 180 | -- | 170 | 230 |
| Floriland | 210 | 360 | 290 | 270 | -- | 290 |
| Seminole | 360 | 529 | 340 | 230 | 918 | 543 |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 10

SUMMARY OF GRAIN YIELDS OF OATS AS AFFECTED BY DATE WHEN CLIPPING CEASED, VARIETY, AND CLIPPING TREATMENT, WINTER 1955-56

| | Pounds per Acre of Grain | |
|---|---|---|
| | Irrigated | Unirrigated |
| Varieties: | | |
| Arlington | 490 | 210 |
| Floriland | 580 | 450 |
| Seminole | 1,040 | 660 |
| L.S.D. at 5% | 110 | 80 |
| Date when clipping ceased: | | |
| Clipped until six weeks before average heading date | 790 | 604 |
| Clipped until two weeks before average heading date | 610 | 281 |
| L.S.D. at 5% | 30 | 80 |
| Effect of clipping treatments: | | |
| 6 inches tall, 2-inch stubble | 760 | 310 |
| 12 inches tall, 2-inch stubble | 700 | 400 |
| 12 inches tall, 5-inch stubble | 950 | 450 |
| 18 inches tall, 2-inch stubble | 540 | 450 |
| 18 inches tall, 5-inch stubble | 560 | 510 |
| 18 inches tall, 9-inch stubble | 720 | 520 |
| L.S.D. at 5% | 110 | 90 |

TABLE 11

ANALYSIS OF VARIANCE: GRAIN YIELDS OF THREE OAT VARIETIES AS AFFECTED BY CLIPPING TREATMENT AND DATE WHEN CLIPPING CEASED, WINTER 1955-56

| Source | D.F. | Irrigated | | Unirrigated | |
|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Main Plots: | | | | | |
| Replications | 5 | 521.3 | 104.3 | 341.8 | 68.4 |
| Varieties | 2 | 26,271.2 | 13,135.6** | 15,065.7 | 7,532.8** |
| Error (a) | 10 | 1,903.7 | 190.4 | 1,020.2 | 102.2 |
| Subplots: | | | | | |
| Date when clipping ceased | 1 | 3,480.1 | 3,480.1** | 11,659.9 | 11,659.9** |
| D x V | 2 | 2,002.0 | 1,001.0** | 1,122.2 | 561.1** |
| Error (b) | 20 | 565.2 | 28.3 | 1,662.0 | 83.1 |
| Sub-subplots: | | | | | |
| Cutting treatments | 5 | 8,243.5 | 1,648.7** | 2,264.8 | 453.0** |
| CT x V | 10 | 14,357.4 | 1,435.1** | 3,449.7 | 345.0** |
| CT x M | 5 | 4,004.2 | 800.8** | 1,918.4 | 383.7** |
| CT x M x V | 10 | 11,205.8 | 1,120.6** | 4,242.6 | 424.6** |
| Error (c) | 145 | 17,247.6 | 118.9 | 11,424.5 | 78.8 |
| Total | 215 | 89,802.0 | | 54,171.8 | |

**Significant at one percent level.

Effect of cutting treatments, varieties, and irrigation, winter 1956-57

The interpretation of yield data from the irrigated and unirrigated experiments, as shown in Tables 12 and 13, was complicated by several hard freezes. The recovery power of plants in plots cut closely just prior to a freeze was impaired much more than those cut closely just after a freeze. Furthermore, a serious infestation of Victoria blight (*Helminthosporium victoriae*) destroyed the Arlington variety during February in the irrigated area but caused little damage on the dryland oats. Quite obviously, it becomes difficult to make conclusions concerning the varieties and the effects of cutting treatments upon them.

Clipping oat plants when six inches tall back to a two-inch stubble resulted in considerable reduction in herbage yields. Height of the stubble apparently had little effect on forage yields except in the case of 18-inch plants where five-inch stubble reduced yields. Close clipping of six-inch plants the first time followed by cutting the plants when 12 inches tall did not change season yields appreciably from that of plants clipped all season at 12 inches. Differences between irrigated and non-irrigated plots were least when plants were clipped at six inches in height to leave a two-inch stubble.

Seasonal distribution of forage was affected very little by cutting treatments. Although the six- and 12-inch

TABLE 12

POUNDS PER ACRE OVEN DRY FORAGE OF THREE IRRIGATED OAT VARIETIES AS INFLUENCED BY CUTTING TREATMENT, WINTER 1956-57

| Cutting Treatments[a] | Arlington | Floriland | Seminole | Mean |
|---|---|---|---|---|
| 6-2 | 1620 | 3220 | 2120 | 2320 |
| 12-2 | 2840 | 4520 | 3470 | 3610 |
| 12-5 | 2600 | 4370 | 3530 | 3500 |
| 18-2 | 3850 | 3470 | 4559 | 3960 |
| 18-5 | 2810 | 3700 | 4460 | 3660 |
| 6-2 first time, 12-2 thereafter | 2520 | 3630 | 3190 | 3110 |
| 6-2 first time, 12-5 thereafter | 2240 | 4470 | 3590 | 3430 |
| 12-2 first time, 6-2 thereafter | 2100 | 3530 | 2180 | 2600 |
| Mean | 2570 | 3860 | 3390 | |

| L.S.D. between: | At 5%: |
|---|---|
| Variety means | 380 lbs. |
| Cutting treatment means | 360 |
| Cutting treatment | |
| Arlington | 750 |
| Floriland | 600 |
| Seminole | 540 |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 13

POUNDS PER ACRE OVEN DRY FORAGE OF THREE UNIRRIGATED OAT VARIETIES AS INFLUENCED BY CUTTING TREATMENT, WINTER 1956-57

| Cutting Treatments[a] | Arlington | Floriland | Seminole | Mean |
|---|---|---|---|---|
| 6-2 | 1580 | 1660 | 1410 | 1550 |
| 12-2 | 2120 | 1720 | 2140 | 1990 |
| 12-5 | 2300 | 1640 | 1960 | 1970 |
| 18-2 | 1740 | 2470 | 3630 | 2610 |
| 18-5 | 1880 | 1790 | 2260 | 1980 |
| 6-2 first time, 12-2 thereafter | 2550 | 1910 | 2560 | 2340 |
| 6-2 first time, 12-5 thereafter | 2120 | 1780 | 2260 | 2050 |
| 12-2 first time, 6-2 thereafter | 1840 | 1560 | 1720 | 1710 |
| Mean | 2020 | 1820 | 2240 | |

| L.S.D. between: | At 5% level: |
|---|---|
| Variety means | 250 pounds |
| Cutting treatment means | 240 " |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

plants cut back to two inches gave quite different total yields for the year, the production curves for Floriland oats in Figure 14 point out the sharp early peak with gradual decline in production for these two treatments. Plants having a five-inch stubble generally tended to remain more productive late in the season.

Since there were interactions between varieties and cutting treatments (Table 14), individual varieties were analyzed separately as shown in Tables 12 and 15. Under irrigation, the Floriland variety generally performed better than Seminole. Seminole, with an erect growth habit, performed best when cut at 18 inches while Floriland was most productive at 12 inches. Floriland showed a serious decrease in forage yield when the first cutting was made at six inches followed by cuttings at 12 inches to leave a two-inch stubble. When a five-inch stubble was used with this variety the remainder of the season, apparently the close early defoliation of young plants was not harmful. This is perhaps explained by the location of the growing point when cutting occurs. Monthly measurement of the growing point heights showed that the growing point of the Seminole variety was at a height of five to seven inches in early January while for Floriland this did not occur until March.

Data from the root samples collected from the

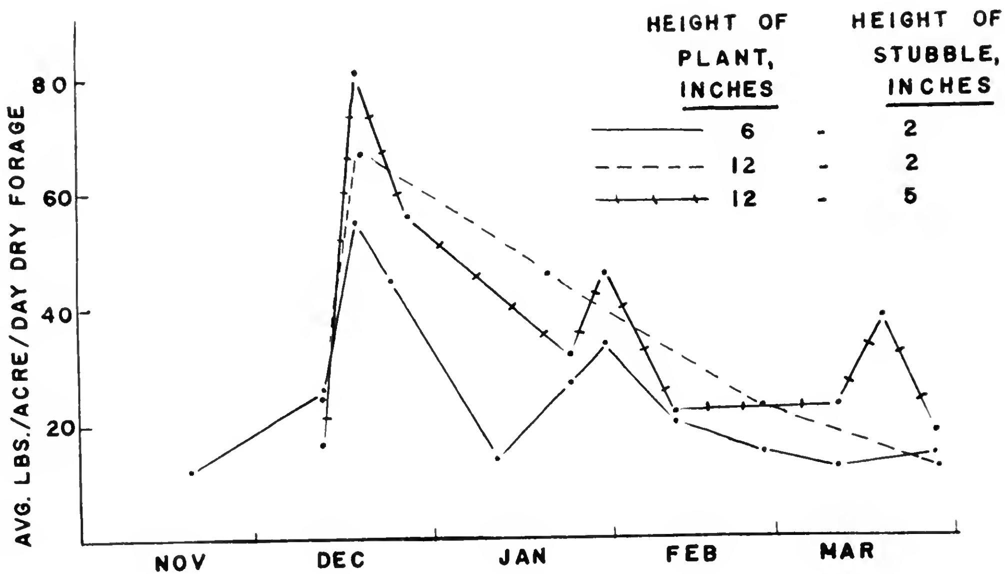


Fig. 14.--Seasonal distribution of irrigated Floriland oat forage as influenced by three cutting treatments, winter 1956-57.

TABLE 14

ANALYSIS OF VARIANCE: EFFECT OF CUTTING TREATMENTS ON FORAGE YIELD OF THREE OAT VARIETIES, IRRIGATED AND UNIRRIGATED, 1956-57

| Source | D.F. | Irrigated | | Unirrigated | |
|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Main Plots | | | | | |
| Replications | 4 | 6,384 | 1,596 | 8,684 | 2,171* |
| Varieties | 2 | 70,122 | 35,061 | 7,497 | 3,748* |
| Error (a) | 8 | 9,061 | 1,133** | 3,812 | 476 |
| Subplots | | | | | |
| Cutting treatments | 7 | 67,586 | 9,655** | 24,019 | 3,431** |
| CT x V | 14 | 40,319 | 2,880** | 20,641 | 1,474** |
| Error (b) | 84 | 41,607 | 495 | 18,713 | 223 |
| Total | 119 | 235,079 | | 83,366 | |

*Significant at five percent level.

**Significant at one percent level.

TABLE 15

ANALYSIS OF VARIANCE: EFFECT OF CUTTING TREATMENTS ON FORAGE YIELDS OF IRRIGATED ARLINGTON, FLORILAND, AND SEMINOLE OATS, 1956-57

| Source | D.F. | Arlington | | Floriland | | Seminole | |
|---|---|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Replications | 4 | 4,820 | 1,205 | 7,294 | 1,824* | 3,331 | 833 |
| Treatments | 7 | 30,894 | 4,413** | 18,698 | 2,671** | 58,313 | 8,330** |
| Error | 28 | 19,142 | 684 | 12,545 | 448 | 9,920 | 354 |
| Total | 39 | 54,856 | | 38,537 | | 71,564 | |

*Significant at five percent level.

**Significant at one percent level.

irrigated oat plots January 15 are shown in Table 16. Close frequent clipping, as with the six-inch plants cut back to two inches, seriously decreased root and crown weights. Allowing the plants to grow 12 inches tall before beginning the intensive defoliation treatment of cutting when six inches tall did not increase the root production. Differences between varieties were highly significant as shown in Table 17. Floriland produced a much larger quantity of roots as compared to the other two varieties. The reason for this is probably twofold. First, Arlington growth was severely retarded by the fungal infestation. Secondly, the growing point of an erect growing variety like Seminole is more easily destroyed by clipping, thus disturbing root development. The data for Seminole root yields indicate that root growth was decreased to a greater extent under two than under five-inch stubble for both 12- and 18-inch plants. This suggests the likelihood that retardation of root growth may be more serious with close clipping of erect growing than decumbent oat varieties.

Freeze damage to irrigated Floriland oats was severe in early January on plots which had recently been cut to leave a two-inch stubble. Minimum daily temperatures in Table 18 indicate that under very cold conditions the air between plants with high stubble may be two or three degrees warmer than where stubble is short. Unfortunately, no more

TABLE 16

ROOT AND CROWN YIELDS OF THREE OAT VARIETIES AS AFFECTED BY CLIPPING TREATMENT, WINTER 1956-57

| Cutting Treatment[a] | Arlington | Floriland | Seminole | Mean |
|---|---|---|---|---|
| 6-2 | 1.14 | 2.95 | 0.99 | 1.69 |
| 12-2 | 2.29 | 3.96 | 1.30 | 2.52 |
| 12-5 | 2.23 | 4.08 | 1.67 | 2.66 |
| 18-2 | 2.25 | 3.41 | 1.89 | 2.52 |
| 18-5 | 2.55 | 3.42 | 2.23 | 2.73 |
| 6-2 first time; 12-2 thereafter | 1.51 | 4.64 | 2.31 | 2.82 |
| 6-2 first time, 12-5 thereafter | 2.02 | 4.85 | 1.64 | 2.84 |
| 12-2 first time, 6-2 thereafter | 1.26 | 3.08 | 1.07 | 1.80 |
| Mean | 1.91 | 3.80 | 1.64 | |

| L. S. D. between: | At 5% level: |
|---|---|
| Variety means | 0.75 gram |
| Cutting treatment means | 0.75 " |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 17

ANALYSIS OF VARIANCE: EFFECT OF CUTTING TREATMENTS ON ROOT AND CROWN YIELDS OF THREE IRRIGATED OAT VARIETIES, WINTER 1956-57

| Source | D.F. | Sum of Squares | Mean Squares |
|---|---|---|---|
| Main Plots: | | | |
| Replications | 4 | 18.12 | 4.53 |
| Varieties | 2 | 110.97 | 55.48** |
| Error (a) | 8 | 17.19 | 2.15 |
| Subplots: | | | |
| Cutting treatments | 7 | 21.16 | 3.02* |
| CT x V | 14 | 14.57 | 1.04 |
| Error (b) | 84 | 89.54 | 1.06 |
| Total | 119 | 271.55 | |

*Significant at five percent level.

**Significant at one percent level.

TABLE 18

AIR TEMPERATURES IN DEGREES FAHRENHEIT BETWEEN ROWS OF IRRIGATED FLORILAND OATS, WINTER 1956-57

| Date | Replication D | | | | Replication B | | | | Therm. at 5 foot Height |
|---|---|---|---|---|---|---|---|---|---|
| | 2" Stb. 3" Thm. Hgt. | 5" Stb. 3" Thm. Hgt. | Diff. | 5" Stb. 6" Thm. Hgt. | 2" Stb. 3" Thm. Hgt. | 5" Stb. 3" Thm. Hgt. | Diff. | 5" Stb. 6" Thm. Hgt. | |
| Jan. 17 | 45.0 | 47.0 | 2.0 | | | | | | |
| Jan. 18 | 26.8 | 29.5 | 2.7 | | | | | | |
| Jan. 19 | 21.2 | 24.2 | 3.0 | 22.8 | 21.8 | 24.2 | 2.4 | 23.4 | 22.4 |
| Jan. 20 | 39.3 | 40.5 | 1.2 | 39.8 | 39.6 | 39.8 | -0.2 | 39.0 | 40.6 |
| Jan. 21 | No records | | | | | | | | |
| Jan. 22 | 60.6 | 61.0 | 0.4 | 61.0 | 60.8 | 60.2 | -0.6 | 60.1 | 62.0 |
| Jan. 23 | 59.0 | 59.0 | 0 | 58.8 | 58.5 | 60.0 | 1.5 | 58.8 | 63.0 |
| Jan. 24 | 56.6* | 56.8* | 0.2 | 56.0* | 56.8* | 56.8* | 0 | 55.8* | 58.0 |
| Jan. 25 | 52.8 | 53.2 | 0.4 | 52.8 | 52.8 | 54.0 | 1.2 | 52.4 | 54.0 |
| Jan. 26 | 51.9 | 52.6 | 0.7 | 51.9 | 52.1 | 51.8 | 0.7 | 52.2 | 52.8 |
| Jan. 27 | 57.7 | 57.6 | -0.1 | 57.8 | 57.6 | 58.6 | 1.0 | 57.2 | 59.8 |
| Jan. 28 | 51.7 | 52.4 | 0.7 | 51.2 | 52.0 | 52.6 | 0.6 | 51.0 | 52.4 |
| Jan. 29 | 61.7 | 62.2 | 0.5 | 61.8 | 61.8 | 62.2 | 0.4 | 61.8 | 63.6 |
| Jan. 30 | 63.1* | 63.8 | 0.7 | 62.9 | 63.2* | 63.6 | 0.4 | 63.0 | 63.6 |
| Jan. 31 | 51.9 | 52.8 | 0.9 | 52.0 | 51.8 | 52.4 | 0.6 | 51.8 | 50.0 |
| Feb. 1 | 53.5 | 53.9 | 0.4 | 52.8 | 53.9 | 54.2 | 0.3 | 53.0 | 55.3 |
| Feb. 2 | 56.1 | 58.0 | 1.9 | 56.8 | 56.2 | 56.8 | 2.6 | 55.8 | 59.0 |
| Feb. 3 | 51.3 | 52.8 | 1.5 | 51.0 | 51.6 | 52.8 | 1.2 | 51.6 | 52.0 |
| Feb. 4 | 52.3 | 53.0 | 0.7 | 51.9 | 52.6 | 53.0 | 0.4 | 51.8 | 52.6 |
| Feb. 5 | 52.7 | 53.8 | 1.1 | 51.9 | 53.2 | 54.4 | 1.2 | 53.2 | 54.6 |

TABLE 18 (Continued)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Feb. 6 | 48.3 | 49.2 | 0.9 | 48.0 | 49.0 | 50.4 | 1.4 | 49.1 | 50.4 |
| Feb. 7 | 49.0 | 50.0 | 1.0 | 48.8 | 49.2 | 50.8 | 1.6 | 50.0 | 51.0 |
| Feb. 8 | 61.1 | 62.0 | 0.9 | 61.0 | 60.6 | 62.0 | 1.4 | 61.8 | 61.6 |
| Feb. 9 | 54.9 | 55.0 | 0.1 | 53.6 | 55.0 | 55.7 | 0.7 | 54.6 | 55.0 |
| Feb. 10 | 55.5 | 56.6 | 1.1 | 54.6 | 55.9 | 57.0 | 1.1 | 56.0 | 52.0 |
| Feb. 11 | 61.7* | 62.2* | 0.5 | 61.2* | 60.2* | 62.2* | 1.0 | 61.5* | 60.5 |
| Feb. 12 | 40.2 | 41.0 | 0.8 | 40.7 | 40.5 | 40.7 | 0.2 | 40.0 | 48.0 |
| Feb. 13 | 31.8 | 32.4 | 0.6 | 31.6 | 32.6 | 31.1 | 0.5 | 31.8 | 30.4 |
| Feb. 14 | No records | | | | | | | | |
| Feb. 15 | 33.7 | 34.6 | 0.9 | 33.6 | 34.1 | 34.9 | 0.8 | 34.6 | 33.0 |
| Feb. 16 | 38.1 | 39.0 | 0.9 | 38.0 | 38.4 | 38.2 | -0.2 | 38.9 | 36.9 |
| Feb. 17 | 41.7 | 42.9 | 1.2 | 42.8 | 42.0 | 42.6 | 0.6 | 42.6 | 43.8 |
| | | Average | 0.93 | | | Average | 0.78 | | |

*Plots clipped back to height of two or five inches as designated above.

low temperatures occurred after mid January. Consequently, no further checks on these results were obtained.

Effect of sheep grazing treatments, winter 1956-57

Yield responses to the various grazing treatments were significantly different as shown in Table 19. Highest yields were achieved by deferring grazing until the plants were 12 inches tall as shown in Table 20. Grazing whenever the plants reached six inches resulted in production being halved but grazing the first time at 12 inches and thereafter at six inches caused a substantial rise in yield. Apparently, stubble height had no effect on the total yield of forage obtained. Height of the plants when grazing was begun determined the subsequent production. The herbage yields of Arlington oats obtained from quadrat studies under grazing conditions compared quite favorably with those obtained in the clipping experiments (Tables 12 and 20).

A serious freeze on December 28 completely killed oats in paddocks which had been recently grazed down to leave a one- to two-inch stubble. As shown in Figures 15 and 16, oat plants having a four- to six-inch stubble were uninjured. This same effect was observed in the clipping experiment under irrigation. Victoria blight (Helminthosporium victoriae) caused a great deal of damage during

January and February until finally the experiment had to be abandoned.

TABLE 19

ANALYSIS OF VARIANCE: POUNDS PER ACRE OVEN DRY FORAGE HARVESTED FROM QUADRATS IN SHEEP GRAZING TRIAL ON ARLINGTON OATS, WINTER 1956-57

| Source | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Replications | 3 | 1,596.0 | 532.0** |
| Grazing treatments | 4 | 20,638.7 | 5,159.7** |
| Error | 12 | 650.4 | 54.2 |
| Total | 19 | 22,885.1 | |

**Significant at one percent level.

TABLE 20

POUNDS PER ACRE OVEN DRY FORAGE HARVESTED FROM QUADRATS IN SHEEP GRAZING TRIAL ON ARLINGTON OATS, 1956-57

| | Pounds per Acre Oven Dry Forage | Number of Times Grazed |
|---|---|---|
| Grazed when plants reached 12 inches, 5-inch stubble | 2,860 | 3 |
| Grazed when plants reached 12 inches, 2-inch stubble | 2,780 | 2 |
| Grazed first time when plants 12 inches tall, 2-inch stubble; thereafter grazed when 6 inches tall, 2-inch stubble | 2,320 | 3 |
| Grazed when plants reached 6 inches, 2-inch stubble | 1,340 | 3 |
| Grazed first time when plants 6 inches tall, 2-inch stubble; thereafter grazed when 12 inches tall, 2-inch stubble. | 1,190 | 2 |
| L.S.D. at 5% | 250 | |


Fig. 15.--Uninjured Arlington oats where plants were not closely grazed prior to freezing temperature on December 28, 1956.

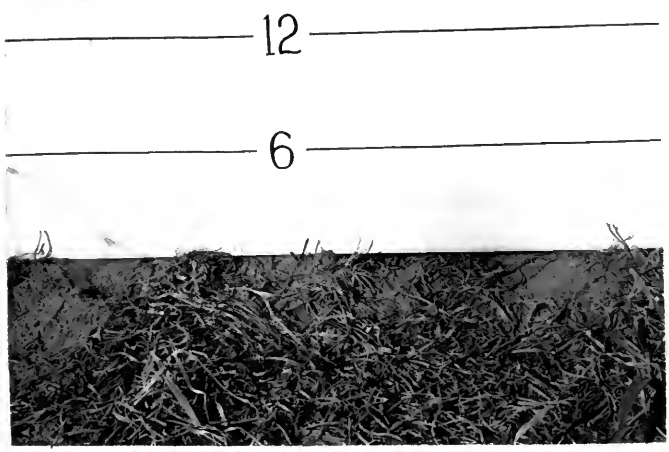


Fig. 16.--Total loss of closely grazed Arlington oat stand by freezing. Plants were grazed to leave a one- to two-inch stubble prior to low temperature on December 28, 1956.

## PEARLMILLET

### Materials and Methods

All of the experiments in this study were established on Arredondo loamy fine sand located at the Agronomy Farm, University of Florida, Gainesville, during the period 1955 through 1958. Weed control in experiments with 19- and 38-inch row spacings was effected by a hand-operated push cultivator equipped with a wide sweep. No weed control was practiced in plots with a seven-inch row spacing.

Effect of cutting treatments and irrigation, 1955

Common pearlmillet was planted in 38-inch rows on April 27 at the rate of 15 pounds per acre. Thirteen cutting treatments, in a randomized block design, were used to simulate different management practices with respect to frequency and severity of defoliation. The plants, on different plots, were cut when they reached heights of 12, 18, 30, and 54 inches. These treatments produced different frequencies of cutting based not on a fixed time interval, but on the rapidity of plant development. Four heights of cut or height of stubble were used: four, six, 10, and 18 inches. These four heights of cut combined in all likely combinations with the four heights at cutting composed a series of 13 defoliation treatments.

Two replications received only rainfall and three replications received two supplemental irrigations of two inches each. The experiment contained a total of 65 plots. On the irrigated plots, 800 pounds of 3-12-12 fertilizer was applied at planting with four supplemental applications of ammonium nitrate, making a season total of 214 pounds actual nitrogen per acre. The unirrigated plots received the same initial fertilization at planting and four supplemental applications of ammonium nitrate, making a season total of 179 pounds actual nitrogen per acre. Rapid plant tissue tests were used to determine when supplemental nitrogen should be applied.

Height of the plants was ascertained by lifting the forage to an erect position to determine its true height. The cutting was done by means of hand sickles, using as a guide an aluminum pole, the ends of which rested on stakes of the desired height. A 13.8-foot strip, 0.001 acre in size, was removed for yield. Adjacent rows on either side were cut similarly and served as borders on the three-row plot. The samples were dried at 130° F., weighed and yields recorded as pounds of dry matter per acre.

Forage samples were collected from two of the irrigated replications at monthly intervals during the clipping season for nitrogen analysis by the Kjeldahl method (4).

An attempt was made to study root production under the different clipping treatments in the irrigated portion of the experiment. One core was collected from each plot at a depth of zero to six inches using a Soil Conservation Service bucket type F-7 four-inch diameter soil auger. Cores were obtained directly from the row on August 29, the top growth being clipped off at the ground level. Each sample was washed on a screen to remove soil and the root material dried and then weighed.

Effect of cutting treatments, varieties, row spacings, and irrigation, 1956

Results of the 1955 pearlmillet management study indicated the need for a more intensive study of the factors influencing forage production. Since only 38-inch rows were used in the 1955 test it became evident that closer row spacings should be studied together with various defoliation practices. The introduction of the higher quality Starr millet (a variety developed at the Georgia Coastal Plain Experiment Station) made it desirable to expand the experiment to include two varieties.

A split plot design was employed, consisting of two varieties as main plots, three row spacings as subplots, and four replications, making a total of 144 plots. The same seeding rate per foot of row was used with all row spacings, resulting in the following rates of seed per acre: 38-inch rows - 10 pounds, 19-inch rows - 20 pounds, and seven-inch rows - 54 pounds.

Prior to planting on March 26, the following fertilizers were applied: 500 pounds per acre 4-12-12, 50 pounds magnesium sulfate, 40 pounds fritted trace elements, and 10 pounds zinc sulfate. Good stands were obtained but a severe sandstorm on April 16 ruined the entire planting so it had to be disced up and replanted on April 24. Additional broadcast applications of 200 pounds per acre ammonium nitrate were made on April 24, June 6, June 25, and July 20, making a total of 284 pounds actual nitrogen for the season. Irrigation water was applied as needed; the total amount applied to the replanted millet being three and one-half inches during the month of May.

Each plot was nine feet long but the width was dependent on the row spacing. With a 38-inch row spacing, a three-row plot was used, the 0.0005 acre harvest area being 6.9 feet of the center row. With the 18-inch row spacing, a five-row plot was used, the 0.00025 acre harvest area being 6.9 feet of the center row. Plots having the narrow row spacing of seven inches had seven rows, of which 6.9 feet of the three center rows were harvested, making a yield area of 0.00028 acre. In all cases, the border rows were cut at the same time and in the same manner as the yield areas.

Cutting was done by hand, using butcher knives. The proper height of cut (four, 10, or 18 inches) was maintained by using as a knife guide a plywood board of the proper height. The board was seven feet long, the exact length of plot to be harvested. Views of the stubble heights and the cutting operation are shown in Figures 17 to 21. Bamboo stakes driven into the ground at one end of each yield row indicated the height to which plants were to be grown before cutting. The height of the stubble was color coded on both stakes and the wooden cutting boards (red = four inch, white = ten inch, blue = 18 inch).

Both green and oven dry weights of forage were recorded. Dry weights from each of the plots were converted to equivalent per acre yields and subjected to statistical analysis. Forage samples for nitrogen analysis were collected in June and July, dried, ground in a Wiley mill, and analyzed for nitrogen by the Kjeldahl method (4).

In order to check on the effectiveness of irrigation, a smaller unirrigated experiment was planted nearby on similar soil. This experiment was of a split plot design with Starr and common varieties of pearlmillet as main plots and three row spacings (seven, 19, and 38 inches) as the subplots. Using three replications, this made a total of 18 plots. All plots were clipped back to a four-inch stubble whenever the plants reached 30 inches tall. Plot

Fig. 17.--Over-all view of pearlmillet clipping study.


Fig. 18.--Pearlmillet plants clipped when 30 inches tall to leave a four-inch stubble.


Fig. 19.--Pearlmillet plants clipped when 30 inches tall to leave a 10-inch stubble.


Fig. 20.--Pearlmillet plants clipped when 30 inches tall to leave an 18-inch stubble.

Fig. 21.--Pearlmillet clipping operation. A 10-inch white board is being used to maintain proper stubble height.

sizes and fertilization were as in the larger irrigated experiment.

Effect of cutting treatments and row spacings, 1957

In order to confirm the rather interesting findings of 1956, the experiment was repeated with the exception that only the Starr variety was used. The experimental design was a split plot with row spacings of seven, 19, and 38 inches as main plots and six cutting treatments as subplots:

(1) Cut when 54 inches tall to leave a four-inch stubble.
(2) Cut when 30 inches tall to leave a four-inch stubble.
(3) Cut when 30 inches tall to leave a 10-inch stubble.
(4) Cut when 30 inches tall to leave an 18-inch stubble.
(5) Cut when 18 inches tall to leave a four-inch stubble.
(6) Cut when 12 inches tall to leave a four-inch stubble.

An initial fertilization of 400 pounds per acre 8-8-8, 50 pounds magnesium sulfate, and 50 pounds of fritted trace elements was made prior to planting the experiment on April 22. Additional applications of 200 pounds per acre sodium nitrate were made on May 9, May 17, June 6, June 12, July 3, July 30, and August 15, giving a total of 256 pounds actual nitrogen for the season. An additional application of 200 pounds per acre 0-8-24 was made on June 12. Planting and harvesting procedures were similar to the methods used the previous year except that irrigation water was applied only at planting to insure a uniform stand. Recovery rate after defoliation was determined by measuring the regrowth of 30-inch plants over a seven day period after the first clipping. Three measurements of regrowth were made in each plot of the four replications for the three stubble heights and three row spacings. Forage samples were collected from two replications on approximately every other harvest date, dried, ground in a Wiley mill, and analyzed for nitrogen by the Kjeldahl method (4).

<u>Effect of cutting treatments and nitrogen levels, 1958</u>

In 1958 a field experiment was begun to test the effect of cutting treatments and nitrogen levels on forage production of Starr pearlmillet. The experimental design was a split plot with nitrogen levels as main plots and cutting treatments as subplots. Six replications were used, making a total of 54 plots. Three nitrogen fertilizer rates were used:

(1) Low - 15 pounds per acre of actual nitrogen applied biweekly.

(2) Medium - 30 pounds per acre of actual nitrogen applied biweekly.

(3) High - 60 pounds per acre of actual nitrogen applied biweekly.

Total amounts of fertilizer applied are shown in Table 21.

TABLE 21

FERTILIZATION SCHEDULE FOR STARR MILLET CLIPPING STUDY, 1958

| Planting Date | Pounds per Acre of Actual Nitrogen Applied Biweekly | | | Fertilizer Material |
|---|---|---|---|---|
| | 15 lbs. | 30 lbs. | 60 lbs. | |
| May 27 | 30 | 30 | 30 | 8-8-8 |
| June 11 | 15 | 30 | 60 | $NH_4NO_3$ |
| June 24 | 15 | 30 | 60 | $NaNO_3$ |
| July 8 | 15 | 30 | 60 | $NH_4NO_3$ - 32 lb/A $K_2O$ |
| July 22 | 15 | 30 | 60 | $NaNO_3$ |
| August 5 | 15 | 30 | 60 | $NH_4NO_3$ |
| August 19 | 15 | 30 | 60 | $NaNO_3$ |
| Season Total | 120 | 210 | 390 | |

Three cutting treatments were imposed on each of the nitrogen levels:

(1) Cut when 12 inches tall to leave a four-inch stubble.

(2) Cut when 30 inches tall to leave a four-inch stubble.

(3) Cut when 30 inches tall to leave a ten-inch stubble.

The experiment was planted May 2 and the stand was destroyed by a sandstorm. Another planting made May 8 was washed out by unusually heavy rain. A successful planting was made May 28 in another area. The Starr variety was planted at ten pounds per acre in 19-inch rows. Each plot was nine feet long and consisted of four rows, of which 0.0005 acre was harvested from the two center rows for yield data. Harvesting methods were similar to those employed in preceeding experiments. Forage samples were collected from two replications on each harvest date, dried, ground in a Wiley mill, and analyzed for total nitrogen by the Kjeldahl method (4). Crude protein was expressed by multiplying the nitrogen content by 6.25.

Changes in the stand of plants were studied by counting the numbers of live plants in a one-foot strip of row. One count was made in each plot on three different dates.

A crude measure of the effect of nitrogen level and cutting treatment on root production was obtained by taking a core four inches in diameter and six inches deep from each plot on June 28 and August 1. Each core was washed on a screen to remove the soil and the root material was dried and then weighed. Trash and rocks were carefully removed. Cores were obtained immediately adjacent to the row of plants rather than directly below the row. Previous experience had shown that it was difficult to decide between crowns and roots so this problem was circumvented by sampling adjacent to the row of plants and excluding the crowns.

Effect of planting date, 1956 and 1957.

Pearlmillet is usually considered to be a plant which makes its production over a very short period of time. The question arose as to whether this growing period is influenced by the date of planting, stimulating the following experiments during 1956 and 1957.

The 1956 experiment originally consisted of six dates of planting at monthly intervals from March to August arranged in a randomized block design with four replications. Severe sandstorms destroyed both the March and April plantings; consequently, the yield data are based only on four planting dates. The Starr variety was planted at ten pounds per acre in 38-inch rows. Each plot was 16 feet long and consisted of three rows, of which 0.001 acre of the center row was harvested for yield. Plants were clipped by hand to leave a four-inch stubble whenever they reached 30 inches. At each planting, the following fertilizers were applied: 400 pounds per acre 8-8-8, 50 pounds magnesium sulfate, and 50 pounds fritted trace elements. Additional nitrogen was supplied by ammonium nitrate whenever the plots were cut as shown in Table 22.

In 1957 the experiment was modified, the changes being based on results from the 1956 season. The Starr variety again was planted, this time in 19-inch rows. Individual plots consisted of six rows nine feet long, of which 0.0005 acre of the two center rows was harvested for yield data. Plantings were made monthly from March through July, using a randomized block design with five replications. Plants were clipped when they reached a height of 30 inches, leaving a ten-inch stubble. The initial fertilizer application at each planting date was the same as in the 1956 experiment. Nitrogen applications are shown in Table 23. Samples were collected at a number of harvests, dried, ground, and analyzed for nitrogen by the Kjeldahl method (4).

TABLE 22

POUNDS PER ACRE OF NITROGEN APPLIED TO STARR MILLET
DATE OF PLANTING TEST, 1956

| Date Fertilizer Applied | Planting Dates | | | |
|---|---|---|---|---|
| | May 1 | June 4 | July 6 | August 3 |
| Initial planting application | 32 | 32 | 32 | 32 |
| June 21 | 66 | | | |
| July 3 | | 66 | | |
| July 6 | 66 | | | |
| August 10 | | 66 | 66 | 66 |
| Total | 164 | 164 | 98 | 98 |

TABLE 23

POUNDS PER ACRE ACTUAL NITROGEN APPLIED TO STARR MILLET
DATE OF PLANTING EXPERIMENT, 1957

| Date Fertilizer Applied | Planting Dates | | | | |
|---|---|---|---|---|---|
| | March 14 | April 16 | May 14 | June 14 | July 15 |
| March 14 | 32 | | | | |
| April 16 | 32 | 32 | | | |
| May 14 | 32 | 32 | 32 | | |
| June 6 | 32 | 32 | 32 | | |
| June 14 | | | | 32 | |
| July 3 | 32 | 32 | 32 | 32 | |
| July 15 | | | | | 32 |
| July 30 | 32 | 32 | 32 | 32 | 32 |
| August 15 | | | 32 | 32 | 32 |
| September 12 | 32 | 32 | 32 | 32 | 32 |
| Total | 224 | 192 | 192 | 160 | 128 |

## Results

Effect of cutting treatments and irrigation, 1955

The results as summarized in Tables 24 and 25 indicate that irrigation had little effect on forage yield of pearlmillet. It is probable that the irrigation at planting coupled with the two and one-half inches of rainfall during May prevented a severe water shortage and minimized the drouth effect.

Highest yields of forage were obtained with the 54-inch growth, cut near the ground leaving a minimum of stubble. Season yields of dry forage in the test ranged from 13,950 down to 5,520 pounds of dry matter per acre in the irrigated plots. Forage production of pearlmillet increased progressively as the plants were permitted to grow taller before clipping.

Plants 54 inches tall showed a progressive decline in forage yield as the cutting height was increased. Cutting of 54-inch plants at 18 inches decreased the yield of forage by one-third as compared to that of the 54-inch plants with a four-inch stubble. There were no significant differences in total yield between the four-, six-, 10-, and 18-inch stubble heights of 30-inch plants. In spite of considerable forage not harvested in the high stubble of the 30-inch plants, the season total yield was similar to that for the low stubble plants. Pearlmillet plants harvested

TABLE 24

TOTAL SEASON FORAGE YIELDS OF COMMON PEARLMILLET AS AFFECTED BY CUTTING TREATMENT AND IRRIGATION, 1955

| Height of Plant | Height of Stubble | Pounds per Acre Oven Dry Forage | |
|---|---|---|---|
| | | Unirrigated | Irrigated |
| Inches | Inches | | |
| 12 | 4 | 4,960 | 5,520 |
| 12 | 6 | 4,940 | 5,560 |
| 18 | 4 | 5,730 | 6,320 |
| 18 | 6 | 6,560 | 6,210 |
| 18 | 10 | 6,420 | 7,740 |
| 30 | 4 | 8,900 | 8,970 |
| 30 | 6 | 8,590 | 9,860 |
| 30 | 10 | 7,500 | 8,780 |
| 30 | 18 | 8,320 | 9,120 |
| 54 | 4 | 11,740 | 13,950 |
| 54 | 6 | 12,940 | 11,700 |
| 54 | 10 | 10,950 | 11,170 |
| 54 | 18 | 7,220 | 8,440 |
| | L.S.D. at 5% | 2,990 | 1,900 |

TABLE 25

ANALYSIS OF VARIANCE: EFFECT OF CUTTING TREATMENT AND IRRIGATION ON THE FORAGE PRODUCTION OF COMMON PEARLMILLET, 1955

| Source | Degrees of Freedom | Sum of Squares | Mean Square |
|---|---|---|---|
| Irrigated: | | | |
| Replications | 2 | 4.06 | 2.03 |
| Treatments | 12 | 231.77 | 19.31** |
| Error | 24 | 30.51 | 1.27 |
| Total | 38 | 266.34 | |
| Unirrigated: | | | |
| Replications | 1 | 0.18 | 0.18 |
| Treatments | 12 | 155.15 | 12.93** |
| Error | 12 | 16.68 | 1.39 |
| Total | 25 | 172.01 | |

**Significant at one percent level.

when 30 inches tall and cut to leave higher stubble tillered out at the top of the cut stems, making their regrowth from this point rather than from the base of the plant. Although this phenomenon occurred with plants harvested when 54 inches tall, it was not as pronounced and regrowth was slower. Yields decreased more sharply in late summer on plants having an 18-inch stubble.

Peak production for all cutting treatments was reached in early June after which there was a gradual decline. Figure 22 shows that plants cut when they reached heights of either 54 or 30 inches continued to produce more forage in late summer than did plants harvested when either 12 or 18 inches tall.

Forage quality was influenced to a considerable degree by the clipping treatment. As shown in Table 26, the crude protein content of the forage was influenced primarily by the height of the plants when cut. As plants were permitted to grow taller before cutting, the protein content decreased. Plants clipped when 12 or 18 inches tall maintained a higher protein content through the season than plants clipped less often. There was a small decline in protein content toward the end of the growing season, the decrease being more pronounced in the less frequently clipped plants. The protein contents were affected only slightly by the height of the stubble. The protein content

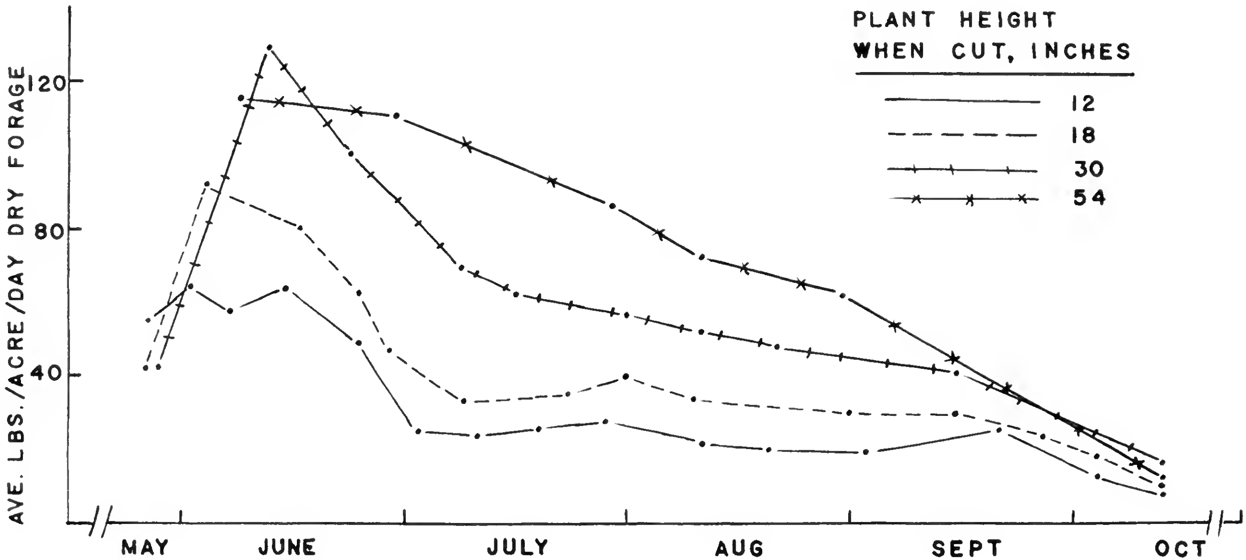


Fig. 22.--Seasonal production of irrigated common pearlmillet, 1955. Each plant height is an average of the various stubble heights.

TABLE 26

EFFECT OF CUTTING TREATMENT ON THE CRUDE PROTEIN CONTENT OF IRRIGATED COMMON PEARLMILLET, 1955

| Height of Forage at Cutting | Height of Cut (Stubble Height) | Percent Crude Protein[a] | | |
|---|---|---|---|---|
| Inches | Inches | June | July | August |
| 12 | 4 | 28.1 | 25.8 | 23.8 |
| 12 | 6 | 27.2 | 30.4 | 25.7 |
| 18 | 4 | 24.9 | 26.0 | 23.8 |
| 18 | 6 | 27.1 | 25.7 | 23.5 |
| 18 | 10 | 24.8 | 25.2 | 20.4 |
| 30 | 4 | 21.6 | 22.5 | 14.4 |
| 30 | 6 | 22.4 | 20.4 | 14.3 |
| 30 | 10 | 22.7 | 20.4 | 13.0 |
| 30 | 18 | 23.1 | 23.3 | 18.8 |
| 54 | 4 | 18.1 | 16.2 | 14.4 |
| 54 | 6 | 19.4 | 19.4 | 11.7 |
| 54 | 10 | 19.2 | 17.0 | 12.8 |
| 54 | 18 | -- | 17.2 | 14.1 |

[a]Each figure is an average of the analyses of two replications from the irrigated plots and expressed on the basis of oven dry forage.

was largely dependent upon the height of the plant prior to cutting and showed a surprising uniformity when only the height of the stubble varied. The only exception was the 30-inch plants cut with an 18-inch stubble which did have a slightly higher protein content. Since forage yields for 30-inch plants with 18-inch stubble were as high or higher than shorter stubble heights, it suggests that yields of protein per acre may have been increased by leaving a high stubble.

The laborious task of collecting root samples yielded little information as to the effect of clipping on root weights. Table 27 gives an indication that the short, more frequently clipped plants produced less roots. However, as shown in Table 28, the extremely large variation between samples resulted in none of these differences being statistically significant.

<u>Effect of cutting treatments, varieties, row spacings, and irrigation, 1956</u>

A heavy infestation of crabgrass was encountered in the area in which the plots were located. This, in addition to daily rains during June and July, made it virtually impossible to obtain any semblance of weed control. Plots having plants clipped frequently to leave a four-inch stubble permitted more light penetration, resulting in heavier growth of crabgrass. The heavy growth of crabgrass

TABLE 27

EFFECT OF CUTTING TREATMENTS ON ROOT YIELD IN IRRIGATED COMMON PEARLMILLET, 1955

| Height of Plants When Cut | Height of Stubble | Grams of Oven Dry Root per Core, Average of Three Replications |
|---|---|---|
| Inches | Inches | 0-6 Inches |
| 12 | 4 | 3.53 |
| 12 | 6 | 2.79 |
| 18 | 4 | 7.61 |
| 18 | 6 | 5.80 |
| 18 | 10 | 2.12 |
| 30 | 4 | 6.58 |
| 30 | 6 | 6.74 |
| 30 | 10 | 8.17 |
| 30 | 18 | 8.91 |
| 54 | 4 | 5.63 |
| 54 | 6 | 7.55 |
| 54 | 10 | 6.05 |
| 54 | 18 | 8.78 |
| | L.S.D. at 5% | n.s. |

n.s. Not significant at five percent level.

TABLE 28

ANALYSIS OF VARIANCE: EFFECT OF CLIPPING TREATMENTS ON ROOT PRODUCTION OF IRRIGATED COMMON PEARLMILLET, 1955

| Source | Degree of Freedom | Sum of Squares | Mean Square |
|---|---|---|---|
| Replications | 2 | 6.93 | 3.46 |
| Treatments | 12 | 176.60 | 14.72 |
| Error | 24 | 253.12 | 10.55 |
| Total | 38 | 436.65 | |

was probably responsible for the shortened life of the pearlmillet stand in 1956.

The summary of yield data in Table 29 does not permit simple conclusions due to the presence of highly significant interactions as shown in Table 30. Individual treatment yields listed in Table 31 indicate the nature of the interactions.

In every treatment combination, a row spacing of 19 inches was more productive than one of 38 inches. However, an even closer row spacing of seven inches did not generally result in an increased yield of forage. With 30-inch plants cut to leave an 18-inch stubble there was a considerable reduction in yield with a seven-inch row spacing, particularly with the Starr variety.

Close and frequent clipping, as in the case of the 12- and 18-inch plants, resulted in a severe decline in the yield of forage. Quite predictably, the 54-inch cutting treatment yielded the largest quantity of dry matter although this material was coarse and stemmy. With common pearlmillet in seven- or 19-inch rows more forage was obtained from 30-inch plants cut to leave a four-inch stubble. This did not seem to be the case when the plants were grown in 38-inch rows. The Starr variety presents a somewhat different picture. The four-inch stubble height favored the seven-inch row spacing but for plants in 19- or

TABLE 29

SUMMARY OF IRRIGATED PEARLMILLET FORAGE YIELDS AS AFFECTED BY ROW SPACING, VARIETY, AND CUTTING TREATMENT, 1956

| | | Pounds per Acre Oven Dry Forage |
|---|---|---|
| Varieties: | | |
| Starr | | 7,510 |
| Common | | 7,220 |
| | L.S.D. at 5% | 240 |
| Row Spacings: | | |
| 7-inch | | 8,200 |
| 19-inch | | 7,810 |
| 38-inch | | 6,100 |
| | L.S.D. at 5% | 1,040 |
| Cutting Treatments: | | |
| 54 inches tall, 4-inch stubble | | 11,700 |
| 30 inches tall, 4-inch stubble | | 8,060 |
| 30 inches tall, 10-inch stubble | | 8,040 |
| 30 inches tall, 18-inch stubble | | 7,360 |
| 18 inches tall, 4-inch stubble | | 4,750 |
| 12 inches tall, 4-inch stubble | | 4,320 |
| | L.S.D. at 5% | 480 |

TABLE 30

ANALYSIS OF VARIANCE: FORAGE YIELDS OF IRRIGATED PEARLMILLET AS AFFECTED BY ROW SPACING, VARIETY, AND CUTTING TREATMENT, 1956

| Source | Degree of Freedom | Sum of Squares | Mean Square |
|---|---|---|---|
| Main Plots: | | | |
| Replications | 3 | 1.94 | 0.65 |
| Varieties | 1 | 3.09 | 3.09* |
| Error (a) | 3 | 0.61 | .20 |
| Subplots: | | | |
| Row Spacing | 2 | 119.81 | 59.90** |
| Row Spacing x Varieties | 2 | 0.29 | 0.14 |
| Error (b) | 12 | 6.52 | 0.54 |
| Sub-subplots: | | | |
| Cutting Treatments | 5 | 855.24 | 171.05** |
| Cutting Treatments x Varieties | 5 | 21.79 | 4.36** |
| Cutting Treatments x Row Spacing | 10 | 30.30 | 3.03** |
| Cutting Treatments x Row Spacing x Varieties | 10 | 19.22 | 1.92** |
| Error (c) | 90 | 62.45 | 0.69 |
| Total | 143 | 1,121.26 | |

*Significant at five percent level.

**Significant at one percent level.

TABLE 31

FORAGE YIELDS OF IRRIGATED PEARLMILLET AS AFFECTED BY ROW SPACING, VARIETY, AND CUTTING TREATMENT, 1956

| | Pounds per Acre Oven Dry Forage per Cutting Treatment[a] | | | | | |
|---|---|---|---|---|---|---|
| | 12-4 | 18-4 | 30-4 | 30-10 | 30-18 | 54-4 |
| Common Variety | | | | | | |
| 7-inch Row | 5,690 | 5,250 | 8,840 | 8,720 | 6,860 | 12,720 |
| 19-inch Row | 4,470 | 5,520 | 9,290 | 8,470 | 7,480 | 10,590 |
| 38-inch Row | 3,380 | 4,160 | 5,820 | 7,340 | 5,760 | 9,620 |
| Starr Variety | | | | | | |
| 7-inch Row | 5,460 | 4,980 | 10,790 | 8,310 | 7,970 | 12,770 |
| 19-inch Row | 4,260 | 5,110 | 7,780 | 8,760 | 9,050 | 12,940 |
| 38-inch Row | 2,660 | 3,480 | 5,820 | 6,670 | 7,020 | 11,430 |

[a]First figure refers to height of plant in inches when cut; second figure is the height of the stubble.

38-inch rows the higher stubble heights of 10 or 18 inches were more productive. Some light is shed on this problem by examining Table 32. Here it will be seen that 30-inch plants of the Starr variety cut to four inches yielded the same number of clippings under all row spacings. However, 30-inch plants with 10-inch stubble yielded one less cutting and the plants with 18-inch stubble yielded three less cuttings when comparing the seven-inch row spacing with the other two row spacings. From this it may be concluded that leaving a high stubble on closely planted Starr millet either decreased the rate of growth or appreciably shortened the productive season.

High stubble appeared to favor the production of Starr pearlmillet in 19- or 38-inch rows. In order to test the significance of this statement, a separate analysis of variance was calculated in Table 33 on the Starr variety in 19- or 38-inch rows. The summary shown in Table 34 indicates that the higher stubble heights definitely favored growth of the Starr variety in 19- or 38-inch rows.

When plants were clipped at 12 or 18 inches in height and grown in 19- or 38-inch rows, both Starr and common varieties made a surge of growth in late May and then declined to a low level for the remainder of the season. The productive life of the planting was approximately two months. However, with a seven-inch row spacing the

TABLE 32

NUMBER OF CLIPPINGS OBTAINED UNDER VARIOUS ROW SPACINGS AND CUTTING TREATMENTS OF TWO PEARLMILLET VARIETIES, 1956

| Height of Plants When Cut (Inches) | Height of Stubble (Inches) | 7-inch Rows | | 19-inch Rows | | 38-inch Rows | |
|---|---|---|---|---|---|---|---|
| | | Common | Starr | Common | Starr | Common | Starr |
| 12 | 4 | 7 | 7 | 9 | 9 | 9 | 8 |
| 18 | 4 | 4 | 4 | 6 | 6 | 6 | 6 |
| 30 | 4 | 4 | 4 | 5 | 4 | 4 | 4 |
| 30 | 10 | 5 | 5 | 6 | 6 | 6 | 6 |
| 30 | 18 | 9 | 8 | 9 | 11 | 9 | 11 |
| 54 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |

TABLE 33

ANALYSIS OF VARIANCE: EFFECT OF CUTTING TREATMENTS ON THE SEASON YIELD OF STARR MILLET GROWN IN 19- AND 38-INCH ROWS, 1956

| Source | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Main plots: | | | |
| Replications | 3 | 2.58 | 0.86 |
| Row Spacing | 1 | 38.92 | 38.92** |
| Error (a) | 3 | 0.41 | 0.14 |
| Subplots: | | | |
| Cutting treatments | 5 | 386.25 | 77.25** |
| CT x RS | 5 | 0.62 | 0.12 |
| Error (b) | 30 | 28.44 | 0.95 |
| Total | 47 | 457.22 | |

**Significant at one percent level.

TABLE 34

EFFECT OF CUTTING TREATMENTS ON THE SEASON YIELD OF STARR MILLET GROWN IN 19- AND 38-INCH ROWS, 1956

| | | | Pounds per Acre Oven Dry Forage |
|---|---|---|---|
| Row Spacing: | | | |
| 19-inch | | | 7,981 |
| 38-inch | | | 6,180 |
| | | L.S.D. at 5% | 344 |
| Cutting Treatment: | | | |
| | Height of Plant When Cut, Inches | Height of Stubble, Inches | |
| | 54 | 4 | 12,180 |
| | 30 | 18 | 8,040 |
| | 30 | 10 | 7,710 |
| | 30 | 4 | 6,800 |
| | 18 | 4 | 4,300 |
| | 12 | 4 | 3,460 |
| | | L.S.D. at 5% | 990 |

frequently clipped plants yielded forage for only six weeks. The extended productive life of the planting due to tall, vigorous plants and leaving a high stubble is illustrated in Figure 23.

Although the Starr variety was somewhat more productive when 30-inch plants were cut to leave an 18-inch stubble, there was little difference between the varieties when close frequent clipping was practiced (Figure 24).

The crude protein content of the forage, obtained from nitrogen determinations made several times during the growing season, is shown in Table 35. A number of samples were lost due to wet weather in storage prior to grinding, resulting in an incomplete table. With the exception of the 54-inch plants, all the treatments gave very high percentages of crude protein. Forage harvested in July from plants of common pearlmillet generally was somewhat lower in crude protein than from plants of the Starr variety.

Results of the unirrigated clipping study are summarized in Tables 36 and 37. Comparing the irrigated plot yields shown in Table 31 with equivalent treatments in the unirrigated experiment, it is evident that irrigation had little or no effect on forage yields. Due to the small size of the experiment, differences between the two varieties were not significant. Here, as in the irrigated plots, the seven- and 19-inch row spacings performed better

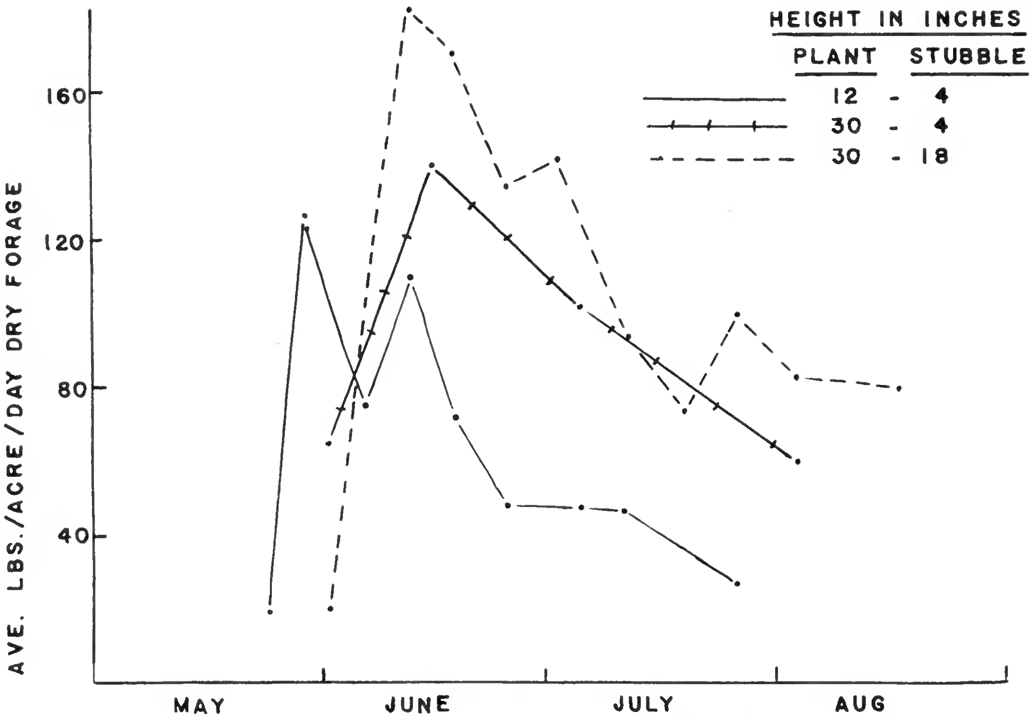


Fig. 23.--Seasonal distribution of Starr pearlmillet grown in 19-inch rows and subjected to three cutting treatments, 1956.

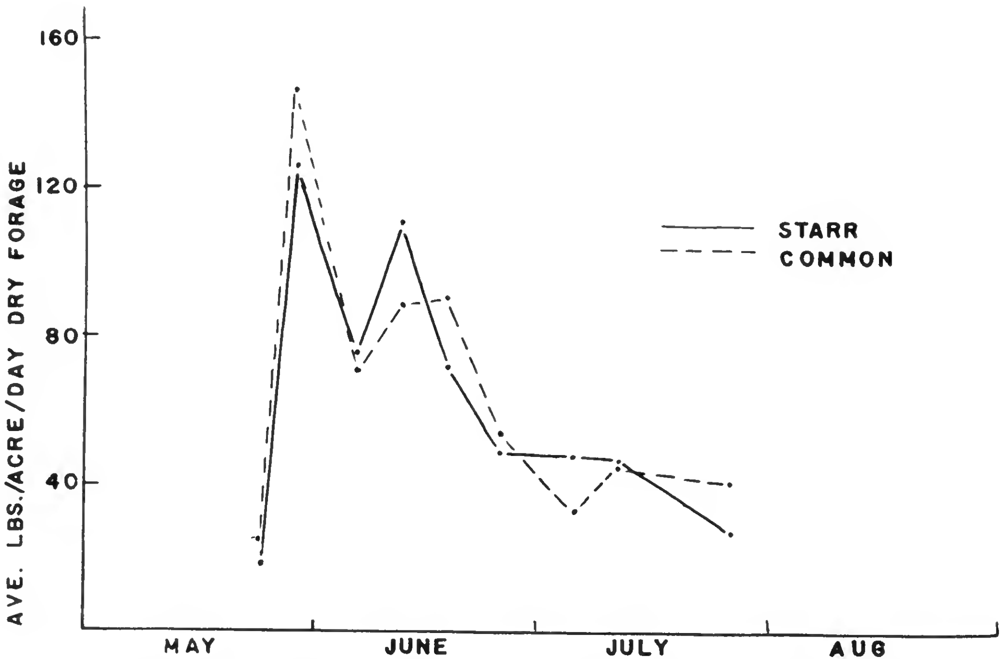


Fig. 24.--Seasonal distribution of Common and Starr pearlmillet varieties when cut at 12 inches to leave a four-inch stubble, 19-inch row spacing, 1956.

TABLE 35

CRUDE PROTEIN CONTENT[a] OF IRRIGATED PEARLMILLET FORAGE AS AFFECTED BY VARIETY, ROW SPACING, AND CUTTING TREATMENT, 1956

| Hgt. of Plant (In.) | Hgt. of Stbl. (In.) | Common Variety | | | | | | Starr Variety | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7-in. Row | | 19-in. Row | | 38-in. Row | | 7-in. Row | | 19-in. Row | | 38-in. Row | |
| | | June | July | June | July | June | July | June | July | June | July | June | July |
| 12 | 4 | 27.5 | 16.2 | -- | 21.2 | 28.4 | 20.0 | 27.2 | 21.9 | 30.3 | 23.1 | 29.4 | 23.4 |
| 18 | 4 | 25.6 | -- | 28.4 | 19.7 | 26.6 | -- | 27.5 | -- | 29.1 | 16.9 | 29.1 | 17.5 |
| 30 | 4 | 25.9 | 14.7 | 27.2 | 16.6 | 28.4 | 17.5 | 22.8 | 16.2 | 24.4 | -- | 26.6 | 20.0 |
| 30 | 10 | 25.6 | 17.2 | 28.8 | 15.6 | 27.5 | 15.6 | 27.2 | 18.4 | 26.2 | 19.1 | 27.5 | 19.7 |
| 30 | 18 | 27.5 | 15.0 | 27.2 | 16.6 | 28.1 | 16.9 | 24.4 | 18.4 | 29.4 | 18.4 | 29.1 | 19.1 |
| 54 | 4 | 14.7 | 10.9 | 15.3 | 14.4 | 16.6 | 11.9 | 17.5 | -- | 16.9 | -- | 20.6 | -- |

[a]Each figure is an average of the analyses of two replications and expressed on the basis of oven dry forage.

TABLE 36

EFFECT OF VARIETY AND ROW SPACING ON POUNDS PER ACRE OF OVEN DRY FORAGE FROM UNIRRIGATED PEARLMILLET CUT WHEN 30 INCHES TALL TO LEAVE A FOUR-INCH STUBBLE, 1956

| Row Spacing | Varieties | | Mean |
|---|---|---|---|
| | Common | Starr | |
| 7-inch | 16,157 | 11,440 | 13,798 |
| 19-inch | 12,880 | 10,973 | 11,926 |
| 38-inch | 9,200 | 6,453 | 7,826 |
| | 12,746 | 9,622 | |

| L.S.D. between: | At 5% level: |
|---|---|
| Variety means: | Not significant |
| Row spacing means: | 2,320 pounds |

TABLE 37

ANALYSIS OF VARIANCE: EFFECT OF VARIETY AND ROW SPACING ON FORAGE YIELD OF UNIRRIGATED PEARLMILLET, 1956

| | Degrees of Freedom | Sum of Squares | Mean Square |
|---|---|---|---|
| Main Plots: | | | |
| Replications | 2 | 33.50 | 16.50 |
| Varieties | 1 | 43.90 | 43.90 |
| Error (a) | 2 | 10.79 | 5.40 |
| Subplots: | | | |
| Row spacing | 2 | 111.95 | 55.98** |
| Spacing x Varieties | 2 | 6.24 | 3.12 |
| Error (b) | 8 | 24.39 | 3.05 |
| Total | 17 | | |

**Significant at one percent level.

than did the 38-inch rows.

Effect of cutting treatments and row spacings, 1957

The yield data of Table 38 point out the superior performance of seven- and 19-inch row spacings. Seven-inch row spacings, however, offered a serious handicap in not allowing cultivation for weed control.

Cutting treatment differences were mainly due to height of the plants when they were cut. Forage yields were considerably reduced by clipping plants when they reached a height of 12 inches. Table 39 notes an interaction between cutting treatments and row spacings. Analysis of the separate row spacings (Tables 38 and 40) shows that 30-inch plants were more productive than 18-inch plants at the two wider row spacings but that with a seven-inch spacing there was little difference between the two heights. Stubble height had little effect on yield except in the seven-inch row spacing where the 18-inch stubble materially reduced production. Although season total yields were not affected by height of cut, plants cut to leave a 10- or 18-inch stubble recovered more quickly after cutting than did plants with a four-inch stubble. Thirty-inch plants, all cut at the same time to three different stubble heights, furnished evidence of this fact in Figure 25. A photographic record of regrowth as affected by clipping height is shown in Figures 26 and 27.

TABLE 38

POUNDS PER ACRE OF OVEN DRY STARR MILLET FORAGE AS INFLUENCED BY ROW SPACING AND CUTTING TREATMENT, 1957

| Cutting Treatment[a] | 38-inch | 19-inch | 7-inch | Mean |
|---|---|---|---|---|
| 12-4 | 4,030 | 5,380 | 7,730 | 5,710 |
| 18-4 | 5,900 | 8,130 | 9,170 | 7,730 |
| 30-4 | 7,480 | 9,860 | 10,260 | 9,200 |
| 30-10 | 7,760 | 9,830 | 10,620 | 9,400 |
| 30-18 | 6,810 | 9,380 | 7,970 | 8,050 |
| 54-4 | 11,120 | 10,760 | 10,730 | 10,870 |
| Mean | 7,180 | 8,890 | 9,410 | |

| L.S.D. between: | At 5% level: |
|---|---|
| Row spacing means: | 1,460 pounds |
| Clipping treatment means: | 960 " |
| Clipping treatments: | |
| 38-inch rows: | 2,210 " |
| 19-inch rows: | 1,350 " |
| 7-inch rows: | 1,660 " |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 39

ANALYSIS OF VARIANCE: EFFECT OF ROW SPACINGS AND CUTTING TREATMENTS ON FORAGE PRODUCTION OF STARR MILLET, 1957

| Source | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Main plots: | | | |
| Replications | 3 | 8.86 | 2.95 |
| Row spacings | 2 | 65.03 | 32.52** |
| Error (a) | 6 | 13.83 | 2.30 |
| Subplots: | | | |
| Cutting treatments | 5 | 185.83 | 37.16** |
| CT x RS | 10 | 34.30 | 3.43* |
| Error (b) | 45 | 62.34 | 1.38 |
| Total | 71 | 370.19 | |

*Significant at five percent level.

**Significant at one percent level.

TABLE 40

ANALYSIS OF VARIANCE: EFFECT OF CUTTING TREATMENTS ON FORAGE PRODUCTION OF STARR MILLET AT SEVEN-, 19-, AND 38-INCH ROW SPACINGS, 1957

| Source | D.F. | 38-inch Rows | | 19-inch Rows | | 7-inch Rows | |
|---|---|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Replications | 3 | 19.90 | 6.63 | 1.92 | 0.64 | 0.87 | 0.29 |
| Cutting Treatments | 5 | 110.73 | 22.15** | 73.84 | 14.77** | 35.56 | 7.11** |
| Error | 15 | 32.19 | 2.15 | 12.01 | 0.80 | 18.15 | 1.21 |
| Total | 23 | 162.82 | | 87.77 | | 54.58 | |

**Significant at one percent level.

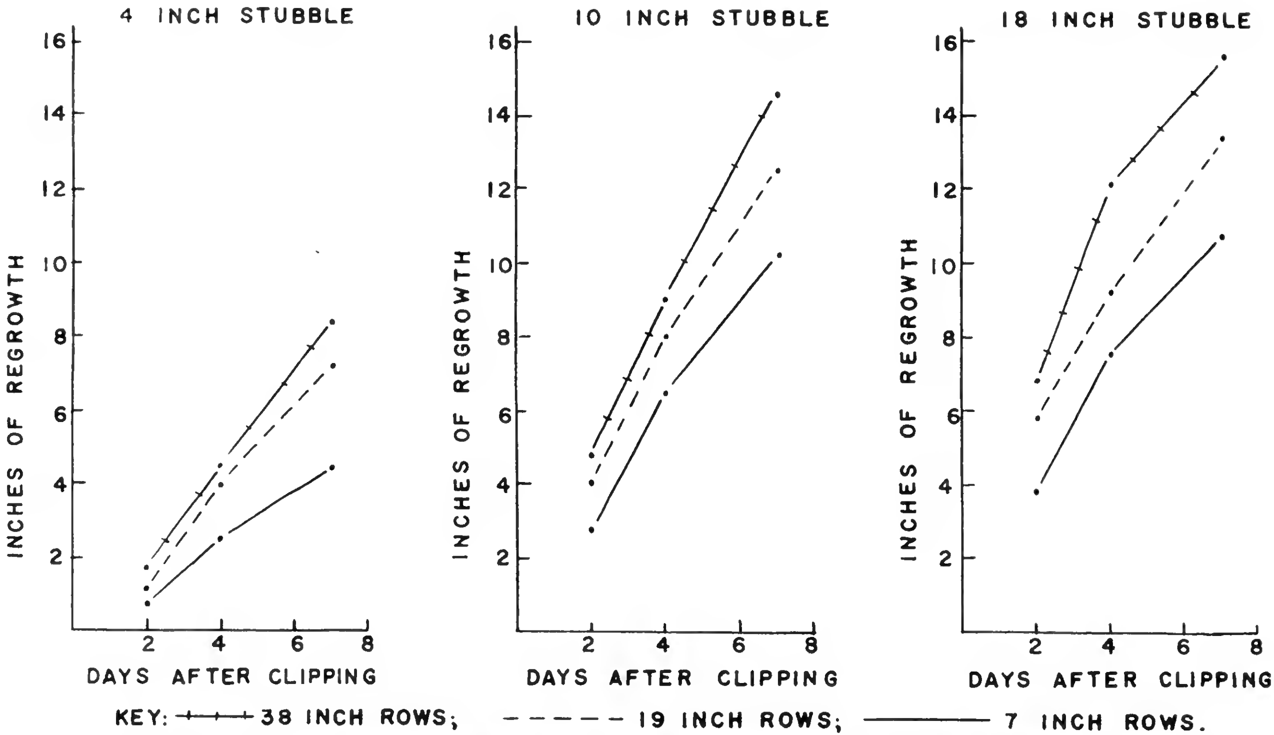


Fig. 25.--Regrowth of Starr millet after clipping 30-inch plants, 1957.

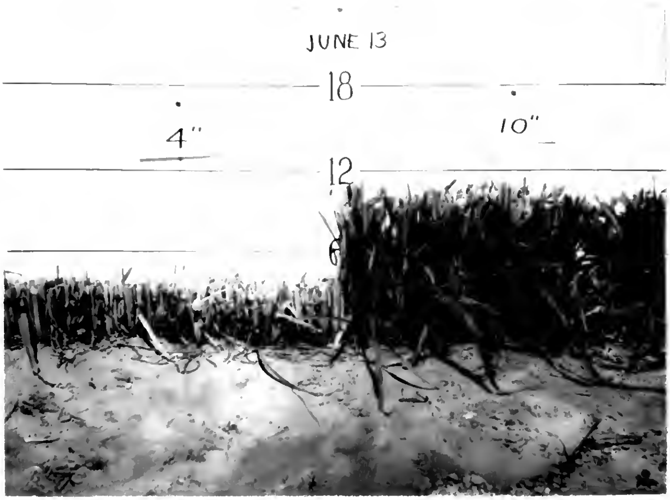


Fig. 26.--Thirty-inch plants of Starr millet clipped back to four and 10-inch stubble heights, 1957.

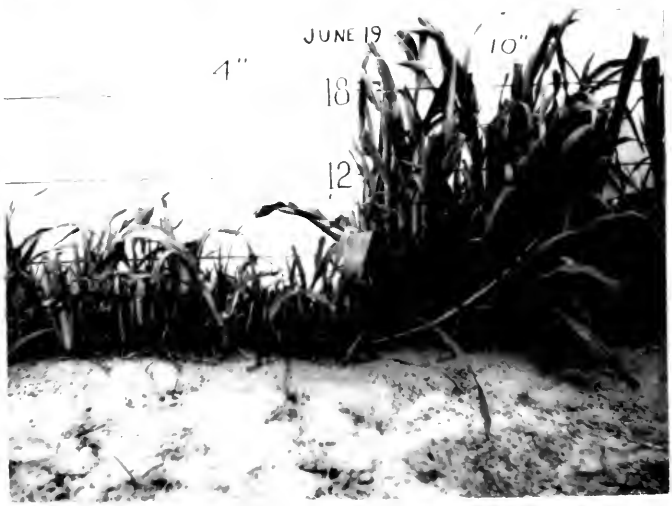


Fig. 27.--Regrowth of Starr millet as affected by stubble heights, six days after cutting, 1957.

Regrowth of individual plants was slower with closer row spacings as shown in Figure 25. Apparently, closer row spacing resulted in more total forage per acre but less forage being produced per plant. This is also attested to by the reduced number of clippings obtained with the seven-inch row spacing as shown in Table 41. Seasonal production of the row spacings were similar but there was a tendency for 30-inch plants clipped to a four-inch stubble to cease growing somewhat earlier than high stubble plants as illustrated in Figure 28. The reverse was true for common pearlmillet in 1955, indicating that varieties may differ in response to clipping.

The crude protein content of the forage (Table 42) remained remarkably high for the duration of the season under all clipping treatments except where plants were cut when 54 inches tall. Protein contents diminished slightly with reduced width of rows. The data suggest that frequent applications of nitrogen fertilizer were capable of maintaining a high crude protein content in Starr millet, even during September when plants were heading, thus overcoming the expected decline in protein with increasing maturity.

TABLE 41

NUMBER OF CLIPPINGS OBTAINED FROM STARR MILLET AS INFLUENCED BY CUTTING TREATMENTS AND ROW SPACINGS, 1957

| Cutting Treatments[a] | Row Spacing in Inches | | |
|---|---|---|---|
| | 38 | 19 | 7 |
| 12-4 | 15 | 16 | 12 |
| 18-4 | 11 | 11 | 8 |
| 30-4 | 5 | 4 | 4 |
| 30-10 | 9 | 8 | 6 |
| 30-18 | 12 | 11 | 8 |
| 54-4 | 2 | 2 | 2 |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

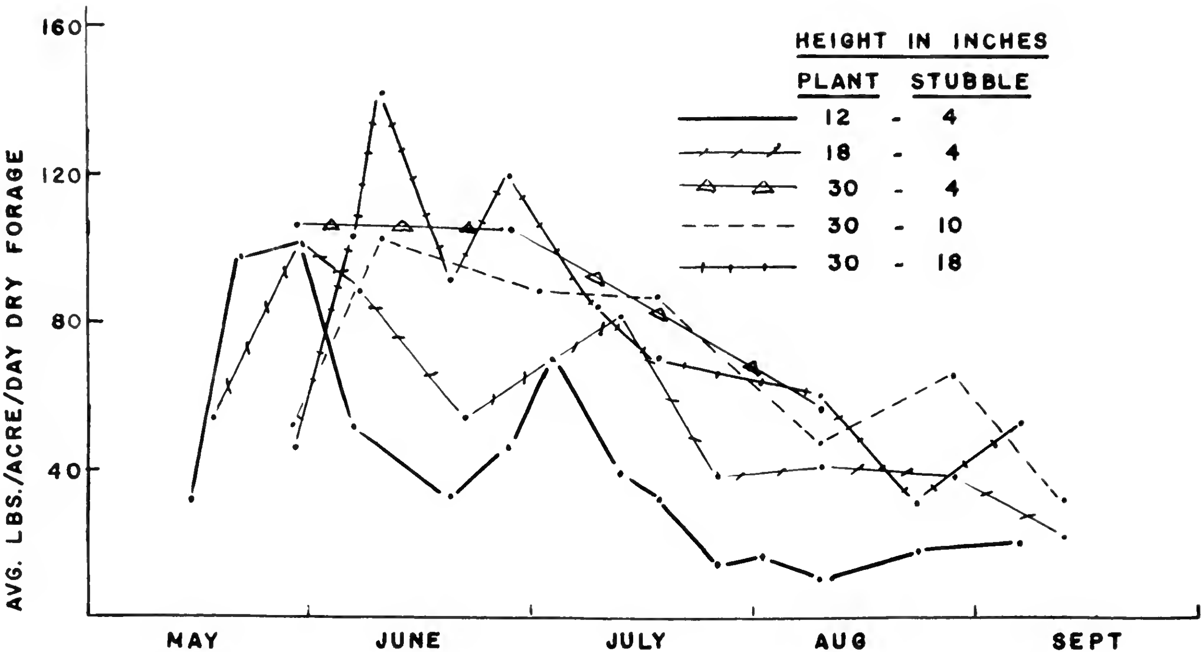


Fig. 28.--Seasonal distribution of forage as affected by cutting treatments, Starr millet in 19-inch rows, 1957.

TABLE 42

PERCENT CRUDE PROTEIN[a] IN STARR MILLET AS INFLUENCED BY CUTTING TREATMENT AND ROW SPACING, 1957

| Date | Row Spacing | Cutting Treatments[b] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 12-4 | 18-4 | 30-4 | 30-10 | 30-18 | 54-4 |
| May 28 | 38 | 25.0 | 21.2 | 17.2 | 19.1 | 19.7 | |
| | 19 | 24.7 | 19.7 | 19.1 | 16.9 | 20.0 | |
| | 7 | 23.4 | 18.1 | 17.8 | 17.8 | 18.8 | |
| June 7 | 38 | | | | | | 13.4 |
| | 19 | | | | | | 14.7 |
| June 19 | 38 | | 24.4 | | | 17.8 | |
| | 19 | | | | | 18.8 | |
| | 7 | | | | | | 13.1 |
| June 21 | 38 | | | 15.6 | 19.1 | | |
| | 19 | | 22.5 | | | | |
| June 27 | 38 | 27.8 | | | | 21.6 | |
| | 19 | 29.4 | | 16.2 | | 18.4 | |
| | 7 | 21.2 | 22.8 | | | 18.4 | |

[a]Each figure listed is an average of the analyses of two replications and expressed on the basis of oven dry forage.

[b]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 42 (Continued)

| Date | Row Spacing | Cutting Treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | 12-4 | 18-4 | 30-4 | 30-10 | 30-18 | 54-4 |
| July 1 | 38 | | | | 20.0 | | |
| | 19 | | | | 15.6 | | |
| | 7 | | | 15.9 | | | |
| July 9 | 38 | | | | | 19.7 | |
| | 19 | | | | | 19.4 | |
| | 7 | 23.1 | | | | 19.1 | |
| July 12 | 38 | 27.2 | | 18.4 | | | |
| | 19 | | 24.7 | | | | |
| | 7 | 28.4 | 20.9 | | 16.9 | | |
| July 17 | 38 | | | | 15.3 | 18.4 | |
| | 19 | 25.9 | | | 17.2 | 16.2 | |
| July 23 | 38 | | 19.1 | | | | |
| August 1 | 38 | 24.1 | | | | 17.8 | 10.0 |
| | 19 | 27.8 | | | | | 9.7 |
| | 7 | 18.4 | | | | 12.8 | |
| August 9 | 38 | | 21.9 | 19.1 | 19.4 | | |
| | 19 | | 21.2 | 12.5 | 18.4 | | |
| | 7 | | 15.6 | 14.4 | | | |
| August 15 | 7 | | | | 14.4 | | 10.6 |
| September 6 | 38 | 21.9 | | | | 19.7 | |

TABLE 42 (Continued)

| Date | Row Spacing | Cutting Treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | 12-4 | 18-4 | 30-4 | 30-10 | 30-18 | 54-4 |
| | 19 | 20.9 | | | | 19.7 | |
| | 7 | 22.5 | | | | 19.7 | |
| September 12 | 38 | | | | 20.6 | | |
| | 19 | | | | 19.1 | | |
| Means: | 38 | 25.2 | 21.6 | 17.6 | 18.9 | 19.2 | 11.7 |
| | 19 | 25.7 | 22.0 | 15.9 | 17.4 | 18.8 | 12.2 |
| | 7 | 22.8 | 19.4 | 16.0 | 16.4 | 17.8 | 11.8 |

Effect of cutting treatments and nitrogen levels, 1958

Forage yields in the 1958 experiment were considerably lower than in preceding years. This can probably be attributed to the late planting date and drouth conditions during late July. This may also help to explain the reduced yield response to the highest level of nitrogen fertilization.

The forage yield data, as shown in Table 43, point out the serious effects of close frequent clipping. Yields were generally cut in half by clipping 12-inch plants back to four inches throughout the growing season as contrasted to cutting when plants reached 30 inches tall. There was little difference in yield between 30-inch plants with four- or ten-inch stubble. Nitrogen applied at the rate of 30 pounds per acre biweekly increased yields above that of the 15 pound rate but doubling the nitrogen application to 60 pounds biweekly did not result in a significant increase in forage production. Thirty-inch plants yielded one extra cutting at the two higher levels of nitrogen (Table 44). In this experiment there was a highly significant interaction between cutting treatments and nitrogen levels (Table 45). Leaving a high stubble of ten inches had little or no effect on yields at the 15 or 30 pound rate of nitrogen but gave a significant increase in production at the 60 pound rate (Table 46). It is also interesting to

TABLE 43

POUNDS PER ACRE OVEN DRY STARR MILLET FORAGE AS INFLUENCED BY NITROGEN FERTILIZATION AND CUTTING TREATMENT, 1958

| Pounds per Acre Nitrogen Biweekly | Total Lbs. per Acre Nitrogen Applied | Cutting Treatments[a] | | | Mean |
|---|---|---|---|---|---|
| | | 12-4 | 30-4 | 30-10 | |
| 15 | 120 | 2,850 | 6,390 | 5,610 | 4,950 |
| 30 | 210 | 3,640 | 6,460 | 6,860 | 5,650 |
| 60 | 390 | 3,430 | 6,630 | 8,030 | 6,030 |
| Mean | | 3,310 | 6,490 | 6,830 | |

| L.S.D. between: | At 5% level: |
|---|---|
| Nitrogen means: | 490 pounds |
| Cutting treatment means: | 384 pounds |
| Cutting treatment yields | 816 pounds |
| at highest nitrogen rate: | 816 pounds |

[a]First number refers to height of plant in inches when cut; second number refers to height of stubble in inches.

TABLE 44

NUMBER OF CLIPPINGS OBTAINED FROM STARR MILLET AS INFLUENCED BY CUTTING TREATMENTS AND ROW SPACING, 1958

| Cutting Treatment[a] | Pounds per Acre Nitrogen Applied Biweekly | | |
|---|---|---|---|
| | 15 | 30 | 60 |
| 12-4 | 12 | 12 | 12 |
| 30-4 | 3 | 4 | 4 |
| 30-10 | 5 | 6 | 6 |

[a]First figure refers to height of the plant in inches when cut; second number is stubble height.

TABLE 45

ANALYSIS OF VARIANCE: FORAGE YIELD OF STARR MILLET AS AFFECTED BY NITROGEN LEVELS AND CUTTING TREATMENTS, 1958

| Sources of Variation | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Main plots: | | | |
| Replications | 5 | 1.22 | 0.24 |
| Nitrogen levels | 2 | 2.72 | 1.36** |
| Error (a) | 10 | 1.07 | 0.11 |
| Subplots: | | | |
| Cutting treatment | 2 | 34.05 | 17.02** |
| CT x N | 4 | 2.22 | 0.56** |
| Error (b) | 30 | 2.31 | 0.08 |
| Total | 53 | 43.59 | |

**Significant at one percent level.

TABLE 46

ANALYSIS OF VARIANCE: EFFECT OF CUTTING TREATMENTS ON FORAGE PRODUCTION OF STARR MILLET RECEIVING 60 POUNDS PER ACRE NITROGEN BIWEEKLY, 1958

| Source | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Replications | 5 | 0.57 | 0.11 |
| Cutting Treatments | 2 | 16.67 | 8.34** |
| Error | 10 | 1.01 | 0.10 |
| Total | 17 | 18.25 | |

**Significant at one percent level.

note that although additional nitrogen increased yields of the 12-inch plants cut back to four inches, the 30-inch plants cut back to four inches gave virtually no response to nitrogen above the lowest level.

In comparing the seasonal production curves of Figures 29, 30, and 31, it is readily apparent that additional nitrogen did not lengthen the productive life of the pearlmillet plant nor did it give a more uniform increase in forage yield over the season. Rather, the effect of high nitrogen was to produce a higher peak in production early in the growing season.

Cutting treatments greatly modified the crude protein content of the forage as shown in Table 47. Differences in protein level between cutting treatments were greatest at the lowest level of nitrogen application. With a high level of nitrogen fertilization it was possible to increase the forage quality, irrespective of the cutting system used. Leaving a 10-inch stubble on 30-inch plants was not effective in raising the protein content except at the lowest level of nitrogen fertilization. This is rather strange in view of the fact that forage from the high stubble plants consisted of more leaves and less stems than from the low stubble plants. Under all cutting treatments and nitrogen levels the crude protein content remained fairly uniform throughout the season with the exception of

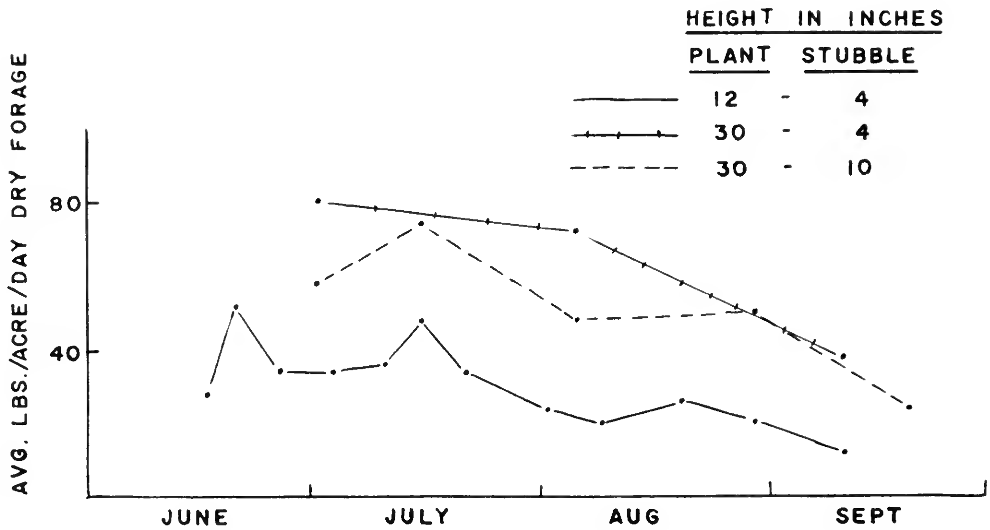


Fig. 29.--Seasonal production of Starr millet fertilized with 15 pounds per acre nitrogen biweekly, 1958.

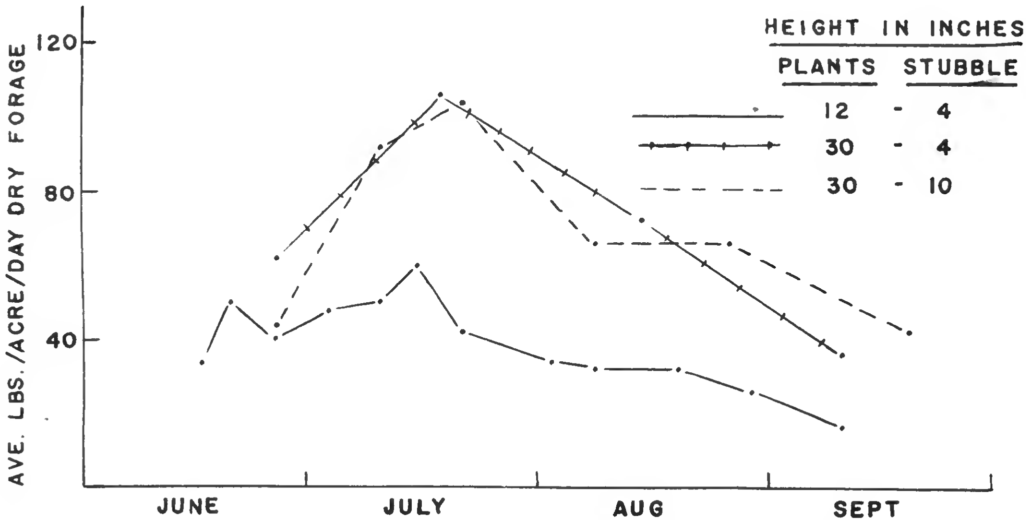


Fig. 30.--Seasonal production of Starr millet fertilized with 30 pounds per acre nitrogen biweekly, 1958.

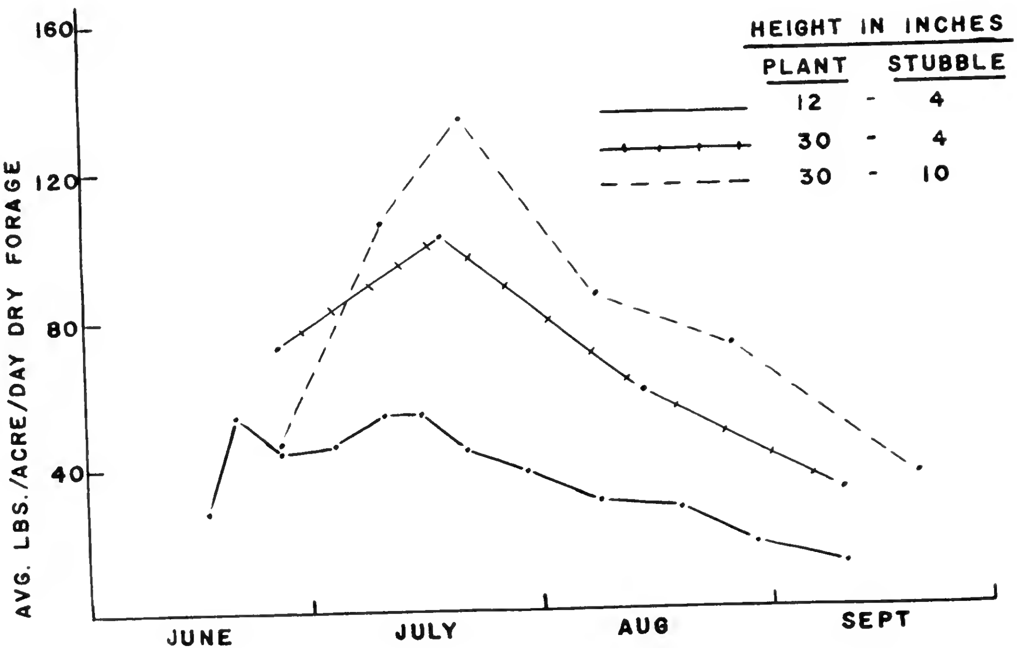


Fig. 31.--Seasonal production of Starr millet fertilized with 60 pounds per acre nitrogen biweekly, 1958.

TABLE 47

PERCENT CRUDE PROTEIN[a] OF STARR MILLET FORAGE AS INFLUENCED BY CUTTING TREATMENT AND NITROGEN FERTILIZATION, 1958

| Harvest Date | 15 Lb/Acre N Biweekly | | | 30 Lb/Acre N Biweekly | | | 60 Lb/Acre N Biweekly | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cutting Treatment[b] | | | Cutting Treatment | | | Cutting Treatment | | |
| | 12-4 | 30-4 | 30-10 | 12-4 | 30-4 | 30-10 | 12-4 | 30-4 | 30-10 |
| June 16 | 27.0 | | | 23.8 | | | 31.1 | | |
| 20 | 27.6 | | | 25.0 | | | 30.4 | | |
| 26 | 23.4 | | | 25.6 | | | 29.3 | 21.0 | 21.8 |
| July 1 | | 12.6 | 14.2 | | 17.1 | 20.2 | | | |
| 3 | 21.2 | | | 23.1 | | | 24.9 | | |
| 10 | 23.9 | | | 25.8 | | 16.2 | 27.5 | | 20.3 |
| 15 | 26.8 | | 13.6 | 26.4 | | | 29.0 | | |
| 18 | | | | | 14.9 | | | 22.0 | |
| 21 | 21.6 | | | 25.6 | | 15.4 | 29.1 | | 19.1 |
| 29 | | | | | | | 28.6 | | |
| August 1 | 20.6 | | | 23.0 | | | | | |
| 5 | | 8.2 | 11.2 | | | | | | |
| 8 | 25.0 | | | 26.1 | | 17.2 | 29.6 | | 23.5 |
| 14 | | | | | 17.3 | | | 23.8 | |
| 19 | 22.5 | | | 24.0 | | | 28.3 | | |
| 26 | | | 13.8 | | | 19.8 | | | 23.8 |
| 29 | 25.9 | | | 26.4 | | | 29.4 | | |

TABLE 47 (Continued)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| September 10 | 16.8 | 9.0 | | 19.2 | 13.4 | | 24.6 | 21.4 | |
| 19 | | | 9.8 | | | 13.4 | | | 18.1 |
| Mean | 23.5 | 10.0 | 12.5 | 24.5 | 15.7 | 17.0 | 28.5 | 22.0 | 21.1 |

[a]Each figure listed is an average of the analyses of two replications and expressed on the basis of oven dry forage.

[b]First number refers to height of the plant in inches when cut; second number is the height of the stubble.

the last harvest.

Total nitrogen production per acre was calculated from two replications of the forage yield data and nitrogen analyses at each clipping. The total nitrogen yields for clipping treatment means, shown in Table 48, indicate that 30-inch plants with high stubble were most productive. However, Table 49 notes a clipping treatment x nitrogen level interaction. Examination of the individual treatment yields shows that at the lowest level of fertilization there was little difference between clipping treatments but as the nitrogen level was increased, the 30-inch plants were more productive. A still further increase in nitrogen production occurred at the highest level of fertilization when 30-inch plants were cut to leave a 10-inch stubble. Nitrogen deficiency symptoms were prominent in 30-inch plants grown at the lowest level of fertilization. Yellowing was much less noticeable in 12-inch plants at this rate of nitrogen application.

Numbers of live shoots declined under all managerial treatments as shown in Tables 50 and 51. The August 11 count indicated that the decline in numbers was greater where plants were clipped to a four-inch stubble. Toward the end of the growing season there was a very sharp decrease in live shoots on plots receiving the highest nitrogen fertilization, irrespective of cutting treatment.

TABLE 48

POUNDS PER ACRE NITROGEN CONTAINED IN STARR MILLET UNDER THREE CLIPPING TREATMENTS AND THREE NITROGEN FERTILIZER LEVELS, 1958

| Pounds per Acre Nitrogen Biweekly | Total Lbs. per Acre Nitrogen Applied | Cutting Treatments[a] | | | Mean |
|---|---|---|---|---|---|
| | | 12-4 | 30-4 | 30-10 | |
| 15 | 120 | 115.6 | 93.2 | 105.2 | 104.7 |
| 30 | 210 | 139.2 | 183.0 | 200.6 | 174.3 |
| 60 | 390 | 156.3 | 208.3 | 271.6 | 212.1 |
| Mean | | 137.0 | 161.5 | 192.5 | |

| L.S.D. between: | At 5% level: |
|---|---|
| Nitrogen means: | 22.4 |
| Clipping treatment means: | 27.1 |

[a]First number refers to height of the plant in inches when cut; second number is the height of the stubble.

TABLE 49

ANALYSIS OF VARIANCE: POUNDS PER ACRE NITROGEN CONTAINED IN STARR MILLET UNDER THREE CLIPPING TREATMENTS AND THREE NITROGEN FERTILIZER LEVELS, 1958

| Source | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Main plots: | | | |
| Replications | 1 | 1,758.2 | 1,758.2* |
| Nitrogen levels | 2 | 35,620.9 | 17,810.4** |
| Error (a) | 2 | 162.3 | 81.2 |
| Subplots: | | | |
| Cutting treatments | 2 | 9,261.3 | 4,630.8** |
| CT x N | 4 | 8,596.0 | 2,149.0* |
| Error (b) | 6 | 2,201.4 | 366.0 |
| Total | 17 | 57,600.1 | |

*Significant at five percent level.

**Significant at one percent level.

TABLE 50

NUMBER OF LIVE STARR MILLET SHOOTS PER ONE FOOT OF ROW AS AFFECTED BY NITROGEN AND CUTTING TREATMENTS, 1958

| Date of Cutting | Biweekly Nitrogen Application (lbs/A) | Cutting Treatments[a] | | | Mean |
|---|---|---|---|---|---|
| | | 12-4 | 30-4 | 30-10 | |
| July 18 | 15 | 45 | 46 | 46 | 46 |
| | 30 | 46 | 41 | 44 | 44 |
| | 60 | 43 | 43 | 46 | 44 |
| Mean | | 44 | 43 | 45 | |
| August 11 | 15 | 31 | 26 | 29 | 29 |
| | 30 | 25 | 26 | 30 | 27 |
| | 60 | 22 | 22 | 31 | 25 |
| Mean | | 26 | 25 | 30 | |
| August 29 | 15 | 22 | 23 | 23 | 23 |
| | 30 | 20 | 19 | 21 | 20 |
| | 60 | 15 | 10 | 12 | 13 |
| Mean | | 19 | 18 | 19 | |

| L.S.D. between: | At 5% level: July 18 | August 11 | August 29 |
|---|---|---|---|
| Nitrogen means: | n.s. | n.s. | 3 |
| Cutting treatment means: | n.s. | 4 | n.s. |

[a]First number refers to height of plant in inches when cut; second number is the height of the stubble.

TABLE 51

ANALYSIS OF VARIANCE: EFFECT OF NITROGEN LEVELS AND CUTTING TREATMENTS ON NUMBERS OF LIVE STARR MILLET SHOOTS, 1958

| Sources of Variation | D.F. | July 18 | | August 11 | | August 29 | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Main plots: | | | | | | | |
| Replications | 5 | 319 | 63.80 | 192 | 38.40 | 126 | 25.20 |
| Nitrogen levels | 2 | 37 | 18.50 | 156 | 78.00 | 1,000 | 500.00** |
| Error (a) | 10 | 1,246 | 124.60 | 260 | 26.00 | 199 | 19.90 |
| Subplots: | | | | | | | |
| Cutting treatment | 2 | 48 | 24.00 | 281 | 140.50** | 20 | 10.00 |
| CT x N | 4 | 73 | 18.25 | 190 | 47.50 | 54 | 13.50 |
| Error (b) | 30 | 2,512 | 83.73 | 928 | 30.93 | 744 | 24.80 |
| Total | 53 | 4,235 | | 2,007 | | 2,143 | |

**Significant at one percent level.

Root production was drastically reduced early in the growing season by close frequent clipping as shown in Tables 52 and 53. Although mean root yields for nitrogen levels indicated no significant differences, the August 1 sampling showed a highly significant interaction between cutting treatments and nitrogen levels. Root weights of 30-inch plants with a four-inch stubble sharply declined with the higher levels of nitrogen whereas the 12-inch plants showed a modest gain in roots as the nitrogen level was increased.

Effect of planting date, 1956 and 1957

The loss of the March and April plantings of Starr millet by blowing sand in 1956 point out a hazard in early planting. The losses incurred in this experiment were probably greater than would be normally expected under farm conditions because the small plot area was entirely surrounded by large open fields of tilled loose soil.

The yield data of Tables 54 and 55 show that early planting of Starr millet resulted in a larger number of harvests and a larger total yield for the season. A highly significant reduction in yield resulted from planting later in the season as evidenced by Tables 56 and 57.

The seasonal distribution of production in 1957 shown in Figure 32 indicates that the length of the productive season was about as long for the early as for the

TABLE 52

GRAMS OF OVEN DRY STARR MILLET ROOTS PER FOUR-INCH DIAMETER CORE ZERO TO SIX INCHES DEEP AS INFLUENCED BY CUTTING TREATMENTS AND NITROGEN LEVELS, 1958

| Pounds per Acre Nitrogen Applied Biweekly | June 28 | | | | August 1 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cutting Treatments[a] | | | Mean | Cutting Treatments | | | Mean |
| | 12-4 | 30-4 | 30-10 | | 12-4 | 30-4 | 30-10 | |
| 15 | 0.14 | 0.24 | 0.24 | 0.21 | 0.15 | 0.41 | 0.28 | 0.28 |
| 30 | 0.11 | 0.22 | 0.26 | 0.20 | 0.20 | 0.25 | 0.36 | 0.27 |
| 60 | 0.12 | 0.21 | 0.24 | 0.19 | 0.24 | 0.22 | 0.29 | 0.25 |
| Mean | 0.12 | 0.22 | 0.25 | | 0.20 | 0.29 | 0.31 | |

| | L.S.D. between: | At 5% level: |
|---|---|---|
| June 28: | Nitrogen means: | n.s. |
| | Cutting treatment means: | 0.04 gm. |
| August 1: | Nitrogen means: | n.s. |
| | Cutting treatment means: | 0.06 gm. |

[a]First number refers to height of the plant in inches when cut; second number is the height of the stubble.

TABLE 53

ANALYSIS OF VARIANCE: EFFECT OF NITROGEN LEVELS AND CUTTING TREATMENTS ON GRAMS OF DRY STARR MILLET ROOTS PER FOUR-INCH DIAMETER CORE, ZERO TO SIX INCHES DEEP, 1958

| Sources of Variation | D.F. | June 28 | | August 1 | |
|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Main plots: | | | | | |
| Replications | 5 | 0.0212 | 0.0042 | 0.0763 | 0.0153 |
| Nitrogen levels | 2 | 0.0013 | 0.0006 | 0.0070 | 0.0035 |
| Error (a) | 10 | 0.0710 | 0.0071 | 0.0699 | 0.0070 |
| Subplots: | | | | | |
| Cutting treatment | 2 | 0.1606 | 0.0803** | 0.1330 | 0.0665** |
| CT x N | 4 | 0.0051 | 0.0013 | 0.1595 | 0.0399** |
| Error (b) | 30 | 0.1182 | 0.0039 | 0.2010 | 0.0067 |
| Total | 53 | 0.3774 | | 0.6467 | |

**Significant at one percent level.

TABLE 54

POUNDS PER ACRE OF OVEN DRY STARR MILLET FORAGE AS AFFECTED BY PLANTING DATE, 1956

| Harvest Date | Planting Date | | | |
|---|---|---|---|---|
| | May 1 | June 4 | July 6 | August 3 |
| June 21 | 2,350 | | | |
| July 5 | 3,520 | | | |
| July 19 | | 3,190 | | |
| August 3 | 2,070 | 1,540 | 2,050 | |
| August 19 | | | 1,220 | |
| September 7 | | 2,100 | | |
| September 11 | | | | 1,900 |
| Total | 7,940 | 6,830 | 3,270 | 1,900 |

| L.S.D. between: | At 5% level: |
|---|---|
| Planting date totals: | 640 pounds |

TABLE 55

POUNDS PER ACRE OF OVEN DRY STARR MILLET FORAGE
AS AFFECTED BY DATE OF PLANTING,
1957

| Harvest Date | Date of Planting | | | | |
|---|---|---|---|---|---|
| | March 14 | April 16 | May 14 | June 14 | July 15 |
| May 14 | 1,560 | | | | |
| May 28 | | 2,560 | | | |
| May 30 | 2,480 | | | | |
| June 19 | 2,400 | 2,020 | | | |
| June 21 | | | 2,060 | | |
| July 9 | 1,840 | | | | |
| July 17 | | 1,900 | 2,020 | | |
| July 25 | 1,040 | | | | |
| August 9 | | | | 1,860 | |
| August 15 | 940 | 1,320 | 1,860 | | |
| August 27 | | | | | 1,520 |
| September 6 | 1,060 | | 1,380 | 1,800 | |
| September 12 | | 680 | | | |
| September 20 | | | | | 1,560 |
| September 26 | 360 | 120 | 300 | 300 | |
| Total | 11,680 | 8,600 | 7,620 | 3,960 | 3,080 |

| L.S.D. between: | At 5% level: |
|---|---|
| Planting date totals | 1,400 pounds |

TABLE 56

ANALYSIS OF VARIANCE: POUNDS PER ACRE OF OVEN DRY STARR MILLET FORAGE AS AFFECTED BY PLANTING DATE, 1956

| Source | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Replications | 3 | 0.32 | 0.11 |
| Dates of planting | 3 | 98.45 | 32.82** |
| Error | 9 | 1.48 | 0.16 |
| Total | 15 | 100.25 | |

**Significant at one percent level.

TABLE 57

ANALYSIS OF VARIANCE: POUNDS PER ACRE OF OVEN DRY STARR MILLET FORAGE AS AFFECTED BY PLANTING DATE, 1957

| Source | D.F. | Sum of Squares | Mean Square |
|---|---|---|---|
| Replications | 4 | 1.07 | 0.26 |
| Dates of planting | 4 | 61.62 | 15.40** |
| Error | 16 | 4.97 | 0.31 |
| Total | 24 | 67.66 | |

**Significant at one percent level.

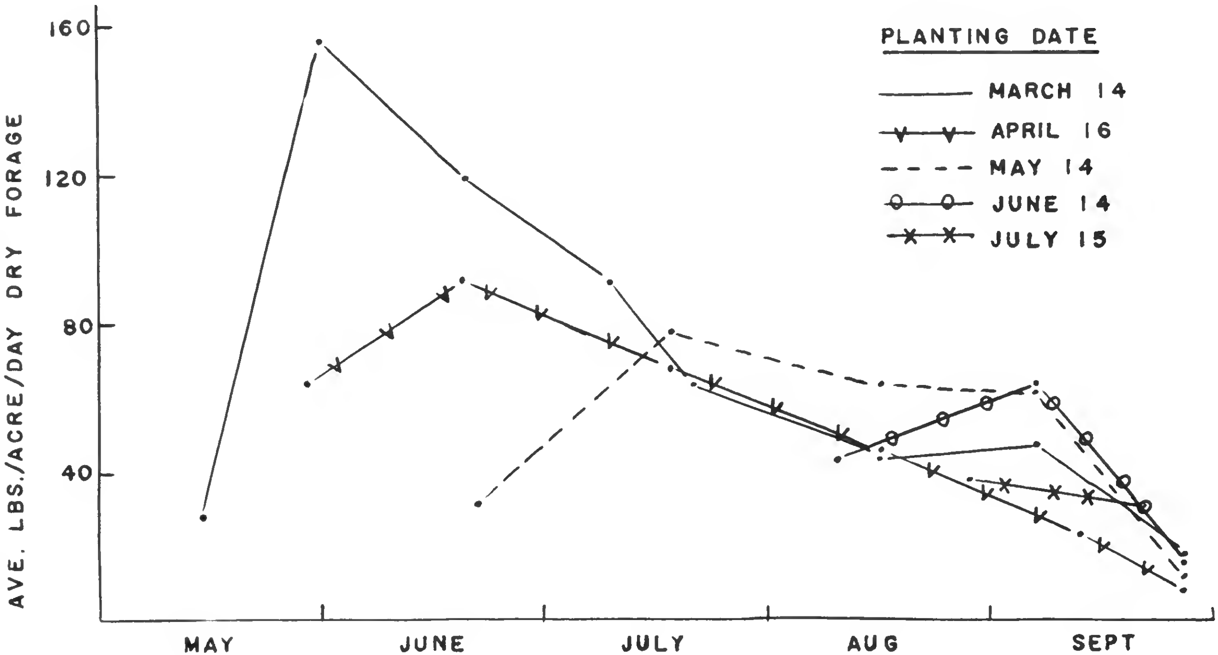


Fig. 32.--Effect of planting date on seasonal distribution of Starr millet forage, 1957.

later plantings. However, in 1956 the early plantings did not remain productive as long. This may be due to the low stubble cut used in 1956 as contrasted to the higher 10-inch stubble of 1957. Another reason for the extended life of early plantings in 1957 may be due to the more frequent smaller applications of nitrogen used throughout the season. Nitrogen fertilization was not applied after July on the May planting in 1956 and this may have been responsible for declining vegetative growth.

Crude protein content, as shown in Table 58, remained much the same throughout the growing season for all dates of planting. With the application of nitrogen at bimonthly intervals, it was possible to maintain the crude protein content of the forage at a high level from March until September.

TABLE 58

PERCENT CRUDE PROTEIN[a] OF STARR PEARLMILLET PLANTED AT FIVE DIFFERENT DATES, 1957

| Date Samples | Date Planted | | | | |
|---|---|---|---|---|---|
| | March 14 | April 16 | May 14 | June 14 | July 15 |
| May 28 | | 13.1 | | | |
| May 30 | | | 17.2 | | |
| June 19 | 18.8 | 18.8 | | | |
| June 21 | | | 15.3 | | |
| July 9 | 15.6 | | | | |
| July 17 | 16.9 | 13.1 | 10.6 | | |
| July 25 | 15.6 | | | | |
| August 9 | | | | 15.9 | |
| August 15 | 20.3 | 15.6 | 14.1 | | |
| August 27 | | | | | 16.2 |
| September 6 | 14.4 | | 18.8 | 15.6 | |
| September 12 | | 11.6 | | | |
| Mean | 16.9 | 14.4 | 15.2 | 15.8 | 16.2 |

[a]Each figure listed is an average of the analyses of two replications and expressed on the basis of oven dry forage.

# DISCUSSION

## Oats

Cutting treatments had less effect on forage yields of oats than on pearlmillet (Tables 4, 12, and 20). This is probably due to low temperature being a much more important factor in limiting the growth of oats during the winter months. The relationship of time when grazing or clipping occurs to the time of a hard freeze is likely to be much more important than the intensity of the defoliation alone.

Forage yields of all three oat varieties tested were sharply reduced by clipping or grazing when the plants reached a height of six inches (Tables 1, 2, 12, 13, and 20). The reduction in yield was nearly as severe with Arlington, a decumbent variety, as with Seminole, which has an erect growth habit. Apparently, when forage of Arlington, a decumbent variety, was lifted up to remove a proportion of the forage similar to Seminole, an erect growing type, the reduction in yield was severe with both varieties. Root development was seriously curtailed, regardless of the variety (Table 16).

Yields of dry matter in the irrigated plots were in most cases doubled by allowing plants to grow 12 inches tall before cutting. These results substantiate previous studies with oats by other workers (40, 80, 39, 45). Under unirrigated conditions the beneficial effects of allowing plants to attain a height of 12 inches before clipping were markedly decreased. This may possibly be due to higher transpirational losses of water by oat plants having more leaf tissue as is the case of plants cut when 12 inches tall.

Close clipping of six-inch plants the first time followed the remainder of the season by cutting when 12 inches tall did not change total yields appreciably from that of plants clipped all season at 12 inches. Likewise, permitting plants to grow 12 inches tall the first time and subsequently cutting when six inches tall, resulted in yields similar to cutting at six inches all season. An explanation for the failure of this initial clipping to have much effect on subsequent yields is suggested by the root data in the 1956-57 experiment (Table 16). Allowing plants to grow 12 inches tall before the first defoliation did not permit adequate development of roots to compensate for the intensive cutting at six inches the remainder of the season.

Clipping at twelve inches in height, in addition to increasing total yields of dry matter, also provided more forage during the midwinter period (Figure 11). This treatment also continued to be somewhat more productive late in the growing season than other cutting systems. Clipping when 12 inches tall was not frequent enough to reduce root growth but may have stimulated more tillering with consequent increased vegetative growth.

Allowing oat plants to grow 18 inches tall before cutting resulted in little or no yield increases except in the case of Seminole, a variety having an erect habit of growth. In addition, this cutting treatment resulted in the productive season beginning considerably later in the winter. Observations made of individual plants indicated that the growing point was decapitated sooner in 18-inch plants than with more intensive defoliation. It has been shown in other work (83) that the recovery power of these tall plants is quickly reduced, resulting in fewer clippings or grazings.

Stubble height after clipping had little or no direct effect on forage yield. There was an indication in the 1956-57 experiment that a five-inch stubble may encourage more root growth in the Seminole variety (Table 16). This would be reasonable to expect in view of its erect habit of growth, thus making the growing point more vulnerable to cutting.

Indirectly, close clipping or grazing just prior to heavy frost was responsible for serious stand losses by freezing. Maintenance of a higher stubble during critical cold periods may be a factor in protection against freezes. During succeeding freezes, temperatures in high stubble were observed to be several degrees higher than in low stubble (Table 18) but this was probably not a factor of major importance. The very small amount of freeze injury on the tops of high stubble plants suggested the possibility that there was an inherent difference in cold resistance between plants of the two stubble heights.

The winters of 1955-56 and 1956-57 were somewhat drier than normal, thus accentuating the response to irrigation. In both winters the major contribution of irrigation was in stimulating growth during December and January (Figure 12). Although the yield per acre of forage produced during this period was not large, this amount of green feed might be quite important in a dairy pasture program. The value of irrigation for forage production early in the winter was almost cancelled by clipping plants when they were only six inches tall. The necessity of maintaining proper plant height under irrigated grazing conditions is obvious.

Grain yields of oats resulting from early cessation of clipping were extremely low and the results of questionable value (Table 10). Under the conditions of this test, the value of forage produced during the pre-heading and heading period would undoubtedly far exceed the value of the grain. It is interesting to note, however, that under irrigated conditions clipping at a height of 12 inches to leave a five-inch stubble was beneficial to grain yields. Under low moisture conditions, clipping treatments had little effect on grain yields except in the case of plants cut at a height of six inches where the yield was reduced.

A five-inch stubble height was beneficial only to the erect growing Seminole variety when clipping ceased six weeks before the average heading date (Table 8). When clipping was continued until two weeks before heading, the value of higher stubble for 12-inch plants was apparent with all varieties, regardless of growth habit. This would suggest that where grain production is expected after a season of grazing, it would be well to maintain a higher stubble height later in the season to avoid destroying the growing point.

## Pearlmillet

Total dry matter production of pearlmillet was chiefly dependent upon the height of the plants when they were defoliated. Common pearlmillet, at all row spacings tested, was most productive when allowed to grow 54 inches tall (Tables 24 and 31). However, 30-inch plants of the Starr variety, grown in seven- or 19-inch rows and cut to leave a four- or ten-inch stubble, resulted in yields approaching those of 54-inch plants (Table 38). Both common and Starr millet cut at a height of 12 inches yielded about half that of 30-inch plants although the reduction was less severe in seven-inch rows (Tables 24, 31, 38, and 43). Likewise, yields were reduced by cutting plants when 18 inches tall but to a lesser degree than with 12-inch plants.

The forage yield reduction from frequent close clipping is most probably a result of reduced root growth. Root production of 12-inch plants was only about half that of 30-inch plants one month after planting as shown by data from the 1958 experiment (Table 52).

Stubble height had a minor effect on total dry matter production of pearlmillet. Yields of 54-inch plants were reduced with an 18-inch stubble (Table 24). Thirty-inch plants generally were indifferent in yield response to various stubble heights. However, the 1956 experiment indicated that the Starr variety in 19- or 38-inch rows may respond favorably to a higher stubble than common pearlmillet. High stubble was found to be more productive under very heavy nitrogen fertilization (Table 43). As pointed out in previous work (20), this may be due to a shorter period of root growth stoppage with high stubble than with close clipping, thus permitting greater utilization of the additional nitrogen.

Cutting to leave a 10- or 18-inch stubble on 30-inch plants extended the productive season of Starr millet in the 1956 and 1957 experiments. This may also be the reason the 1957 date of planting test, with a 10-inch stubble, remained productive longer than the 1956 test, cut to leave a four-inch stubble. It is interesting to note that in 1955, common pearlmillet remained productive longer with a short stubble, indicating that varieties do not respond the same.

Regrowth on 30-inch plants was much more rapid with a 10- or 18-inch stubble than with a four-inch stubble as evidenced by the 1957 results (Figures 38, 39, and 40). This was mainly due to extension of new leaf tissue on high stubble plants whereas closely clipped pearlmillet plants, having lost their growing points, were forced to develop new leaves from buds at the crown. Nevertheless, the latter did admirably well as indicated by the yields. Comparable results have been reported by other workers (80, 50). This immediately suggests that the productivity might be further enhanced by cutting each time just above the growing point, thus raising the height of the stubble at intervals throughout the season. This might result in less disruption of root development with consequent uniform forage growth.

The additional productivity potential of an improved variety such as Starr may be negated by improper defoliation. Both varieties gave similar low yields when clipped at a height of 12 inches. Data from the 1956 experiment (Table 34) suggest that the Starr variety may respond favorably to a higher stubble height, although this was not fully substantiated in the 1957 and 1958 tests except under high nitrogen fertilization (Table 43).

Pearlmillet row spacings of seven and 19 inches were definitely superior to 38 inches, thus supporting previous work in Georgia (19). This might well be expected due to the erect growth habit of this species. Differences between the seven- and 19-inch spacings were not significant (Tables 29 and 38) but the latter was more desirable as it permitted cultivation for weed control. Furthermore, the seven-inch row spacings generally did not remain productive as long as wider spacings. The erect, stemmy appearance and sparse number of leaves on plants in seven-inch rows suggested that competition for light may be greater, thus encouraging premature lengthening of the growing point. If extension of the growing point was greater with a seven-inch row spacing, then it would not be difficult to see how close clipping might shorten the length of the productive period.

Although soil tensiometers indicated a moisture deficiency during part of the growing period, no increase in yield was noted from irrigation during 1955 and 1956. The value of irrigation for pearlmillet probably resides in its ability to aid in seed germination during a temporary dry period, thus insuring early stands. It is probable that the large differences noted in yield between dates of planting (Tables 54 and 55) would not have been so pronounced except for the use of irrigation at planting. The date of planting was an important factor in determining pearlmillet yields (Tables 54 and 55). Total dry matter production was highest from March and April seedings with a steady decline in yield for each month of delay in planting. One hazard of March or April plantings in north Florida is the possibility of stand loss by sandstorms, a difficulty encountered in the 1956 experiment. All planting dates showed the same seasonal pattern of a large initial surge of growth followed by a gradual decline in productivity. However, early dates of planting generally remained productive as long as those planted in midsummer. This may not necessarily be true under a lower level of nitrogen fertilization than was used in these tests. The decline in production is associated with a decrease in the numbers of live shoots, irrespective of cutting treatment, as shown in the 1958 experiment (Table 50). The reduction in numbers of shoots was greatest under high nitrogen fertilization.

In examining the graphs showing distribution of forage growth over the growing season (Figures 22, 23, 24, 28, 29, 30, 31, and 32), it is quite apparent that they all show a similar pattern of development--a sharp peak in production early in the life of the plant followed by a steady decline in the remainder of the season. This general trend seemed to be little affected by the date of planting, variety, nitrogen level, or system of defoliation. Although it was quite possible to change the total forage production by various management practices, the general shape of the production curve remained the same. It is likely that a study of the phasic development of the pearlmillet plant would be needed to explain this phenomenon.

Crude protein percentage of the forage generally declined as the plants were permitted to grow taller before cutting (Tables 26, 35, 42, and 47). Twelve- and 18-inch plants contained far more protein than could be economically utilized by livestock, suggesting that this would be a very wasteful grazing system, aside from its low yield of dry matter.

Forage from the plants cut with an 18-inch stubble was somewhat higher in crude protein than where a lower stubble was used, due largely to the larger proportion of leaves harvested. However, in terms of nitrogen produced per acre, there was little difference between cutting treatments at the lowest level of nitrogen fertilization (Table 48). With additional increments of nitrogen fertilizer, the nitrogen returned in the forage increased more rapidly with 30-inch plants cut to leave a high stubble than for other treatments, due largely to the higher yield of dry matter.

In application of these results to pasture practices, it would appear highly desirable to allow pearlmillet to attain a height of 24 to 30 inches before grazing is begun. It is obviously impossible to graze these plants down to a four-inch stubble and this apparently is not necessary as a higher stubble results in as much or, under certain conditions, more forage. It would seem likely that a system where livestock are grazed frequently on taller pearlmillet in rotational fashion, as in strip grazing, would result in more high quality forage being produced.

## SUMMARY AND CONCLUSIONS

Field studies were conducted during the four year period 1955-58 at Gainesville, Florida to determine the behavior of pearlmillet (Pennisetum glaucum (L.)) under differential cutting treatments. Plants were cut when 54, 30, 18, or 12 inches tall leaving stubble heights of 18, 10, six, and four inches. The effects of row spacings, irrigation, planting date, and nitrogen levels were studied to a more limited extent.

Three varieties of oats (Avena sativa L.) also were subjected to various cutting treatments under both irrigated and unirrigated conditions during the winters of 1955-56 and 1956-57. Plants were cut when they reached heights of 18, 12 and six inches in combination with stubble heights of nine, five, and two inches.

Clipping treatments had less effect on forage yields of oats than pearlmillet. However, forage yields of three oat varieties having decumbent, intermediate, and erect growth habits were sharply reduced by clipping at a height of six inches. Dry matter yields under both irrigated and unirrigated conditions were generally doubled by allowing plants to grow 12 inches tall before cutting. Root development was also seriously curtailed by close, frequent defoliation. Clipping at 12 inches in height provided more forage during the midwinter period. Permitting the plants to grow 18 inches tall before clipping did not increase total dry matter yields for the Arlington and Floriland varieties but was beneficial to Seminole, an upright growing variety.

Stubble height after clipping did not directly affect forage yields of oats. A two-inch stubble resulted in yields similar to that obtained with cutting at five inches; however, heavy stand losses occurred where oats had been clipped or grazed to leave a one- or two-inch stubble just prior to a freeze.

Grain yields of oats resulting from early cessation of clipping were extremely low. Under irrigation, leaving a five-inch stubble after clipping 12-inch plants increased grain yields. Clipping plants at a height of six inches reduced grain yields under unirrigated conditions but not where additional water was applied.

Irrigation did not increase yields of pearlmillet but had a beneficial effect on oat forage production. Irrigation was most useful in stimulating production early in the winter. The value of irrigation early in the winter was erased by clipping oat plants when they were only six inches tall.

The dry matter production of pearlmillet, as affected by clipping, was generally in inverse proportion to the frequency of defoliation. Plants cut when 54 inches tall produced the most dry matter when a 38-inch row spacing was used. However, when a closer row spacing of seven or 19 inches was used, the dry matter yields of 30-inch plants of the Starr variety were nearly as large. Yields of both common and Starr millet cut at a height of 12 inches were about half that of 30-inch plants although the reduction was less severe in seven-inch rows. Yields were also reduced by cutting plants when 18 inches tall but to a lesser degree than with 12-inch plants. Root production of 12-inch plants was only about half that of 30-inch plants one month after planting.

The height of the plant when cut, reflecting stage of maturity, determined the protein content of the forage. Accordingly, the crude protein content of 12-inch plants was twice that of plants cut when 54 inches tall. Closer row spacings generally resulted in a slightly lower crude protein content.

Stubble height had little or no effect on total dry matter production of pearlmillet plants 30 inches or less in height at lower levels of nitrogen fertilization. However, the crude protein content of forage from 30-inch plants with a 10- or 18-inch stubble was somewhat higher than for plants with a four-inch stubble. Thirty-inch plants with a stubble height of 10 inches fertilized at a high rate of nitrogen produced considerably more forage and total nitrogen than did plants with a four-inch stubble.

Pearlmillet row spacings of seven and 19 inches were definitely superior to 38 inches. Seven-inch row spacings generally did not remain productive as long as wider spacings.

The date of planting was one of the most important factors in determining forage yields of pearlmillet. Total dry matter production was highest from March and April seedings with a steady decline in yield for each month of delay in planting. Each planting date showed a peak in production during the first one or two clippings, followed by a gradual decline. Early dates of planting generally remained productive as long as those planted in midsummer.

Numbers 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.

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## BIOGRAPHICAL SKETCH

Carl S. Hoveland was born October 25, 1927 on a dairy farm near Sand Creek, Wisconsin. His elementary education was obtained in a local one-room rural school and high school work in the nearby towns of Chetek and Colfax, Wisconsin.

Upon graduation from high school, he enrolled at the University of Wisconsin in June 1945 and completed three semesters before entering the U. S. Marine Corps in August 1946. In June 1948 he reentered the University of Wisconsin, majoring in soils. The Bachelor of Science degree with honors was granted in June 1950 and after further graduate work, the Master of Science degree with a major in soils was bestowed in February 1952.

From March 1952 until April 1955 he served as assistant agronomist at Texas Agricultural Experiment Station, Substation 19, Crystal City, Texas. The work over this three-year period was mainly concerned with research on irrigated pastures. An interim assistantship in agronomy at the University of Florida from June 1955 to February 1957 was followed by a research assistantship in agronomy and later a teaching assistantship in the botany department. During this period of time, work was undertaken toward a doctor of philosophy degree with a major in agronomy and a minor in animal nutrition.

He is a member of Alpha Zeta, Sigma Xi, and Gamma Sigma Delta honorary fraternities. Professional societies in which he holds membership are: American Society of Agronomy, American Society of Range Management, American Geographical Society, and American Society of Plant Physiologists.

He is married to the former Dorothy Anderson of Dodgeville, Wisconsin.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

January 31, 1959

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