REGROWTH OF PEARL MILLET

by

ROBERT JOHN STEPHENSON

B.S., Western Illinois University, 1978

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1981

Approved:

Gerry L Posler

Major Professor

ILLEGIBLE

THE FOLLOWING DOCUMENT (S) IS ILLEGIBLE DUE TO THE PRINTING ON THE ORIGINAL BEING CUT OFF

ILLEGIBLE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I wish to express my deepest gratitude to Dr. Gerry Posler, my major professor, for his assistance with the planning and execution of my thesis. His patience, advice, and guidance helped my successful completion of the M. S. degree.

My appreciation also goes to the other committee members, Dr. Frank Barnett and Dr. Richard Vanderlip, for their support and guidance.

I would also like to thank Mr. Nick Hill, Adib Jamshedi, Abdul Durar, and many other students for all their help and encouragement. Also my sincere thanks to Dr. Richard Sundheim (statistical consultant) and Rose Mary Reese (typist) for their help.

A very special thanks goes to my parents for all their support, encouragement, and love while I was completing my degree.

CHAPTER I

INTRODUCTION

Summer annuals have become more important as forage crops in the United States during the past several years. Pearl millet (Pennisetum americanum (L.) Leeke) contains little prussic acid and when managed properly has high quality (4, 5, 6, 17).

Recommendations concerning optimum cutting height and frequency vary, but it is generally agreed that leaving a higher stubble height is better for regrowth in sudangrass and millets than for perennial grasses (1, 5, 8, 22, 28). The primary point(s) of regrowth varies depending on the stubble height. Proportionately more regrowth occurs from terminal buds as the height of defoliation is raised, while axillary and basal tillering are more important as the stubble height is lowered (17). This regrowth pattern varies among species because of the diversity in tillering habits of forages. For example, Clapp and Chamblee (8) noted that the proportion of 'Gahi-1' pearl millet regrowth from terminal buds increased as the stubble height was raised from 8 to 25 cm, while basal and axillary tillering remained relatively constant. 'Trudan II' sudangrass hybrid (Sorghum sudanense (Piper Staph.) showed an increase in axillary tillering as stubble height was raised. Mays et al (21) reported that two sudangrass-sorghum hybrids, Asgrow 'Grazer' (Sorghum bicolor var. sudanense) and Dekalb 'Sudax SX-11', Gahi-1 pearl millet, and 'Greenleaf' sudangrass (Sorghum bicolor L. Moench) when cut to 10 and 20 cm produced new growth primarily from basal tillers. Beaty et al (1) suggested that 'Tift' sudangrass (Sorghum sudanense (Piper Staph.), Gahi-1 pearl millet, and Sudax SX-11 sudangrass-sorghum be cut no lower than 10 to 15 cm. They reported that cutting to stubble heights of 2.5 to 7.5 cm resulted in death of some plants. Most regrowth of sudangrass and sudan-sorghum occurred from axillary and basal tillers, while a majority of the pearl millet regrowth occurred from terminal buds.

During a two year study at Kansas State University (27), some pearl millet plants died when cut to the 15 cm height, particularly at the boot stage of growth. This prompted further evaluation of factors influencing regrowth of pearl millet under Kansas conditions. Objectives of this study were: (a) to ascertain the effects of stubble height, stage of harvest, and plant population on forage yield of pearl millet, (b) to evaluate the point(s) of regrowth after defoliation, and (c) to determine the influence of carbohydrate content on plant regrowth.

CHAPTER II

LITERATURE REVIEW

Optimum Stubble Height in Forages

An important management decision for pearl millet is the optimum stubble (cutting) height, because the amount of foliage removed greatly influences regrowth and yield. The optimum stubble height has been studied in several forages (1, 3, 4, 5, 12, 19).

As the stubble height is lowered, more terminal meristems are removed resulting in more axillary and basal tillering. The increased tillering results from reduced auxins in the shoot apex of sudangrass (18). Cooper (13) noted a yield reduction in rush-sedgegrass when the cutting height was raised from 5 to 10 to 15 cm. Beaty et al (1) showed that forage production of pearl millet increased as stubble height was lowered, but that stubble height had less effect on yield than did frequency of cutting. However, yield was reduced when 7/8 of the foilage was removed. Burger and Hittle (5) concluded there was no advantage for cutting summer annual grasses at 15 cm compared with 7.5 cm in a 3 or 4 cut system. The average crude protein content was higher in the forage cut at a 15 cm stubble height because a larger proportion of stem versus leaf tissue was harvested at the 7.5 cm stubble height.

Heath et al (17) stated that optimum stubble height varies depending upon the species and its intended use. They noted that pearl millet is more sensitive to cutting at low stubble heights then are some sorghums.

Optimum Stage of Development for Pasture, Hay, or Green Chop

The best stage of development to harvest forages for pasture, hay, or green chop has been studied by several workers (4, 19, 36). Cutting summer annuals, especially sudangrass and sudangrass-sorghum hybrids at a very early stage of development increases the risk of hydrocyanic acid (HCN), or prussic acid poisoning. Since pearl millet contains very little, if any, HCN, the stage of development for grazing is not as critical. The vegetative or grazing stage is generally defined as 60-90 cm in height. Pearl millet will usually reach the boot stage at approximately 80-120 cm, suitable for hay, silage, or green chop (17).

Burger et al (6) reported large yield reductions in sudangrass when cut under the pasture system of management (vegetative stage - 50 cm) as opposed to the hay management system (boot - early bloom stage). Broyles and Fribourg (4) reported in sudangrasses and millets that the early bloom stage produced dry matter yields which were significantly superior to those obtained from the vegetative stage. Although the later stages of maturity may be considered for hay or green chop, they are not suitable for pasture (grazing).

Ellett and Carrier (13) reported that summer annuals grasses cut when they approach maturity have little aftermath as compared to grasses kept grazed. It was observed at Kansas State University that pearl millet defoliated at the boot stage sometimes produced little regrowth or died (27).

Optimum Plant Population for Forage

Forage yield of summer annuals, including pearl millet is influenced by cultural practices including optimum plant populations (3, 17). Plant cultivars, soil type, and environmental conditions greatly influence optimum plant populations. Hart and Burton (16) reported no significant differences in forage yields between 17 cm and 88 cm row spacings of pearl millet. The wider rows were inefficient in utilizing light and soil moisture early in the season. Later in the growing season as the plant canopy and root system developed the wider rows became more efficient. Nelson (25) showed grain yields in 'Proso' millet (Panicum miliaceum L.) increased as row widths decreased from 71 to 18 cm. Heath et al (17) stated that row spacing in summer annuals had little effect on total forage production. Where mechanical harvesting is used, Dovrat and Ophir (11) suggested reseeding pearl millet after each harvest to maintain the plant populations.

Effects of Cutting Frequency on Forage Yield and Quality

The frequency of clipping affects grass yield and the points of regrowth. Since regrowth is directly related to the amount of leaf area remaining after defoliation and the development of meristems, the frequency of harvest dramatically affects yield. As the cutting interval is shortened, the amount of regrowth between each successive cut decreases, reducing the total seasonal yield. A study on sudangrass-sorghum hybrids by Beuerlein et al (3) showed that increasing the number of harvests reduced dry matter production. The frequent removal of foliage causes stand reductions and general loss of vigor in summer annuals (4, 29). Burger et al (6) reported a large decrease in sudangrass yields from 2.33 to 1.54 metric tons/ha. when cut under the hay and pasture systems of management. Joulie (20) showed a reduction of 4.9 metric tons of dry hay/ha. when pearl millet was cut six times per year instead of twice. Beaty et al (1) reported that by extending the harvesting interval of summer annuals from 2 to 5 weeks, yields increased by 46%. They also reported an increase in dead plants with close and frequent cuttings. However, Mays et al (21) reported that the frequency of harvest did not influence yield when plant height was allowed to reach 86 to 96.5 cm.

An advantage of frequent removal of new growth is improved forage quality. As the time between harvests is lengthened, the proportion of fiber and other cell wall components increases (13, 17). Rusoff et al (30) showed that lignin content in 'Starr' millet (Pennisetum glaucum L.) increased from 3.23 to 6.75% from the first to the fifth cut and crude protein dropped from 13.1 to 5.9%. Nuwanyakpa (27) showed that in pearl millet, acid-detergent fiber increased from 24.23 to 26.19% from the first to fourth cut vegetative stage. Crude protein decreased from 21.54 to 18.60% for the same harvests.

Foliage Remaining After Harvest

Clapp et al (8) showed that summer annuals clipped at 15 to 20 cm had enough remaining foliage for new growth but when clipped at 5 to 10 cm, the regrowth occured primarily from stored food reserves.

The amount of foliage removed influences the recovery time of summer annual forages, but seems to be less important with pearl millet. Beaty et al (1) reported that removing 3/4 of the foliage in summer annuals increased forage production by 17.55% over removing the top 1/3 of the plant.

Dovrat and Ophir (11) reported that in pearl millet the amount of foliage removed influences plant regrowth. When plants were cut to 15 cm, 96% of the original shoots were regrowing from plants cut 30 days after emergence. However, with plants cut to 5 cm, the regrowth rate was only 76%. Part of these results may also be due to the position of buds at the time of harvest. Begg (2) noted that 'Bulrush' millet (*Pennisetum typhoides* S. & H) is very susceptible to defoliation once internode elongation has commenced. Millet shoots regrew following defoliations made during the first four weeks after emergence, when the meristems were below the cutting height. Later defoliations resulted in loss of plant vigor and stands due to removal of meristems.

Total Nonstructural Carbohydrate Levels and Their Effect on Plant Regrowth

Heath et al (17) defined nonstructural carbohydrates as photosynthetic products in plants existing as a solute or stored insoluable material, not as strucutral components of the plant. Fructose, glucose, sucrose, and starch are primary examples. Smith (32) described total nonstructural carbohydrates (TNC) as an estimate of the carbohydrate energy readily available to the plant. During normal growth, grasses accumulate carbohydrates in various plant parts such as rhizomes, stolons, or basal regions of the stems. Total nonstructural carbohydrate content in pearl millet is important because it has been shown that carbohydrates are in part used for regrowth following defoliation (23).

Reduction of photosynthetic area due to defoliation or shading reduces carbohydrate levels throughout the plant (23, 24, 35). Mays and Washko (23) reported substantial dependence on carbohydrate reserves for regrowth when pearl millet was cut to a stubble height of 5 cm. As stubble height was raised to 15 cm, dependence on carbohydrate reserves decreased and the plant's ability to synthesize its own food for new growth was enhanced. Sullivan and Sprague (34) reported similar findings in ryegrass and orchardgrass.

Effects of Wheel Traffic on Plant Regrowth

Observations have shown that wheel traffic of field equipment often bends and damages stubbles remaining after green chop harvests (17). Dovrat and Ophir (11) reported severe injury to stands of pearl millet at the 5, 10, and 15 cm stubble heights when simulated wheel pressure was inflicted. Gill et al (15) did extensive work on the effects of wheel traffic on soil compaction in summer annuals. When the soil is wet, soil compaction, reduced porosity, and wheel slippage occurs. Fribourg et al (14) showed a 15 to 20% reduction in dry matter yield, often as high as 30%, and occasionally reaching 50% when a 1,745 kg tractor and 1,360 kg wagon was run over Sudax-11 sorghum and Gahi-1 pearl millet stubble. There was more damage to Gahi-1 pearl millet than Sudax-SX-11 sorghum during dry conditions indicating that pearl millet was more brittle and susceptable to wheel traffic damage. Sheesley et al (31) showed that in alfalfa (*Medicago sativa* L.) hay fields, root growth was limited by soil compaction and mechanical damage from harvesting, resulting in reduced plant vigor and stands.

CHAPTER III

MATERIALS AND METHODS

Field Procedures

Regrowth of pearl millet was evaluated in a two year study conducted at the Kansas State University Agronomy Research Center near Manhattan, Kansas. The study was conducted in 1979 and 1980 under dry-land conditions. The 1979 experiment was seeded 7 June on Ivan fine-silty loam, mixed mesic family of the Cumulic Hapludalls soil. Rainfall and temperature data shown in Table 1 were obtained from the Weather Data Library at Kansas State University.

Twelve treatments were included in a randomized complete block design with four replications. Treatments included all combinations of 3 populations harvested at two stubble heights, and two stages of development (Table 2). Plant populations consisted of three densities with the following spacings: (1) 185 th. plants/ha, in rows 36 cm wide and 15 cm between plants within the rows, (2) 368 th. plants/ha. in rows 18 cm wide x 15 cm within the rows, and (3) 736 th. plants/ha. in rows 18 cm wide by 7.5 cm. Stages of development at harvest were vegetative and boot and residual stubble heights were 15 and 25 cm.

Prior to planting, nitrogen and phosphorus were applied and disced into the soil at a rate of 36 and 18 kg per hectare, respectively. Treated, certified seed of Northrup King 'Millex 23' hybrid pearl millet was planted with a Planet Junior seeder in plots 2 meters x 6 meters. On June 26 and 27 the plots were thinned to the specified populations using ropes with appropriate markings alongside each row. Neutron tubes were placed in each of the four corners of the study to monitor soil

Table 1. Mean Temperatures (^{o}C) and Total Precipitation (cm), Manhattan, Kansas, 1979 and 1980.

	1979			
	Temperature		Precipitation	
Month	Mean	Departure from Normal	Total	Departure from Normal
April	11.78	-1.3	4.72	-2.90
May	17.56	-0.9	6.96	-4.09
June	23.11	-0.3	7.85	-6.99
July	25.50	-0.7	14.10	2.97
August	25.50	-0.3	7.42	-1.73
September	21.50	0.9	3.20	-6.86
October	15.55	0.7	15.11	8.20

	1980			
	Temperature		Precipitation	
Month	Mean	Departure from Normal	Total	Departure
April	12.22	-0.8	3.51	-4.11
May	18.17	-0.3	4.57	-6.48
June	25.78	2.3	7.14	-7.70
July	31.00	4.8	3.05	-8.80
August	28.83	3.1	7.46	-1.68
September	22.50	1.9	6.40	-3.66
October	13.33	-1.5	8.71	1.80

Table 2. Treatments Imposed on 'Millex-23' Hybrid Pearl Millet, 1979-1980.

Plant Spacings	Population (Plants/ha.)	Growth Stage At Harvest	Stubble Heights
18 x 7.5 cm	736 Th.	Veg. and Boot	15[ab], 25[ab], 30[b] cm
18 x 15 cm	368 Th.	Veg. and Boot	15[ab], 25[ab], 30[b] cm
36 x 15 cm	185 Th.	Veg. and Boot	15[a], 25[a] cm
54 x 10 cm	185 Th.	Veg. and Boot	15[b], 25[b], 30[b] cm

a - 1979

b - 1980

moisture during the growing season (Table 3).

Prior to each harvest, plant heights were taken on ten random plants per plot. Plant heights were taken from ground level to the top of the plant canopy at the vegetative stage and to the flag leaf at the boot stage. The mean of these ten plants for each plot was recorded as plant height. Plots were harvested at the vegetative stage when they reached approximately one meter in height and when the heads were just emerging for the boot stage. A self-propelled Carter flail harvester was used to harvest all plots on the dates shown in Table 4. Plot weights were taken from the center 92 cm of each plot and remaining guard rows were cut and discarded. Plot weights were recorded and sub-samples (grab-samples) were taken for moisture determination. The samples were dried in a forced air dryer at approximately 65^{o} C for five days.

Stubbles in the guard rows of each plot were sampled on the day of harvest and seven days post harvest for total nonstructural carbohydrate (TNC) determinations. Since the stubble heights varied, the lower 15 cm were taken to ensure uniformity. The samples were dried and ground to pass through a 40-mesh screen, bottled, and stored in the dark.

Tiller counts were taken 7-10 days post harvest from one center row in each plot, categorized visually into basal, axillary, terminal, or dead, and expressed as percentages. Basal tillers were defined as new shoots arising at the base of the existing tillers and main shoots, while axillary tillers were new shoots coming from nodes between ground level and the uppermost node. Terminal regrowth was that which occured from the point of defoliation, while tillers that exhibited no regrowth after cutting were counted as dead (Figures 1-4). Chinch bugs (Blissus leucopterus Say) were a problem and plots were sprayed with Furadan at a rate

Table 3. Soil Moisture: Total Water (cm/meter of soil)

*1979			**1980		
Date	Total H_2O ($\overline{X}$)	$S_{\overline{X}}$	Date	Total H_2O ($\overline{X}$)	$S_{\overline{X}}$
July 14	32.83	3.25	July 16	27.80	1.64
August 3	34.79	4.36	July 28	25.50	1.37
August 25	35.11	4.23	August 11	23.55	2.90
September 1	34.93	4.18	August 29	23.45	3.64

*Means ($\overline{X}$) of 4 values

**Means ($\overline{X}$) of 3 values

Table 4. Harvesting Dates for Stages of Development and Stubble Heights, 1979-1980.

Stubble Heights	1979			
	Veg-1	Veg-2	Veg-3	Boot-1
15 cm	July 12	Aug 2	Aug 12	Aug 2
25 cm	July 12	July 26	Aug 12	Aug 2

Stubble Heights	1980				
	Veg-1	Veg-2	Veg-3	Boot-1	Boot-2
15 cm	July 23	Aug 12	Sept 5	Aug 12	Sept 19
25 cm	July 23	Aug 8	Aug 27	Aug 12	Sept 9
30.5 cm	July 23	Aug 8	Aug 27	Aug 12	Sept 9

Fig. 1 Basal Tillers (upper)

Fig. 2 Axillary Tillers (lower)

Fig. 3 Terminal Tillers (upper)

Fig. 4 Dead Tillers (lower)

of 1.2 kg A. I./ha. on 29 June and 9 July 1979. Weeds were controlled by cultivation.

Procedures for the 1980 experiment were the same as in 1979 except for the following changes. The plots were seeded on 9 June 1980 on Wymore fine, silty clay loam, montmorillonitic, mesic family of the Aquic Argindolls and thinned to the correct populations on 27-30 June. Plant populations were the same, but a spacing change from 36 x 15 cm to 54 x 10 cm was made (Table 2). A stubble height of 30 cm was added to the study and the two growth stages at harvest remained the same. Chinch bugs were again a problem and plots were sprayed with Sevinmol at a rate of 4.7 liters A. I. per hectare on 1 July.

Axillary tillers were redefined as new tillers emerging from nodes above ground level to the point of defoliation. The change was made because it was noted that tillering on the main shoot below the point of defoliation was the result of axillary buds.

Laboratory Procedures

Total Nonstructural Carbohydrates

The genus Pennisetum reportedly contains sucrose in the lower portions of the plant (10). Many different methods are available for determining total nonstructural carbohydrate content (TNC), including acid solutions (7, 33,) and enzymes (26, 32, 33), such as takadiastase. The latter was used with a few modifications.

Duplicate analysis were run on each sample with the average recorded as percent TNC. Two blanks were included in each run. Samples of 500 mg. were placed in 125 ml Erlenmeyer flasks and 15 ml of distilled water was added. They were boiled for 1-2 minutes, cooled to room temperature, and

10 ml of buffer and takadiastase enzyme solutions added. The flasks were then covered with parafilm and incubated for 24 hours at 38^{o}C. The enzyme mycolase was used because replicated trials showed it to be twice as active as 'Clarase 900'.

The solutions were then filtered through Whatman #1 filter paper into 250 ml volumetric flasks. The Erlenmeyer flasks and filter paper were washed with distilled water four times. Two ml of 10% lead acetate solution was added and the volumetric flasks were brought to volume with distilled water. The solutions were well mixed and approximately 30 ml were poured into 50 ml centrifuge tubes and centrifuged for 7 minutes at 1,700 rpm. The liquid was decanted into 50 ml Erlenmeyer flasks containing 100 mg powdered potassium oxalate and placed in a refrigerator overnight.

The following day the samples were filtered through Whatman #43 filter paper into 50 ml Erlenmeyer flasks. A 10 ml aliquot was taken from each flask and placed in a 25 x 200 mm ignition tube. Ten ml of Reagent 50 was added to the ignition tubes and they were heated in a boiling water bath for 15 minutes. After the tubes had cooled to room temperature, a 2 ml solution of potassium iodate-potassium oxalate was added, followed by 10 ml of 1.0 N H_2SO_4. The tubes were agitated and 4 drops of starch solution was added as an indicator. The last step was to titrate to a milky-green endpoint with 0.02 N sodium thiosulfate. Seven glucose standards were used for each run: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 ml of glucose solution per 10 ml.

The actual percentage of TNC were calculated using the procedure as described by Smith (32). Samples were rerun if the duplicate samples varied more than 0.5% from each other.

CHAPTER IV

RESULTS AND DISCUSSION

Agronomic Characteristics

Plant Height

Few differences in plant height were noted among treatments in 1979 but more variation existed in mean plant heights during 1980 (Appendix Tables 1 and 2).

The plants at the lowest population (also the wide row spacing) had a significantly shorter mean plant height than either of the denser populations. With adequate soil moisture in 1979, these results were not unusual. With narrow rows and heavier plant populations, light penetration into the canopy is reduced and less auxin is broken down, resulting in taller plants. The other mean difference that existed in 1979 occurred between stubble heights at the third vegetative harvest. The plants were harvested at different times throughout the season which could explain the significant difference. Plant heights at the second and third harvests were much greater than the first and greater than those in 1980 because the plants were allowed to reach a greater plant height before harvest. With adequate moisture, the plants reached a greater plant height before reaching the boot stage than those in 1980.

Data for the significant stubble height ^{x} population interaction are shown in Table 5. At the 15 cm stubble height, mean plant heights decreased at the intermediate plant population but increased at the heaviest population. Mean plant heights at the 25 cm stubble height increased at the intermediate population but decreased at the highest plant popula-

Table 5. Mean Plant Heights (cm) - 1979.

Stubble Height (cm)	Population (th. plants/ha.) 185	368	736
15	66	60	69
25	53	65	60
Mean	60	62	64

LSD .05 level for comparing stubble height x population interaction = 4.0

tion. These differences are what caused the significant stubble height x population interaction.

Dry Matter Content

Differences in dry matter were found between stubble heights at the first and third cuts of the vegetative stage, but dry matter percentages of the two stubble heights were reversed between the two cuts. This reversal plus similar values for the second cut resulted in nonsignificant mean differences between the 15 and 25 cm stubble heights.

In 1980 few differences were noted in mean dry matter percentages at the vegetative stage. Significant differences occurred among stubble heights at the first cut and among populations at the third cut.

At the boot stage of development, variation existed among populations and stubble heights for both 1979 and 1980. In 1979 the most densely populated plots had a significantly higher dry matter content and forage cut at the taller stubble height had higher dry matter content. In 1980 two cuts were made at the boot stage, but the mean dry matter percentages among populations were reversed from those in 1979. As in 1979, forage dry matter content increased with greater stubble heights.

A stage x stubble height interaction occurred in 1979 as shown in Table 6. The interaction was primarily caused by the significantly lower dry matter content of the 15 cm stubble height at the boot stage.

Forage Yield

Several workers (5, 8, 29) have shown that the frequency of harvest greatly influences forage yield. Variability exists among varieties and yield is influenced by management practices and environment. It is gen-

Table 6. Mean Dry Matter Content (%), 1979.

	Stubble Height (cm.)	
Stage	15	25
Vegetative	13.1	13.0
Boot	10.8	12.6
Mean	12.0	12.8

LSD .05 level for comparing stage x stubble height interaction = 2.0

erally agreed (5, 8, 29) that more frequent removal of foliage results in less forage yield. Such was the case in this study. As the time between harvests increased, higher yields were recorded. In both 1979 and 1980, the total forage yield at the boot stage (one and two harvests, respectively) was more than that from the three cuts taken at the vegetative stage (Appendix Table 5). In 1979 the plants harvested once yielded 7.4 metric tons/ha, while those cut three times yielded 5.3 metric tons/ha.

Plant populations may influence total yield. While variability existed among harvests at the vegetative stage in 1979, differences in total yield were nonsignificant. At the boot stage, forage yield increased as population density increased; from 6.5 to 7.4 to 8.2 metric tons/ha. at 185, 368, and 736 thousand plants ha, respectively. Adequate moisture occurred in 1979, and Burton (15) reported that under normal rainfall, narrow rows and high populations yield more than wider, less populated rows. When rainfall is limiting, the wider less populated rows are better because of reduced competition for moisture.

There were no differences in forage yield between stubble heights during 1979 except at the first vegetative harvest. Yields were greater than those in 1980 for all treatments except the highest population cut at the boot stage. The yields for the second harvest in 1979 were much greater than the other two cuts because the plants reached a greater height before harvest.

The analysis of variance for forage yield is given in Appendix Table 4, and a significant stage x population interaction occurred with the mean values presented in Table 7. At the boot stage of maturity total forage yield increased in a linear manner as population density increased. At the vegetative stage, forage yield increased with population density,

Table 7. Mean Forage Yields (metric tons/ha.), 1979-1980.

	Population (th. plants/ha.)					
	1979			1980		
Stage	185	368	736	185	368	736
Vegetative	5.0	5.8	5.3	4.8	4.0	4.1
Boot	6.5	7.4	8.2	6.8	4.7	5.4
Mean	5.7	6.6	6.7	5.8	4.4	4.7

LSD .05 level for comparing 1979 stage x population interaction = 0.3

LSD .05 level for comparing 1980 stage x population interaction = 0.7

	Stubble Height (cm.)		
	1980		
Stage	15	25	30
Vegetative	5.4	3.6	3.8
Boot	6.5	5.3	5.3
Mean	6.0	4.4	4.5

LSD .05 level for comparing 1980 stage x stubble height interaction = 0.7

but decreased slightly at the highest population which caused the significant interaction.

In 1980 differences in total forage yield were noted among populations at both the vegetative and boot stages. The highest yields were obtained at the lowest population (also the wider row spacing). A probable explanation was that precipitation in 1980 was much below normal and soil moisture competition was greater in the narrower more populated rows.

In 1980 the lowest stubble height had a significantly higher yield at the vegetative stage. These results were similar to those reported by Beaty et al (1) for summer annuals.

A substantial drop in yield occurred at the second harvest of the boot stage in 1980, from 5.1 to 1.5 metric tons/ha. (Appendix Table 5), because plants reached the boot stage at a much shorter plant height after the first harvest. Part of the difference in yields was caused by the warm, dry growing season which hastened maturity, and the position of the buds at the time of first harvest. At the more mature harvest stage, a large number of apical and lateral buds were above the point of defoliation and regrowth was more dependent upon basal buds.

Two significant interactions for forage yield occurred in 1980 and the mean values are presented in Table 7. A stage x population interaction resulted primarily from the magnitude of differences for the populations at the two stages because the yield trends were similar.

The stage x stubble height interaction also was caused primarily by differences in magnitude of response in total yields. At the vegetative stage, forage yield decreased sharply between 15 and 25 cm stubble heights, but was slightly higher at the 30 cm stubble height. At the boot stage, the decline between 15 and 25 cm stubble heights was less marked, and the two taller heights were almost equal. Differences in yield among stubble heights were not as great at the boot stage as for the vegetative stage.

Percent Basal Tillers

All tiller counts were expressed on a percentage basis. In 1979 the percent basal tillers was significantly higher at the vegetative stage for the two higher populations (Appendix Table 7), but in 1980 differences among populations were nonsignificant.

In 1979 percentage of basal tillers at the vegetative stage increased slightly as the stubble height was raised, but the differences were nonsignificant. In 1980 a larger percentage of basal tillers occurred at the 15 cm stubble height at the second and third harvests, causing a significant difference. These results correspond with Clapp et al (8), who reported a greater percentage of basal tillers in sorghum-sudangrass hybrids as the stubble height was lowered from 30 to 15 cm.

At the boot stage, significant differences in percent basal tillers occurred only among stubble heights in 1979 and 1980. As the stubble height was lowered to 15 cm, a reduction in basal tillers occurred. This reduction was much greater in 1979.

A stage x stubble height interaction existed in 1979 (Appendix Table 6) with means shown in Table 8. It is clear from these data that the stage of harvest greatly influenced the tillering habit of the plants, but differences were larger at the shorter stubble heights. Contrary to 1979, the percent basal tillers at the boot stage (3.9%) was significantly greater than for the vegetative stage (1.8%, LSD .05=2.0).

Clapp et al (8) reported an increase in the number of basal tillers after the first harvest which surpassed the number of axillary tillers.

Table 8. Mean Percent Basal Tillers, 1979.

	Stubble Height (cm.)	
Stage	15	25
Vegetative	5.1	5.5
Boot	0.3	2.3
Mean	2.7	3.9

LSD .05 level for comparing stage x stubble height interaction = 2.1

In this study, the number of axillary tillers were much greater than the number of basal tillers. This difference may have been caused by differences in cultivars, environments, and the manner in which the tiller counts were taken.

Percent Axillary Tillers

The percentage of axillary tillers (Appendix Table 8) was not greatly influenced by population density in 1979 or 1980. At the vegetative stage in 1980, the intermediate population had fewer axillary tillers at the second harvest than the other two populations. This caused a difference in population means.

Differences in percent axillary tillers were also noted among stubble heights at the second harvest in 1980. The greatest percent axillary tillers occurred at the 15 cm height and the fewest at the 25 cm height, with the 30 cm height intermediate.

At the boot stage, the intermediate population was significantly lower in percent axillary tillers in 1979, but in 1980 differences among populations were nonsignificant. Similarly, the shorter stubble height had significantly fewer axillary tillers in 1979, but no differences were found in 1980. This contradicts Clapp et al (8) who noted that in general, as the height of defoliation is lowered, the percentage of basal and axillary tillers increases.

At the boot stage in 1980, many axillary tillers (38.8%) were produced after the first harvest, but few (5.1%) after the second harvest. Little regrowth occurred after the second harvest and the drop in percent axillary tillers corresponds to the marked increase in dead tillers (Appendix Table 11).

A stage x stubble height interaction existed in both years (Appendix Table 6) and the data are presented in Table 9. The interaction in 1979 was largely caused by a much greater difference in axillary tillers between stages at the shorter stubble heights.

In 1980 the interaction was caused by the magnitude of the difference between stages at the three stubble heights. The percent axillary tillers was always greater at the vegetative stage, but the advantage was much greater at the lowest stubble height.

The greater percentage of axillary tillers in 1980 compared to 1979 was due primarily to the manner in which they were defined.

Percent Terminal Tillers

In the case of pearl millet, most of the regrowth occurs from terminal buds, especially at the vegetative stage. With a longer time between harvests and greater plant maturity, more terminal meristems are removed. This forces the plant to rely on axillary and basal tillers. It has been reported that if summer annual grasses are defoliated to stubble heights less than 15 cm, the percentage of terminal growth decreases, and basal and axillary tillers develop (8). Heath et al (17) agrees that in pearl millet, most regrowth occurs from terminal meristems. Cutting at higher stubble heights generally leads to more vigorous growth and leafiness.

The analyses of variance for percent terminal tillers in 1979 and 1980 are shown in Appendix Table 9. The amount of stubble remaining after harvest affected the percentage of terminal regrowth. A much smaller percentage of terminal tillers occurred at the 15 cm stubble height for both stages of maturity (Appendix Table 10). However, the differences

Table 9. Mean Percent Axillary Tillers, 1979-1980.

	Stubble Height (cm)				
	1979		1980		
Stage	15	25	15	25	30
Vegetative	2.7	3.5	27.2	20.2	23.9
Boot	0.4	2.6	23.4	19.7	22.7
Mean	1.6	3.0	25.3	19.9	23.3

LSD .05 level for comparing stage x stubble height interaction - 1979 = 1.8

LSD .05 level for comparing stage x stubble height interaction - 1980 = 7.0

were significant only at the vegetative stage. Lowering the stubble height from 25 to 15 cm reduced the percentage of terminal tillers by nearly one-half. Although a population x stubble height interaction occurred in 1979, (Table 10) the percent terminal tillers were always greater at the taller stubble height. The greatest difference between stubble heights was at the middle population.

In 1980 variation existed among populations and stubble heights (Appendix Table 10). Stage of maturity affected the percentage of terminal regrowth more in 1980 than in 1979. The mean values for each treatment were lower at the boot stage than the vegetative stage. Since most of the regrowth occurs from terminal buds, a smaller percentage of terminal tillers would be expected at the boot stage because of stem elongation and more apical meristems being exposed.

Stage x population and stage x stubble height interactions occurred in 1980 with appropriate data presented in Table 10.

The stage x population interaction was caused primarily by the relative differences in percent terminal tillers between stages for the three populations. Also at the intermediate population, the percentage of terminal tillers at the vegetative stage increased, while at the boot stage the percentage decreased. Despite the significant stage x population, interacting percent terminal tillers was always much greater at the vegetative stage of harvest.

The stage x stubble height interaction resulted mainly from the smaller difference between stages at the 30 cm stubble height compared to 15 and 25 cm heights. Percent terminal tillers was again consistently higher at the vegetative stage than the boot stage.

Table 10. Mean Percent Terminal Tillers, 1979-1980.

	1979 - Population (th. plants/ha.)		
Stubble Height (cm)	185	368	736
15	38.0	31.6	47.9
25	56.6	62.4	57.7
Mean	47.3	47.0	52.8

LSD .05 level for comparing stubble height x population interaction = 8.0

	1980 - Population (th. plants/ha.)		
Stage	185	368	736
Vegetative	62.4	66.4	65.9
Boot	42.6	40.4	31.4
Mean	52.5	53.4	48.6

LSD .05 level for comparing stage x population interaction = 8.0

	1980 - Stubble Height (cm)		
Stage	15	25	30
Vegetative	60.2	68.5	66.2
Boot	31.6	38.8	44.0
Mean	49.5	53.6	55.1

LSD .05 level for comparing stage x stubble height interaction = 11.7

Percent Dead Tillers

As noted earlier, the percentage of dead tillers was inversely proportional to the percentage of terminal tillers. The data for percent dead tillers are presented in Appendix Table 11 with the corresponding analyses of variance in Appendix Table 9. A smaller percent dead tillers occurred in 1980 than in 1979 even though it was much hotter and drier in 1980. The difference may be partly attributed to a better row spacing in 1980 (185 th. plants/ha.) and an absence of wheel slippage which sometimes occurred under the wet harvest conditions during 1979.

At the vegetative stage, little variability existed among populations in either year.

Stubble height strongly affected the percentage of dead tillers in 1979 but not in 1980. Lowering the stubble (cutting) height from 25 to 15 cm increased dead tillers almost two-fold (28.9% vs. 52.9%) in 1979 but the 15 cm stubble height was similar to the others in 1980.

At the boot stage in 1980, the 15 cm stubble height had a significantly higher percent dead tillers than the 25 and 30 cm stubble heights (Appendix Table 11). This response to stubble height has been substantiated by several workers who found that shorter cutting heights resulted in reduced plant vigor and stands (1, 8). Population density did not affect percent dead tillers.

A significant stubble height x population interaction occurred in both 1979 and 1980 and a stubble height x stage interaction occurred in 1980 (Table 11).

The stubble height x population interaction that occurred in 1979 was caused primarily by the difference between stubble heights at the

Table 11. Mean Percent Dead Tillers, 1979-1980.

Stubble Height (cm)	1979-Population (th. plants/ha.)		
	185	368	736
15	55.0	62.9	46.6
25	35.7	28.6	35.1
Mean	43.4	45.8	40.8

LSD .05 level for comparing stage x stubble height interaction = 16.7

Stubble Height (cm)	1980 - Stage		1980-Population (th.plants/ha.)		
	Vegetative	Boot	185	368	736
15	10.0	37.7	19.0	24.2	19.9
25	10.3	29.7	20.2	18.6	15.2
30	8.6	28.3	14.1	17.0	18.0
Mean	9.6	31.9	17.8	19.9	17.7

LSD .05 level for comparing stubble height x stage interaction = 6.8

LSD .05 level for comparing stubble height x population = 8.4

intermediate population. The largest percent dead tillers occurred at the 15 cm stubble height and lowest percent at the 25 cm height. The percent dead tillers was always greater at the 15 cm height.

In 1980 the stubble height x population interaction was caused by fluctuating data. The highest percent dead tillers occurred at the intermediate population and 15 cm stubble height, while the lowest values occurred at the highest population and 25 cm height and the lowest population and 30 cm stubble height.

The 1980 stubble height x stage interaction was probably caused by the relative difference between stages at the three stubble heights. The difference was greater at the 15 cm height than at the 25 and 30 cm heights.

Despite the significant stubble height x stage interaction in 1980, percent dead tillers was always greater at the boot stage. The number of dead tillers at the boot stage in 1980 was about three times as great as the vegetative stage for all stubble heights.

Besides the management practices mentioned, environmental factors such as temperature, rainfall and soil moisture also affect forage yield and plant regrowth. This study was conducted under two totally different growing seasons. The precipitation was slightly above normal and temperatures were near normal during 1979. Above normal temperatures and below average precipitation occurred in 1980. Soil moisture was monitored on four separate occasions each year. The readings are presented in Table 4 and it is evident that in 1979 more soil moisture was present in the upper 100 cm of soil. Seasonal means indicate that soil moisture was approximately 18% greater in 1979 than in 1980.

Laboratory Analysis

Total Nonstructural Carbohydrates

When most of the leaf area is removed, the plant must rely on alternative supplies of energy. Many plants accumulate carbohydrates in the roots, rhizomes, and basal stubbles of the plant. Similar to the objectives of Mays and Washko (23), this study was designed to determine to what extent pearl millet relies on total nonstructural carbohydrates (TNC) for regrowth. By comparing carbohydrate levels on the day of harvest with those seven days post harvest, the utilization of TNC for plant regrowth could be estimated. It was postulated that differential levels of TNC might partially explain the poor growth which sometimes occurred at the boot stage.

The carbohydrate percentages (TNC) of samples taken the day of harvest for both 1979 and 1980 are shown in Appendix Table 13. The appropriate analyses of variance are given in Appendix Table 12.

In 1979, significant differences in carbohydrate percentages occurred between stubble heights at the third vegetative harvest. This greater CHO percentage for the 15 cm stubble height also caused a greater mean value for the vegetative harvests. A stage x stubble height interaction occurred in 1979 and is presented in Table 12. The interaction was caused by a decrease in CHO% at the vegetative stage and a slight, but nonsignificant increase, at the boot stage of maturity.

At seven days post harvest (Appendix Table 14), little variation existed among treatments, except stubble heights at the third cut of the vegetative stage. The carbohydrate values correspond closely to those on the day of harvest.

Table 12. Mean Percent Carbohydrate Content - Day of Harvest, 1979.

	Stubble Height (cm.)	
Stage	15	25
Vegetative	5.17	3.99
Boot	5.75	6.33
Mean	5.46	5.16

LSD .05 level for comparing stage x stubble height interaction = 1.6

During 1980, on the day of harvest, carbohydrate levels varied slightly among treatments, but few differences were significant. The carbohydrate levels were much higher in 1980 than in 1979 (Appendix Table 13). Carbohydrate levels at the boot stage were significantly lower at the lowest stubble height.

At seven days post harvest, a significant difference in carbohydrate content occurred at the first vegetative harvest (Appendix Table 14). This difference corresponds to levels taken the day of harvest. The differences caused significant variation in the means for the three populations. Variation existed among stubble heights at both the vegetative and boot stages. Carbohydrate levels increased as stubble height was raised.

The analyses of variance for CHO% are presented in Appendix Table 12. At seven days post harvest, the stage x stubble height and population x stubble height interactions occurred. These data are presented in Table 13. No clear pattern in CHO% is evident for the stage x population interaction. However, large differences in carbohydrate percentages between stages at the intermediate population were what probably caused the interaction.

The stage x stubble height interaction resulted from the greater differences between stubble heights for the vegetative and boot stages. CHO% was always greater at the vegetative stage and increased with taller stubble heights for both stages.

The population x stubble height interaction also shows no clear pattern for CHO%. The trend was toward higher CHO% at higher populations and taller cutting heights. However, differences were very slight at the 15 cm height, and the intermediate population had the highest CHO%

Table 13. Mean Percent Carbohydrate Content-7 Days Post Harvest, 1980.

	Population (th. plants/ha.)		
Stage	185	368	736
Vegetative	5.00	6.29	5.74
Boot	4.74	4.46	4.92
Mean	4.87	5.38	5.33

LSD .05 level for comparing stage x population interaction = 1.16

	Stubble Height (cm)		
Stage	15	25	30
Vegetative	5.11	5.88	6.03
Boot	3.40	4.97	5.78
Mean	4.26	5.43	5.91

LSD .05 level for comparing stage x stubble height interaction = 1.43

	Stubble Height (cm)		
Population (th. plants/ha.)	15	25	30
185	4.27	5.05	5.03
368	4.57	6.12	5.97
736	4.21	4.88	6.44
Mean			

LSD .05 level for comparing population x stubble height interaction = 1.43

at the 25 cm height. CHO% increased with each increase in population at the 30 cm height.

The results of this study were similar to those obtained by Mays and Washko (23). In several instances the more severe cutting treatments resulted in the greater carbohydrate reduction. The carbohydrate levels taken seven days post harvest showed a general increase in TNC as the stubble height was raised. This indicates that those plants cut at the higher stubble heights with more leaf area remaining after harvest were able to synthesize food more readily and relied less on carbohydrate reserves. The proportion of TNC used for regrowth was determined as follows:

$$\text{\% TNC used during regrowth} = \frac{\text{CHO\% (Day of Harvest)} - \text{CHO\% (7 days post harvest)}}{\text{CHO\% (Day of Harvest)}}$$

At the vegetative stage in 1979 and 1980, 42 and 39% of the TNC was used between the day of harvest and seven days post harvest. At the boot stage, 64 and 53% TNC was utilized during regrowth.

The levels of carbohydrates were influenced by the stage of harvest. In both years the carbohydrate levels declined more at the boot stage during the seven days post harvest. This indicates that at the boot stage, less leaf area remained after harvest and regrowth came primarily from stored food reserves in the stubble. Similar results have been reported by other workers (18, 34). Holt and Alston (18) also showed that plants at the boot stage were very slow in replenishing carbohydrate reserves after harvest. With a longer recovery period and environmental stresses, each successive harvest resulted in less dry matter than the previous harvest.

CHAPTER V

SUMMARY AND CONCLUSIONS

The major objectives of this study were to ascertain the effects of selected management practices on regrowth and forage yield in pearl millet, and to determine the major points of regrowth.

Frequent harvests greatly decreased regrowth and total forage yield. In 1979 forage cut once at the boot stage (7.3 metric tons/ha) yielded significantly more than three harvests at the vegetative stage (total of 5.3 metric tons/ha).

In 1980 the forage yield at the boot stage (2 harvests) was 5.6 metric tons/ha and the vegetative stage (3 harvests) yielded 4.3 metric tons/ha. The lowest stubble height (15 cm) in 1980 yielded 36% more than the 25 and 30 cm stubble heights at the vegetative stage and 25% more at the boot stage.

The results of the study clearly show that the majority of pearl millet regrowth occurred from terminal tillers. These results support previous work with several cultivars of the <u>Pennisetum</u> and <u>Sorghum</u> genera. Lowering the stubble (cutting) height from 30 or 25 cm to 15 cm reduced the number of live tillers at both the vegetative and boot stages of maturity. The percentage of basal and axillary tillers were greater at the 15 cm stubble height than the 25 and 30 cm heights. Cutting pearl millet to 15 cm removed many terminal tillers, increasing the proportion of basal and axillary tillers.

A higher percentage of dead tillers occurred at the lower stubble height and at the boot stage of maturity. This was due in part to the number of growing points and leaf area removed and TNC available for regrowth.

With more frequent harvests (vegetative stage), the amount of total nonstructural carbohydrates (TNC) was reduced. Plants harvested at the boot stage contained more TNC the day of harvest, but regrowth was more dependent on the stored carbohydrates as shown by reduced carbohydrate levels at seven days post harvest. It is clear that pearl millet relies on stored carbohydrates for regrowth. The lowest stubble height (15 cm) relied more heavily on TNC for regrowth.

LITERATURE CITED

1. Beaty, R. R., Y. C. Smith, R. A. McCreery, W. J. Ethredge, and K. Beasley. 1965. Effect of Cutting Height and Frequency on Forage Production of Summer Annuals. Agron. J. 57: 277-279.

2. Begg, J. E. 1965. The Growth and Development of a Crop of Bulrush Millet (Pennisetum typhoides S. & H.) J. Agri. Sci. 65: 341-349.

3. Beuerlein, J. E., H. A. Fribourg, and F. F. Bell. 1968. Effects of Environment and Cutting on the Regrowth of a Sorghum-Sudangrass Hybrid. Crop Sci. 8:152-155.

4. Broyles, K. R., and H. S. Fribourgh. 1959. Nitrogen Fertilization and Cutting Management of Sudangrass and Millets. Agron. J. 51: 277-279.

5. Burger, A. W., and C. N. Hittle. 1967. Yield, Protein, Nitrate, and Prussic Acid Content of Sudangrass, Sudangrass Hybrids, and Pearl Millets Harvested at Two Cutting Frequencies and Stubble Heights. Agron. J. 59: 259-262.

6. Burger, A. W., J. A. Jackobs, and C. N. Hittle. 1958. Yield of Sudangrass Varieties as Affected by Time and Frequency of Cutting. Agron. J. 50: 37-49.

7. Burris, J. S., R. H. Brown, and R. E. Blaser. 1967. Evaluation of Reserve Carbohydrates in Midland Bermudagrass (Cynodon dactylon L.) Crop Sci. 7: 22-24.

8. Clapp, J. G., and D. S. Chamblee. 1970. Influence of Different Defoliation Systems on the Regrowth of Pearl Millet, Hybrid Sudangrass, and Two Sorghum-Sudangrass Hybrids From Terminal, Axillary, and Basal Buds. Crop Sci. 10: 345-349.

9. Cooper, C. S. 1956. The Effect of Time and Height of Cutting on the Yield, Crude Protein Content and Vegetative Composition of a Native Flood Meadow in Eastern Oregon. Agron. J. 48: 257-258.

10. De Cugnac, A. 1931. Recherghes sur ler Glucides de Graminees. Ann. Sci. Nat. 13: 1-129.

11. Dovrat, A., and N. Ophir. 1965. The Effect of Number of Cuttings, Seeding Rate, and Row Spacing on the Yield and Leaf Area Index of Pearl Millet (Pennisetum glaucum L. R. B. R.) Israel Journel of Agri. Research. 15(4): 179-186.

12. Edwards, N. C., Jr., H. A. Fribourg, and M. J. Montgomery. 1971 Cutting Management Effect on Growth Rate and Dry Matter Digestibility of the Sorghum-Sudangrass Cultivar SX-11. Agron. J. 63: 267-271.

13. Ellett, W. B., and L. Carrier. 1915. The Effect of Frequent Clipping on Total Yield and Composition of Grasses. J. Amer. Soc. of Agron. 7: 85-87.

14. Fribourg, Henry A., J. R. Overton, and J. A. Mullins. 1975. Wheel Traffic on Regrowth and Production of Summer Annual Grasses. Agron. J. 67: 423-426.

15. Gill, W. R., and G. E. Vanden Berg. 1967. Soil Compaction Chapter 8 in Soil Dynamics in Tillage and Traction. U.S.D.A. Agri. Handbook No. 316.

16. Hart, Richard H., and Glenn W. Burton. 1965. Effect of Row Spacing, Seeding Rate, and Nitrogen Fertilization on Forage Yield and Quality of Gahi-1 Pearl Millet. Agron. J. 57: 376-378.

17. Heath, M., D. S. Metcalfe, and R. F. Barnes. 1973. Forages. 3rd Edition. The Iowa State University Press, Ames, Iowa.

18. Holt, E. C., and G. D. Alston. 1968. Response of Sudangrass Hybrids to Cutting Practices. Agron. J. 60: 303-306.

19. Howland, C. S., and D. E. McCloud. 1957. Manage Millet for Better Yields. Sunshine State Agron. Report. 2:(2) 14.

20. Joulie, H. 1881. Permanent and Temporary Meadows and Pastures and Their Function in the Economy of Agricultural Practice. J. of the Royal Agricultural Society. 18: 195.

21. Mays, D. A., J. R. Peterson, and H. T. Bryant. 1966. A Clipping Management Study of Two Sudangrass-Sorghum Hybrids, Sudangrass, and Gahi Millet for Forage Production. Virginia Agricultural Experimental Research Report 113. 6 p.

22. Mays, D. A., and J. B. Washko. 1961. Cutting and Grazing Management for Sudangrass and Pearl Millet. Pennsylvania Agr. Exp. Sta. Bull. 682. 14 p.

23. Mays, D. A., and J. B. Washko. 1962. Refractometric Determination of "Sucrose Equivalent" Levels in the Stubble of Sudangrass and Pearl Millet. Crop Sci. 2: 81-82.

24. McAllister, D. F., and O. A. Krober. 1958. Response of Soybeans to Leaf and Pod Removal. Agron. J. 50: 674-676.

25. Nelson, L. A. 1977. Influence of Various Row Widths on Yields and Agronomic Characteristics of Proso Millet. Agron. J. 69: 351-353.

26. Nelson, C. J. and D. Smith. 1968. Growth of Birdsfoot Treefoil and Alfalfa, III Changes in Carbohydrate Reserves and Growth Analysis Under Field Conditions. Crop Sci. 8: 25-28.

27. Nuwanyakpa, M. 1979. Part I. Evaluation for Yield and Quality of Six Summer Annual Grasses. Part II. Comparative Feeding Value of Summer Annual Grass, Hays and Silages for Lambs. M. S. Thesis, Kansas State University.

28. Odland, T. E., T. R. Cox, and C. H. Moran. 1942. Adaptation of Various Crops for Supplementary Pasture. J. Amer. Soc. Agron. 34: 229-237.

29. Prine, G. M., and G. W. Burton. 1956. The Effect of Nitrogen Rate and Clipping Frequency Upon the Yield, Protein Content and Certain Morphological Characteristics of Coastal Bermudagrass (Cynodon dactylon (L) Pers). Agron. J. 48: 296-301.

30. Rusoff, L. L., A. S. Achascoso, C. L. Mondart, Jr., and F. L. Bonner. 1961. Relationship of Lignin to Other Chemical Constituents in Sudan and Millet Forages. Louisiana Agr. Exp. Sta. Bul. 542.

31. Sheesley, R., D. W. Grimes, W. D. McClellan, C. G. Summers, and V. Marble. 1974. Influence of Wheel Traffic on Yield and Stand of Alfalfa. California Agr. 28(10): 6-8.

32. Smith, D. 1969. Removing and Analyzing Total Nonstructural Carbohydrates From Plant Tissue. Wisc. Agric. Exp. Sta. Res. Report 41: 1-11.

33. Smith, D., G. M. Paulsen, and C. A. Ragues. 1964. Extraction of Total Available Carbohydrates From Grass and Legume Tissue. Plant Physiol. 39: 960-962.

34. Sullivan, J. T., and V. G. Sprague. 1943. Composition of the Roots and Stubble of Perennial Ryegrass Following Partial Defoliation. Plant Physiol. 18: 656-670.

35. Thorne, J. H., and H. R. Koller. 1974. Influence of Assimilate Demand on Photosynthesis, Diffuse Resistance, Translocation and Carbohydrate Levels of Soybean Leaves. Plant Physiol. 54: 201-207.

36. Worker, G. F. 1973. Sudangrass and Sudangrass Hybrids Responses to Row Spacing and Plant Maturity on Yields and Chemical Composition. Agron. J. 65: 957-977.

APPENDIX

Appendix Table 1. Analyses of Variance - Percent Dry Matter and Mean Plant Height, 1979-1980.

	% Dry Matter						Mean Plant Height					
	1979			1980			1979			1980		
Source	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F
Replicates	3	1.45		3	45.44		3	6.06		3	28.48	
Cut (C)	3	272.44	<0.01	4	34.34	0.09	3	8182.73	<.01	4	291.12	<.01
Stage (S)	(1)	(10.19)	0.09	(1)	(5.85)	0.51				(1)	(0.657)	0.45
Error	9	3.03		12	13.07		9	23.11		12	10.91	
Population (P)	2	3.52	0.18	2	17.04	0.20	2	25.83	0.18	2	3.29	0.58
Stubble Ht (H)	1	1.62	0.37	2	16.22	0.22	1	126.62	<.01	2	6.08	0.36
C x P	6	1.91	0.06	8	13.62	0.26	6	26.65	0.11	8	13.94	0.02
(S x P)	(2)	(5.47)	0.07	(2)	(21.16)	0.14				(2)	(7.15)	0.30
C x H	3	19.21	<0.01	8	25.28	0.02	3	92.48	<.01	8	22.04	<.01
(S x H)	(1)	(30.91)	<0.01	(2)	(16.69)	0.21				(2)	(11.98)	0.14
P x H	2	1.16	0.56	4	6.33	0.66	2	97.54	<.01	4	4.79	0.53
C x P x H	6	0.71	0.90	16	9.87	0.54	6	31.24	0.06	16	10.06	0.06
Error	60	1.98		120	10.56		60	14.55		120	5.96	

Appendix Table 2. Plant Heights, 1979-1980.

Treatment	Plant Heights (cm)										
	Vegetative Stage								Boot Stage		
	1979				1980				1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	Mean
Population (th. plants/ha.)											
185	43^{*b}	103^{a}	93^{a}	79^{a}	53^{a}	63^{a}	75^{a}	64^{a}	105^{a}	88^{a}	97^{a}
368	56^{a}	103^{a}	91^{a}	83^{a}	46^{b}	58^{a}	70^{ab}	58^{b}	105^{a}	80^{a}	92^{a}
736	58^{a}	103^{a}	96^{a}	85^{a}	50^{ab}	61^{a}	69^{b}	50^{b}	103^{a}	62^{b}	83^{b}
Mean	52	103	93	82	50	61	71	60	104	77	91
LSD .05	10	8	16	13	4	6	6	2	27	13	6
Stubble Ht. (cm)											
15	54^{a}	103^{a}	103^{a}	87^{a}	49^{ab}	59^{b}	64^{b}	57^{c}	99^{a}	70^{b}	85^{b}
25	50^{a}	103^{a}	83^{b}	79^{a}	48^{b}	58^{b}	73^{a}	85^{a}	102^{a}	74^{ab}	88^{b}
30	--	---	---	--	53^{a}	67^{a}	77^{a}	65^{b}	112^{a}	87^{a}	100^{a}
Mean	52	103	93	83	50	61	71	60	104	77	91
LSD .05	8	7	14	11	4	6	6	2	27	13	6

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 3. Dry Matter Percentages, 1979-1980.

Treatment	Dry Matter Percentages											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_1	C_2	Mean
Population (th. plants/ha.)												
185	11.3^{*a}	11.1^{a}	17.5^{a}	13.3^{a}	19.6^{a}	17.0^{a}	17.4^{b}	18.0^{b}	11.1^{b}	21.2^{a}	19.3^{a}	20.4^{a}
368	10.1^{b}	10.7^{a}	17.2^{a}	12.7^{a}	20.1^{a}	18.6^{a}	18.2^{ab}	19.0^{a}	11.5^{b}	20.4^{a}	18.9^{a}	19.7^{ab}
736	10.2^{b}	11.2^{a}	18.4^{a}	13.2^{a}	19.8^{a}	17.4^{a}	18.5^{a}	18.6^{ab}	12.5^{a}	17.2^{a}	18.1^{a}	17.6^{b}
Mean	10.5	11.0	17.7	13.0	19.8	17.7	18.1	18.5	11.7	19.6	18.8	19.2
LSD .05	0.7	1.7	2.0	10.9	1.2	2.1	1.0	0.9	1.0	4.2	12.8	2.5
Stubble Ht. (cm)												
15	9.7^{b}	10.9^{a}	18.8^{a}	13.1^{a}	18.4^{b}	16.8^{a}	18.0^{a}	17.7^{b}	10.8^{b}	17.5^{b}	19.8^{a}	18.7^{ab}
25	11.2^{a}	11.1^{a}	16.5^{b}	13.0^{a}	21.1^{a}	18.2^{a}	18.1^{a}	19.1^{a}	12.6^{a}	19.1^{ab}	17.1^{a}	18.1^{b}
30	---	---	---	---	20.0^{a}	18.0^{a}	18.0^{a}	18.6^{a}	---	22.1^{a}	19.0^{a}	20.8^{a}
Mean	10.5	11.0	17.7	13.0	19.8	17.7	18.1	18.5	11.7	19.6	18.8	19.2
LSD .05	0.6	1.4	1.6	0.7	1.2	2.1	1.0	0.9	1.1	4.2	2.8	2.5

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 4. Analyses of Variance-Forage Yield, 1979-1980.

	Forage Yield (metric tons/ha.)					
	1979			1980		
Source	DF	MS	Prob>F	DF	MS	Prob>F
Replicates	3	0.45		3	0.16	
Cut (C)	3	40.14	<0.01	4	4.63	<0.01
Stage (S)	(1)	(1.65)	0.01	(1)	(6.42)	<0.01
Error	9	0.17		12	0.10	
Population(P)	2	0.48	0.01	2	0.32	0.01
Stubble Ht (H)	1	0.04	0.55	2	0.71	<0.01
C x P	6	0.40	<0.01	8	0.08	0.34
(S x P)	(2)	(1.02)	<0.01	(2)	(0.38)	<0.01
C x H	3	0.23	0.09	8	0.11	0.14
(S x H)	(1)	(0.14)	0.25	(2)	(0.72)	<0.01
P x H	2	0.19	0.17	4	0.04	0.68
C x P x H	6	0.03	0.92	16	0.03	0.97
Error	60	0.10		120	0.07	

Appendix Table 5. Forage Yield, 1979-1980.

Treatment	Forage Yield (metric tons/ha.)											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Total	C_1	C_2	C_3	Total	C_1	C_1	C_2	Total
Population (th. Plants/ha.)												
185	1.0^{*b}	3.0^{a}	1.1^{b}	5.0^{a}	1.9^{a}	1.5^{a}	1.4^{a}	4.8^{a}	6.5^{b}	4.8^{a}	2.0^{a}	6.8^{a}
368	1.2^{ab}	2.6^{a}	1.9^{a}	5.8^{a}	1.4^{c}	1.5^{a}	1.1^{b}	4.0^{b}	7.4^{ab}	3.5^{b}	1.3^{b}	4.7^{b}
736	1.4^{a}	2.4^{a}	1.5^{ab}	5.3^{a}	1.6^{b}	1.3^{a}	1.1^{b}	4.1^{b}	8.2^{a}	4.3^{a}	1.1^{b}	5.4^{ab}
Mean	1.2	2.7	1.5	5.3	1.6	1.4	1.2	4.3	7.3	4.2	1.5	5.6
LSD .05	0.3	0.9	0.7	1.0	0.2	0.4	0.2	0.4	1.0	0.6	0.5	2.0
Stubble Ht. (cm)												
15	1.4^{a}	2.7^{a}	1.2^{a}	5.3^{a}	2.0^{a}	2.1^{a}	1.3^{a}	5.4^{a}	7.5^{a}	5.1^{a}	1.5^{a}	6.5^{a}
25	1.0^{b}	2.6^{a}	1.8^{a}	5.4^{a}	1.4^{b}	1.0^{b}	1.2^{a}	3.6^{b}	7.1^{a}	4.0^{b}	1.3^{a}	5.3^{a}
30	---	---	---	---	1.4^{b}	1.2^{b}	1.2^{a}	3.8^{b}	---	3.5^{b}	1.7^{a}	5.2^{a}
Mean	1.2	2.7	1.5	5.3	1.8	1.4	1.2	4.3	7.3	4.2	1.5	5.6
LSD .05	0.2	0.7	0.7	0.8	0.2	0.4	0.2	0.4	0.8	0.6	0.5	2.0

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 6. Analyses of Variance - Percent Basal and Axillary Tillers, 1979-1980.

Source	% Basal Tillers						% Axillary Tillers					
	1979			1980			1979			1980		
	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F
Replicates	3	7.56		3	11.23		3	14.33		3	118.15	
Cut (C)	3	414.65	<0.01	4	155.94	<0.01	3	20.30	0.14	4	468.21	<0.01
Stage (S)	(1)	(287.8)	<0.01	(1)	(190.86)	<0.01	(1)	(48.35)	0.04	(1)	(253.29)	0.23
Error	9	3.81		12	15.18		9	8.43		12	156.54	
Population (P)	2	21.64	0.04	2	5.42	0.33	2	3.75	0.48	2	134.14	0.17
Stubble Ht (H)	1	17.77	0.10	2	10.13	0.13	1	30.38	0.02	2	486.47	<0.01
C x P	6	8.92	0.23	8	2.72	0.81	6	4.29	0.54	8	82.79	0.37
(S x P)	(2)	(3.78)	0.56	(2)	(6.86)	0.25	(2)	(5.08)	0.37	(2)	(92.89)	0.30
C x H	3	16.32	0.06	8	15.21	<0.01	3	16.59	0.03	8	226.69	<0.01
(S x H)	(1)	(287.80)	<0.01	(2)	(8.34)	0.18	(1)	(48.35)	<0.01	(2)	(414.97)	0.07
P x H	2	2.41	0.69	4	7.61	0.18	2	8.57	0.19	4	16.94	0.93
C x P x H	6	2.75	0.86	16	2.87	0.89	6	11.99	0.04	16	84.12	0.93
Error	60	6.43		120	4.83		60	5.04		120	75.33	

Appendix Table 7. Percent Basal Tillers, 1979-1980.

Treatment	Percent Basal Tillers											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_1	C_2	Mean
Population (th. Plants/ha.)												
185	8.1^{*a}	2.5^{b}	0.9^{b}	3.8^{b}	1.8^{a}	3.0^{a}	1.1^{a}	2.0^{a}	1.8^{a}	6.2^{a}	2.1^{a}	4.1^{a}
368	11.5^{a}	4.2^{ab}	1.8^{ab}	5.7^{a}	1.2^{a}	3.4^{a}	1.1^{a}	1.9^{a}	1.3^{a}	7.0^{a}	1.6^{a}	4.3^{a}
736	11.2^{a}	5.1^{a}	2.2^{a}	6.2^{a}	1.1^{a}	2.5^{a}	1.1^{a}	1.6^{a}	0.7^{a}	4.9^{a}	1.7^{a}	3.3^{a}
Mean	10.3	4.0	1.6	5.3	1.4	3.0	1.1	1.8	1.3	6.0	1.8	3.9
LSD .05	4.6	2.0	1.4	1.7	1.1	2.0	0.8	0.8	1.6	3.2	1.2	1.7
Stubble Ht. (cm)												
15	9.7^{a}	3.1^{b}	2.4^{a}	5.1^{a}	1.5^{a}	5.0^{a}	1.6^{a}	2.7^{a}	0.3^{b}	5.5^{a}	0.9^{a}	3.2^{b}
25	10.9^{a}	4.8^{a}	0.7^{b}	5.5^{a}	1.3^{a}	1.4^{b}	0.8^{b}	1.2^{b}	2.3^{a}	5.1^{a}	2.0^{a}	3.5^{ab}
30	---	---	---	---	0.8^{a}	2.5^{b}	0.8^{b}	1.3^{b}	---	7.5^{a}	2.5^{a}	5.0^{a}
Mean	10.3	4.0	1.6	5.3	1.4	3.0	1.1	1.8	1.3	6.0	1.8	3.9
LSD .05	3.8	1.6	1.1	1.4	1.1	2.0	0.8	0.8	1.3	3.2	1.2	1.7

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 8. Percent Axillary Tillers, 1979-1980.

Treatment	Percent Axillary Tillers											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_1	C_2	Mean
Population (th. Plants/ha.)												
185	2.6^{*a}	4.4^{a}	3.1^{a}	3.4^{a}	3.2^{a}	34.8^{a}	40.0^{a}	26.0^{a}	2.3^{a}	37.6^{a}	9.0^{a}	23.3^{a}
368	3.0^{a}	2.4^{a}	3.8^{a}	3.1^{a}	3.8^{a}	23.6^{b}	36.2^{a}	21.2^{b}	0.9^{b}	3.6^{a}	3.6^{a}	21.2^{a}
736	2.0^{a}	3.7^{a}	3.0^{a}	2.9^{a}	3.1^{a}	30.7^{a}	38.2^{a}	24.0^{ab}	1.3^{b}	39.9^{a}	2.8^{a}	21.4^{a}
Mean	2.3	3.5	3.3	3.1	3.4	29.7	38.2	23.7	1.5	38.8	5.1	21.9
LSD .05	1.7	2.1	3.9	1.6	1.3	5.7	5.4	2.7	1.0	13.8	6.6	7.7
Stubble Ht. (cm)												
15	2.8^{a}	3.6^{a}	1.8^{a}	2.7^{a}	3.6^{a}	40.4^{a}	37.5^{a}	27.2^{a}	0.4^{b}	40.0^{a}	6.8^{a}	23.4^{a}
25	2.4^{a}	3.4^{a}	4.7^{a}	3.5^{a}	3.0^{a}	20.3^{c}	36.7^{a}	20.2^{c}	2.6^{a}	36.7^{a}	2.7^{a}	19.7^{a}
30	---	---	---	---	3.0^{a}	28.4^{b}	40.3^{a}	23.9^{b}	---	39.6^{a}	5.9^{a}	22.7^{a}
Mean	2.6	3.5	3.3	3.1	3.4	29.7	38.2	23.7	1.4	38.8	5.1	21.9
LSD .05	1.4	1.7	3.1	1.3	1.3	5.7	5.4	2.7	0.8	13.8	6.6	7.7

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 9. Analyses of Variance - Percent Terminal and Dead Tillers, 1979-1980.

	% Terminal Tillers						% Dead Tillers					
	1979			1980			1979			1980		
Source	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F
Replicates	3	316.93		3			3			3		
Cut (C)	3	4367.35	<0.01	4	18051.43	<0.01	3	7334.09	<0.01	4	17140.18	<0.01
Stage (S)	(1)	(848.72)	0.06	(1)	(32477.04)	<0.01	(1)	(2800.02)	<0.01	(1)	(21220.92)	<0.01
Error	9	188.86		12	298.91		9	197.97		12	243.97	
Population (P)	2	334.47	0.30	2	226.36	0.10	2	241.70	0.42	2	98.02	0.26
Stubble Ht (H)	1	9325.98	<0.01	2	1239.04	<0.01	1	11301.36	<0.01	2	340.63	0.01
C x P	6	132.38	0.82	8	425.45	<0.01	6	141.36	0.80	8	80.19	0.35
(S x P)	(2)	(142.80)	0.60	(2)	(327.34)	0.04	(2)	(149.77)	0.09	(2)	(114.83)	0.20
C x H	3	1377.20	<0.01	8	488.62	<0.01	3	1330.53	<0.01	8	138.36	0.06
(S x H)	(1)	(848.72)	0.08	(2)	(1247.43)	<0.01	(1)	(144.78)	0.47	(2)	(463.57)	<0.01
P x H	2	880.44	0.05	4	220.10	0.07	2	1070.11	0.03	4	135.22	0.01
C x P x H	6	173.62	0.70	16	203.15	0.01	6	279.88	0.43	16	161.19	0.01
Error	60	273.10		120	97.09		60	278.54		120	71.30	

Appendix Table 10. Percent Terminal Tillers, 1979-1980.

Treatment	Percent Terminal Tillers											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_1	C_2	Mean
Population (th. Plants/ha.)												
185	68.1[*a]	53.0[a]	45.2[a]	55.4[a]	92.6[a]	54.4[b]	40.3[b]	62.4[b]	44.8[a]	50.4[a]	34.7[a]	42.6[a]
368	67.3[a]	41.2[a]	34.4[b]	47.6[a]	88.2[b]	64.7[a]	46.3[ab]	66.4[a]	45.1[a]	47.4[a]	33.3[a]	40.4[a]
736	71.1[a]	40.3[a]	36.1[b]	49.2[a]	88.6[b]	61.3[a]	47.9[a]	65.9[a]	41.8[a]	30.9[b]	31.8[a]	31.8[b]
Mean	68.8	44.9	38.6	50.8	89.8	60.2	44.8	64.9	43.9	42.9	33.3	38.1
LSD .05	23.4	13.6	6.6	9.3	4.0	6.8	6.8	3.4	21.5	12.3	8.7	7.5
Stubble Ht. (cm)												
15	67.2[a]	29.9[b]	21.0[b]	39.4[b]	90.6[ab]	44.8[c]	45.1[a]	60.2[b]	38.6[a]	36.1[a]	27.0[b]	31.6[b]
25	70.5[a]	59.8[a]	56.1[a]	62.1[a]	87.4[b]	72.6[a]	45.3[a]	68.5[a]	49.2[a]	44.3[a]	33.3[ab]	38.8[ab]
30	---	---	---	---	91.4[a]	63.0[b]	44.0[a]	66.2[a]	----	48.4[a]	39.5[a]	44.0[a]
Mean	68.8	44.9	38.6	50.8	89.8	60.2	44.8	64.9	43.9	42.9	33.3	38.1
LSD .05	19.1	11.1	5.4	7.6	4.0	6.8	6.8	3.4	17.5	12.3	8.7	7.5

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 11. Percent Dead Tillers, 1979-1980.

Treatment	Percent Dead Tillers											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_1	C_2	Mean
Population (th. Plants/ha.)												
185	21.2*a	39.9a	51.0a	37.4a	3.0b	7.8a	18.7a	9.8a	51.1a	5.8a	54.2a	30.0a
368	18.1a	52.3a	60.0a	43.5a	6.8a	8.2a	16.4ab	10.5a	52.7a	6.8a	61.5a	34.2a
736	15.7a	50.9a	58.6a	41.7a	7.5a	5.4a	12.7b	8.5a	56.2a	7.5a	55.4a	31.5a
Mean	18.3	47.7	56.5	40.9	5.8	7.1	15.9	9.6	53.3	6.7	57.0	31.9
LSD .05	21.7	15.2	9.1	9.3	3.3	3.7	4.0	2.1	21.9	4.5	13.3	7.0
Stubble Ht. (cm)												
15	20.4a	63.4a	74.8a	52.9a	4.4b	9.8a	15.7a	10.0a	60.7a	10.1a	65.3a	37.7a
25	16.2a	32.0b	38.3b	28.9b	8.1a	5.5b	17.2a	10.3a	45.9a	5.6ab	53.7a	29.7b
30	----	----	----	----	4.8ab	6.0b	14.9a	8.6a	----	4.5b	52.1a	28.3b
Mean	18.3	47.7	56.5	40.9	5.8	7.7	15.9	9.6	53.3	6.7	57.0	31.9
LSD .05	17.7	12.4	7.5	7.6	3.3	3.7	4.0	2.1	17.9	4.5	13.3	7.0

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 12. Analyses of Variance-Carbohydrate Percentages, 1979-1980.

Source	% CHO-Day of Harvest						% CHO-7 Days Post Harvest					
	1979			1980			1979			1980		
	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F	DF	MS	Prob>F
Replicates	3	0.10		3	28.48		3	0.11		3	7.77	
Cut (C)	3	24.25	0.06	4	291.12	<0.01	3	23.83	<0.01	4	293.48	<0.01
Stage (S)	(1)	(38.25)	0.04	(1)	(0.66)	0.81	(1)	(4.41)	0.20	(1)	(67.89)	<0.01
Error	9	6.84		12	10.91		9	2.27		12	5.44	
Population (P)	2	1.74	0.65	2	3.29	0.58	2	1.75	0.30	2	8.93	0.02
Stubble Ht (H)	1	12.95	0.08	2	6.08	0.36	1	33.24	<0.01	2	33.54	<0.01
C x P	6	5.57	0.24	8	13.94	0.02	6	0.74	0.80	8	5.67	0.01
(S x P)	(2)	(1.70)	0.66	(2)	(7.15)	0.30	(2)	0.24	0.84	(2)	(5.95)	0.06
C x H	3	29.78	<0.01	8	22.04	<0.01	3	24.56	<0.01	8	5.57	0.01
(S x H)	(1)	(38.25)	<0.01	(2)	(11.98)	0.14	(1)	(4.41)	0.08	(2)	(38.05)	<0.01
P x H	2	7.76	0.16	4	4.79	0.53	2	1.48	0.36	4	5.64	0.03
C x P x H	6	1.72	0.86	16	10.06	0.06	6	1.27	0.51	16	2.19	0.40
Error	60	4.08		120	5.96		60	1.44		120	2.08	

Appendix Table 13. Carbohydrate Content-Day of Harvest, 1979-1980.

Treatment	Percent Carbohydrate-Day of Harvest											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_1	C_2	Mean
Population (th. Plants/ha.)												
185	5.76^{*a}	4.33^{a}	5.71^{a}	5.27^{a}	11.59^{b}	6.36^{a}	9.16^{a}	9.04^{a}	4.98^{a}	13.67^{a}	8.07^{a}	10.87^{a}
368	3.99^{b}	3.74^{a}	5.32^{a}	4.35^{a}	13.83^{a}	6.68^{a}	7.72^{a}	9.41^{a}	6.65^{a}	11.36^{b}	6.09^{b}	8.73^{b}
736	3.96^{b}	3.16^{a}	5.29^{a}	4.14^{a}	12.56^{ab}	7.17^{a}	8.72^{a}	9.48^{a}	6.50^{a}	12.26^{ab}	7.83^{ab}	10.05^{a}
Mean	4.57	3.74	5.44	4.58	12.66	6.74	8.53	9.31	6.04	12.43	7.33	9.88
LSD .05	1.46	2.14	2.24	1.14	11.68	1.55	1.84	0.98	2.61	1.92	1.81	1.32
Stubble Ht. (cm)												
15	4.71^{a}	3.36^{a}	7.44^{a}	5.17^{a}	11.23^{b}	8.48^{a}	8.93^{a}	9.55^{a}	5.75^{a}	10.60^{b}	6.20^{b}	8.40^{b}
25	4.43^{a}	4.12^{a}	3.43^{b}	3.99^{b}	13.85^{a}	5.86^{b}	8.22^{a}	9.31^{a}	6.33^{a}	13.06^{a}	7.54^{ab}	10.30^{a}
30	----	----	----	----	12.95^{a}	5.88^{b}	8.45^{a}	9.08^{a}	----	13.63^{a}	8.24^{a}	10.94^{a}
Mean	4.57	3.74	5.44	4.58	12.66	6.74	8.53	9.31	6.04	12.43	7.33	9.88
LSD .05	1.19	1.75	1.83	0.93	1.68	1.55	1.84	0.98	2.13	1.92	1.81	1.32

*Means within a column follwed by the same letter(s) are not significantly different at the 0.05 level of probability.

Appendix Table 14. Carbohydrate Content-7 Days Post Harvest, 1979-1980.

Treatment	Percent Carbohydrate-7 Days Post Harvest											
	Vegetative Stage								Boot Stage			
	1979				1980				1979	1980		
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_1	C_2	Mean
Population (th. Plants/ha.)												
185	2.76[a]	1.91[a]	4.59[a]	3.09[a]	8.65[b]	2.61[a]	3.74[a]	5.00[b]	1.98[a]	5.03[a]	3.89[a]	4.74[a]
368	2.19[a]	1.47[a]	3.50[a]	2.39[b]	11.52[a]	2.99[a]	4.35[a]	6.29[a]	2.29[a]	5.29[a]	3.63[a]	4.46[a]
736	2.29[a]	1.54[a]	3.80[a]	2.54[ab]	10.15[ab]	2.80[a]	4.26[a]	5.74[b]	2.26[a]	5.04[a]	4.42[a]	4.92[a]
Mean	2.41	1.65	3.96	2.67	10.11	2.80	4.12	5.68	2.18	5.12	3.98	4.71
LSD .05	1.44	0.83	1.28	0.70	1.60	0.68	0.72	0.77	1.46	1.09	1.40	0.89
Stubble Ht. (cm)												
15	2.67[a]	1.80[a]	6.04[a]	3.50[a]	8.75[b]	3.00[a]	3.57[b]	5.11[b]	2.03[a]	3.54[b]	3.25[b]	3.40[b]
25	2.15[a]	1.48[a]	1.88[b]	1.84[b]	10.69[a]	2.75[a]	4.21[ab]	5.88[a]	2.32[a]	5.77[a]	3.77[ab]	4.97[a]
30	---	---	---	---	10.88[a]	2.65[a]	4.55[a]	6.03[a]	---	6.06[a]	4.93[a]	5.78[a]
Mean	2.41	1.64	3.96	2.67	10.11	2.80	4.12	5.68	2.18	5.12	3.98	4.71
LSD .05	1.17	0.68	1.04	0.57	1.60	0.68	0.72	0.77	1.19	1.09	1.40	0.89

*Means within a column followed by the same letter(s) are not significantly different at the 0.05 level of probability.

REGROWTH OF PEARL MILLET

by

ROBERT JOHN STEPHENSON

B.S., Western Illinois University, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1981

ABSTRACT

REGROWTH OF PEARL MILLET

In 1979 and 1980 'Millex 23' hybrid pearl millet was studied at Manhattan, Kansas to determine the point(s) of regrowth and the effects of selected management practices on forage yield. All possible combinations of three stubble heights: 15 cm, 25 cm, and 30 cm (30 in 1980 only) and three populations: 185, 386, and 736 thousand plants/ha. were harvested at the vegetative and boot stages of maturity. Treatments were arranged in a randomized complete block design with four replications. There were three vegetative cuttings each year with one boot stage harvest in 1979 and two in 1980.

The major point of regrowth was from terminal tillers, with a greater percentage initiated at the vegetative stage and a higher stubble height. Terminal regrowth provided 50.75 and 64.93% of the total tillers at the vegetative stage in 1979 and 1980, respectively. At the boot stage, 43.89 and 38.10% of the regrowth was from terminal meristems. Axillary and basal tillering increased in both years as the stubble height was lowered.

Stage of maturity at harvest affected total dry matter yield. At the vegetative stage, the total yields were 5.3 and 4.3 metric tons/ha. in 1979 and 1980. Dry matter yields at the boot stage were 7.4 and 5.6 metric tons/ha. in 1979 and 1980, respectively. Stubble heights also affected total forage yields (metric tons/ha.) as follows:

1979	Vegetative Stage	Boot Stage
15 cm	5.32	7.54
25 cm	5.37	7.14

1980	Vegetative Stage	Boot Stage
15 cm	5.44	6.53
25 cm	3.62	5.26
30 cm	3.80	5.15

Regrowth at the boot stage of maturity was more dependent upon stored reserves because carbohydrate levels declined more between the day of harvest and seven days post harvest. The percentages of carbohydrates used for regrowth at the vegetative stage were 42 and 39% versus 64 and 53% for the boot stage in 1979 and 1980, respectively.

Rainfall affected yield with the narrower, more densely populated rows yielding higher when moisture was adequate (1979) and the wider, less populated rows yielding more when rainfall was below normal (1980).