STUDIES ON TILLERING OF SUDANGRASS (SORGHUM SUDANENSE, STAPF) WITH SPECIAL ATTENTION TO THE EFFECTS OF RIDGING

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This is to certify that the

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C M Harrison

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ABSTRACT

Studies on Tillering of Sudangrass (Sorghum sudanense, Stapf) with Special Attention to the Effects of Ridging

By Teh-chien Shen

Experiments were conducted in the field and under controlled conditions to study the tillering process of Sudangrass, its reaction to light intensity, nutrition and more especially to ridging treatments. (Ridging - the heaping of soil over the plant crowns.)

Sudangrass plants produced more than enough tiller buds for normal tillering under favorable conditions before the tillering stage. Seedlings at the nth leaf stage differentiated n+2 primary tiller buds or their primordia on the main stem and even secondary tiller buds on the first four primary ones.

Ridging had a marked effect in reducing the number of tillers per plant in all experiments conducted in growth chambers and greenhouse. Under field conditions, early ridging reduced the number of stalks per unit length of row and yield when seeded at 10 pounds per acre. These effects disappeared when ridging treatments were applied at a later time or on plots with a higher seeding rate of 20 pounds per acre.

The effects of ridging in suppressing tillering were mainly due to the mechanical hindrance of soil on the emergence of tillers and the reduction of the oxygen supply for developing tiller buds. Young tillers were etiolated and often became crooked when they were arrested in the ridged soil. Peroxide addition in the ridged soil increased

the number of emerged tillers per plant.

Low light intensity delayed the tillering process, suppressed further growth of young tillers, and enhanced the effect of ridging. Low light intensity of 300 f.c. almost completely suppressed tillering.

Nutrient deficiency reduced the number of tillers per plant but had no interaction with ridging. Higher fertilities advanced tillering and increased the number of tillers of ridged plants later in the growing season.

Ridging treatments generally increased the plant height, dry weight and yield of a single plant. These effects were attributed to the well developed crown parts and root systems.

Ridging was considered to be a possible practice for increasing yields of crops of Gramineae when time of ridging and spacing were well arranged.

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By

Teh-chien Shen

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INTRODUCTION

The extent of tillering is one of the factors which affect the yield of crops belonging to the grass family, Gramineae. The yield of a sugarcane crop may be simply expressed by the product of the average weight of millable stalks and the total number per unit area of land. Tillering becomes more important when profuse tillering, thin-stemmed cane varieties are used in commercial production as in Taiwan during recent years.

In the cane production area of Taiwan, ridging or "earthing up" has been practiced by the farmers for a good many years. The most marked effect of this practice is suppressed tillering. However, yield data have shown that ridging to a suitable height at the right time is of value in sustaining a higher yield. This increased yield is attributed to the effects of ridging in suppressing late tillers, preventing lodging and improving drainage of the field, though the effects of ridging on the tillering process and the subsequent growth and development of sugarcane plants are still not clearly understood.

Sudangrass has growth and tillering habits similar to sugarcane and was used as the experimental plant in this study of tillering and its possible control. Various segments of the environment were controlled to see what effect such measures would have on the tillering process.

REVIEW OF LITERATURE

Tillers are lateral shoots coming from axillary buds at the nodes of grass plants. They are connected by vascular tissues (2) with the main stem. Therefore, tiller formation and growth are closely related with the development and the physiological condition of the main stems.

The differentiation of tiller buds seems not to be affected by environmental factors. Studying rice seedlings grown under three seed spacings, Nishikawa and Hanada (10) found a definite relationship between the development of main stems and the differentiation of tiller buds. When the nth leaf had emerged, i.e. at nth stage, the (n+4)th leaf of the main stem had differentiated, and simultaneously the primordia of the (n+2)th and (n+1)th tillers were found as merely swellings in the axils of the (n+2)th and (n+1) th leaf respectively. The nth tiller, which was a primordium at (n-2)th and (n-1)th leaf stages, began to develop and grow as a tillering bud differentiating one or two leaf primordia at nth stage, and thereafter continued to grow if the environmental factors were suitable.

The development of young tillers and their further growth, on the other hand, are found to be related to the status of the main stems and are affected by environmental factors. Direct evidence of translocation of organic food material from the main stem to the tillers and vice versa under normal conditions have not been reported.

However, experiments have shown that translocation of materials between main stems and tillers took place under certain conditions. Dungan (2) reported that tillers might nourish the main stem under some conditions. Removing tillers from corn plants in the early milk stage caused a slight reduction in yield and test weight of grain. Rosenquist (11) covered the tillers of common Nebraska dent field corn with a layer of burlap to exclude light and prevent photosynthesis. Both main stem and tillers developed poorly. Labanauskas and Dungan (7) reported that foliated main stems of oats increased the yield of tillers from 21 to 58% compared to that of tillers attached to defoliated main stems. Foliated tillers increased the yield of the main stem from 33 to 58% compared to that of main stems to which defoliated tillers were attached. Therefore, tillers and main stems of growing plants interchange materials such as water, foods and nutrients under certain conditions.

Takahashi, Okajima, Takagi and Honda (18) found that during the life time of rice plants, the concentration of nitrogen in leaf blades and leaf sheaths decreased gradually while that in stems increased at the tillering stage. In phosphorus deficient plants, the concentration of nitrogen in the stem was low during the tillering stage. These plants had only a small number of tillers. Potassium deficiency did not cause a decrease in the number of tillers; translocation of nitrogen from leaves to stems was also high during the time of tillering. They suggested that nitrogen content in the main stem may play a significant role in the development of tillers.

Fukaki (3) studied the effects of light intensity on the growth of main-culms and tillers of rice. He found that tillering and the growth of tillers were more sensitive to light intensity than the growth of mainstems. Under high light intensity, the growth of tillers was greater than that of main-culms. On the contrary, under low light intensities, the growth of tillers was shorter than that of main-culms. The repression of growth by low light intensity on lately emerged tillers was stronger than that on old tillers. The order of repression was (1) the tiller that will emerge in future, (2) the tillers that are emerging now, and (3) the main stem. The effects of shading on the developing plants were thus (1) decrease in number of tillers and (2) decrease in the ratio of tillers/main stem in respect of their dry weights.

Sato and Shimizu (12) investigated competition in composition of tillers under 15 different planting densities adjusted by the number of seedlings (1-5) per hill and that of hills per unit area (36-72 hills per tsubo). On the number of tillers analysed according to their order, third tillers decreased on any plot under intense effect of competition, second tillers began to decrease at the point of 3-4 seedlings per hill in spite of an increase in number of hills per unit area. First tillers increased with the increase in number of seedlings per hill so far as this experiment was concerned.

Working on dry land crops, Sieglinger and Martin (14), and Wiggans and Frey (20, 21) found that a decrease in spacing or increase in planting rates decreased the number of stalks or head-bearing culms per plants in sorghum and oats respectively.

Kaukis and Reitz (5) planted 4 oat varieties at the spacings of 2.5 and 5.0 inches apart in 7 inch rows. At the 2.5 inch spacing, regression of yield on number of tillers expressed in grams per tiller was within the range of 0.824 to 1.155. At the wider spacing, the corresponding values were 1.117 and 1.580. Based on the varieties grown over the 2-year period, 75% more grain was produced under the 5 inch spacing than under a spacing of 2.5 inches. The data indicated that 77% of the total yield increase in the widely spaced plants resulted from increased tillering, 16% from increased yield per tiller, and 7% from the interaction of both factors.

Burger and Campbell (1) reported the average number of tillers per 3 square feet of Sudangrass at 3 drill spacings (4, 8 and 16 inch row width) and 3 rates of seeding (12, 18 and 24 pounds per acre). In the first harvest, number of tillers per 3 square feet increased with increasing seeding rate and decreased with increasing row width in the drilled plots. However, any differences in tiller counts which might have been attributed to either rate or method of seeding in the first harvest were largely lost by the end of second harvest.

The effects of ridging or "earthing up" on sugarcane have been reported in several papers published in Taiwan. Lee (8) reported that ridging sugarcane plants to a height of 40 cm above the seed piece decreased the number of tillers from 11.16 per stool in non-ridged plot to 9.81 in the ridged plot. The total number of millable stalks of non-ridged plots was 20% more than that in the ridged plots. However, average stalk length, diameter and weight per stalk of ridged plants were higher than those of the control. No significant difference in cane tonnage and sugar yield were obtained. It was found that early tillers formed between September and December made up 50% of the total yield of ridged plots while 66.9% of the total yield of non-ridged plots was contributed by tillers formed between November and February. More plants lodged in the non-ridged plots.

Loh and Tseng (9) reported that 40 to 60 lateral sprouts were produced by a single stool under the ground surface which could become tillers should the environmental conditions be favorable. In fact, with the exception of the thin-stalked varieties which usually produced 20 to 50 tillers, the two-eyed stool of the existing varieties commercially planted in Taiwan produced only 10 to 20 tillers during the tillering period. The remainder usually died before they emerged. These authors suggested that high mortality of emerged tillers was caused by sugarcane borers and the lack of rooting of tillers. Ridging was proposed for suppressing late tillers and to promote early tillers into millable stalks.

Experiments conducted by Sun and Liu (16) on a fine sandy loam soil in the Tainan area of Taiwan showed that ridging to 30 cm decreased the number of tillers over non-ridging. However, the mortality of emerged tillers was also significantly reduced by ridging. No significant difference was found between the number of millable stalks per plot at the time of harvest. Increased length of stalk and 12% more millable cane yield was obtained by ridging. The authors suggested that the ridging practice might increase cane yield through minimizing lodging, inhibiting the development of late tillers and accelerating the rate of elongation of stalks.

Sun, Liu, Tang, Chow, Sze, Chang and Ho (17) reported the regional tests of the ridging practice conducted on 123 farms of Taiwan Sugar Company in two successive crop years. Three ridging practices in sugarcane culture namely (1) the customary system consisting of three soil applications beginning from 2-3 months after planting and ending with a total thickness of 30-36 cm above seed sets; (2) the simplified system, in which only one soil application, 20-25 cm above the seed sets was made right after the rows close in, planting furrows being first filled up through intertillage; and (3) non-ridging except with the leveling of furrows through intertillage. It was concluded that ridging before the start of the rainy season was of value in sustaining a higher yield under the environmental conditions of all cane-growing districts of Taiwan (with the possible but improbable exception of the East Coast Plains which were not included in this study). All varieties reacted similarly to the customary and the simplified system of ridging except

N:Co 310, the thin-stalked variety, which reacted favorably to the more elaborate high ridging system.

Halwagy (4) mentioned the effect of producing a robust shoot by periodical burial by sand on Agropyron junceum L., Elymus arenarius L. and Ammophila arenaria Link and reported his trial on the responses of wheat to different depths of transplanting. This author transplanted wheat culms of the length of 50 cm into clay loam soil at depths of 10, 15, 20, 25 and 28 cm. It was shown that the 15 cm depth gave the maximum total number of shoots, number of flowering shoots, dry weight of shoots, dry weight of spikes and dry weight of whole plants. Further increase in depth of transplanting decreased the number of shoots and the other items. Field trials in this respect were proposed by the author. Ridging may be a substitute for deep transplanting in agricultural practice.

Krishnaswamy and Thangavelu (6) observed that under deep water conditions, tillers of rice were produced from upper nodes. This suggests that a high oxygen supply may be needed for the development of tiller buds. It is possible that under the conditions of ridging, limitation of oxygen supply may also be one of the factors which suppress the development or growth of tiller buds.

Working on the relationship of the growth of sugar beet roots and oxygen diffusion rate of soils, Wiersma and Mortland (19) applied calcium peroxide as an oxygen supplier in clay, silty clay loam and loamy sand with free water table 12 inches from the surface of the soil. Peroxide treatment increased the beet yield on the loamy sand which had the lowest oxygen diffusion rate.

Scott (13) applied calcium peroxide in a compacted soil layer of a bulk density of 1.95 and found that more fibrous roots of alfalfa were present in the compacted layer receiving peroxide treatments as compared to compaction without peroxide. He concluded that impedance is not the physical soil factor which restricts the growth of roots in unconsolidated layers with a bulk density as high as 1.95 but that oxygen is the factor restricting or retarding the normal growth of roots.

Experiment I. Effects of Ridging on Tillering and Growth of Sudangrass

MATERIALS AND METHODS

Greenhouse Experiment

Piper Sudangrass seeds were sown on Sims clay and Grandby sand in 10 inch clay pots on February 1, 1963. One plant was kept in each pot after thinning. Simulative ridging was made by adding 1 1/2 inches more soil to the pots to cover the basal parts of plants at different stages of development. The first ridging treatment (R_1) was applied on February 22 when plants had an average height of 15.9 cm on clay soil and 13.5 cm on sandy soil. The second ridging treatment (R_2) was applied on March 11 when the primary tillers of plants on clay soil had an average height of 17.0 cm and on sandy soil 14.2 cm. The third ridging (R_3) was applied on plants grown on clay soil on April 1 when the longest secondary tillers were about 15 cm in length. It was applied to the plants on sandy soil on April 10 when they attainded the same stage of development. Non-ridged plants were used as a control (R_0). Four plants were used for each treatment. Mode of tillering was observed during the course of the experiment. Plants were harvested on April 27.

Field Experiment

This experiment was conducted on the Crop Science Farm of Michigan

State University at East Lansing, Michigan. The soil was Conover loam with moderate natural fertility. The land was fertilized with 400 pounds of 5-20-20 fertilizer per acre and disked on May 8; soil was harrowed on May 14, 1963. Piper Sudangrass was seeded on May 15. Ammonium nitrate was broadcast on the surface at a rate of 300 pounds per acre on May 20, about 8 days before emergence.

Piper Sudangrass was seeded at 10 and 20 pounds per acre. Ridging treatments were applied at different times by earthing the rows with soil to cover the basal 2 inches of the stem.

R_0 treatment -- non-ridged control.

R_1 treatment -- ridging on June 13 when plants had 6 leaves.

R_2 treatment -- ridging on June 21 when plants had 7-8 leaves.

R_3 treatment -- ridging on June 29 when plants had 8-9 leaves.

A complete randomized block design was used. Each block consisted of 8 treatments; each plot 5, 10-foot rows 10 inches apart. Treatments were replicated 6 times.

There was adequate moisture for germination and early growth. The field was dry during late June and early July. Plots were sprinkler irrigated with 2-3 inches of water on July 6 and it rained on July 24. Two cuttings were made on July 20 and August 31. Number of stalks per yard of the central three rows was counted one day before each harvesting.

EXPERIMENTAL RESULTS

Greenhouse Experiment

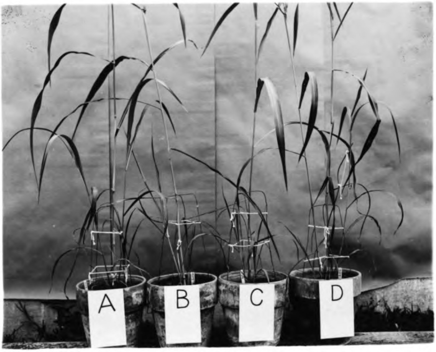
The number of tillers was counted as they emerged from the leaf sheaths or the ridged soil during the course of the experiment. Sudangrass plants grew more vigorously on Sims clay and developed more tillers than those on Grandby sand. During the late part of this experiment, e.g. in April, plants on the sandy soil showed signs of nitrogen deficiency although 2.5 gm. of 15-15-15 fertilizer had been applied to the soil of each pot at planting time. R_1 and R_2 treatments reduced the number of tillers of plants on both soils. Average date of the appearance of the first tiller in the R_1 treatment was about 10 days later than in the non-ridged plants in the clay soil culture while the appearance of the first tiller of the R_1 treatment in sand culture was about 19 days later than where not ridged (Figure 1, 2 and Table I).

The mode of tillering was very uniform on both soils. The first two tillers from the axils of the first and second foliage leaves emerged on the same day or successively within 2 or 4 days. The tiller from the axil of the third leaf appeared about 10-20 days later depending on the vigor of growth. These primary tillers were in the same plane as the foliage leaves. The secondary tillers arose immediately after or a few days later than the development of the third primary tiller.

Figure 1. Plants grown on clay soil. A, non-ridged control, B, C, and D are plants of R_1, R_2 and R_3 treatments, respectively.

Figure 2. Plants grown on sandy soil. A, non-ridged control, B, C, and D are plants of R_1, R_2 and R_3 treatments, respectively.


A
B
C
D


A
B
C
D

In this experiment, most of the secondary tillers of the plants grown on clay soil started to grow between 42-53 days after planting while those of plants on sandy soil started to grow between 53-60 days after planting. The secondary tillers grew on planes perpendicular to that of the primary tillers. The fourth primary tiller and the axillary buds in a higher position grew occasionally and irregularly at later periods of growth.

Field Experiment

In the first cutting, the first ridging treatment (R_1) reduced both fresh grass yield and number of tillers per yard at the 1% level of significance at a seeding rate of 10 pounds per acre. However, ridging had no effect when the seeding rate was increased to 20 pounds per acre. The high rate of seeding increased both fresh grass yield and the number of stalks per yard significantly at the 1% level (Table II). A significant coefficient of correlation of 0.4440 between fresh grass yield and the number of stalks per yard was obtained. r values of 0.8327, 1.0000 and 0.7915 were obtained by analysis of covariance of ridging, seeding rate and their interaction respectively, but none of them was significant at the 5% level due to low degrees of freedom. No significant effect of ridging was found in the second cutting. The seeding rates, however, still had effects on both fresh grass yield and the number of stalks per yard. The coefficient of correlation between number of stalks per yard and yields decreased to 0.3648 in the second crop. It was significant at the 5% level.

Experiment II. Anatomical Study of Tiller Formation

MATERIALS AND METHODS

Piper Sudangrass seeds were sown 1 cm below the surface of builder's sand in wooden trays on April 14, 1963. They germinated uniformly on April 18. Complete nutrient solution was applied twice a week.

Samples of the basal part of stems were taken at different stages of development.

Date of sampling	Stage of growth
April 18	First foliage leaves were 1.5-2.0 cm out of the coleoptile; first leaf stage
April 20	Second leaves were 1.5-2.0 cm out of the first leaves; second leaf stage
April 25	Third leaf stage
April 30	Fourth leaf stage
May 5	Fifth leaf stage
May 9	Sixth leaf stage

Tillers became apparent at the sixth leaf stage.

Table I. Effects of ridging on tillering of Sudangrass in the greenhouse

Soil	Treatment	Av. date of tillering (days after planting)	Total number of tillers per plant	Fresh wt. of plant (gm)	Length of main stem (cm)
Sims clay	R_0	30.7	11.0	83.5	101.5
	R_1	41.3	6.5	73.0	104.3
	R_2	31.0*	7.3	104.7	92.7
	R_3	34.5*	11.8	90.0	80.3
Grandby sand	R_0	32.8	5.8	50.5	114.0
	R_1	51.3	3.8	49.0	104.5
	R_2	31.0*	5.0	38.0	106.3
	R_3	33.0*	7.0	63.0	108.0

* Plants tillered before ridging.

Table II. Number of stalks per yard of row and fresh grass yield of first and second cuttings

Seeding rate	Ridging treatment	First cutting		Second cutting	
		No. of stalks per yard	Yield (lbs.)	No. of stalks per yard	Yield (lbs.)
10 lbs. per acre	R_0	34.33 a*	15.25 a	78.17	16.55
	R_1	25.50 abc	13.88 abc	75.33	16.16
	R_2	31.00 b	15.38 b	70.00	17.16
	R_3	31.67 c	15.20 c	72.50	17.15
	Average	30.63 d	14.93 d	74.42 a	16.76 a
20 lbs. per acre	R_0	38.00	15.65	90.33	17.78
	R_1	39.50	15.72	85.16	17.42
	R_2	39.33	15.63	85.83	17.85
	R_3	38.17	16.18	90.00	18.17
	Average	38.75 d	15.80 d	87.83 a	17.80 a

* Means within same seeding rate and averages of seeding rates in the same column with the same letter are different at 1 or 5% levels.

Samples were fixed in a mixture of ethyl alcohol, water and formaldehyde (60:40:4 by volume). Paraffin sections were made and stained with safranin, orange G and gentian violet by the Fleming triple stain method.

EXPERIMENTAL RESULTS

Differentiation of primary tiller buds was studied in longitudinal section cut in the same plane as that of the foliage leaves. Microscopic observations revealed the differentiation of axillary buds and their development.

At the first leaf stage, 5 nodes had been formed on the main stem (including the node of the coleoptile). Three bud primordia were found in the axils of the first three foliage leaves on 5 out of 10 plants observed. These primordia were just small groups of cells at the axils. Four plants were found to have 2 bud primordia in the axils either of the first and second leaves or of the second and third leaves. One plant had not formed any bud primordia. Figures 3, 4 and 5 show the bud primordia at this stage. No bud had been formed at the node of the coleoptile and no bud appeared in the following stages of growth. Macroscopic observations also showed that it was not a tiller bearing node.

At the second leaf stage, 6 nodes had been formed on the main stem. Most plants observed had 4 bud primordia. Differentiation in size occurred. Basal bud primordia grew faster than those located at higher nodes. The first bud had already differentiated one node on 4 out of 8 plants observed.

At the third leaf stage all plants had 7 nodes on the main axis with 5 buds and their primordia at the axils of foliage leaves. The first axillary bud had differentiated 2-3 leaves and the second axillary buds had 1-2 leaves.

This pattern of differentiation held true until the fifth leaf stage. At the nth leaf stage, n+4 nodes had been formed on the main stem. n+2 axillary buds had been differentiated (Table III). At the sixth leaf stage, eleven nodes had formed on the main stems and most plants had a total of 9 axillary buds, some as yet still in the primordial stage. The five basal buds had differentiated leaves (Figure 6).

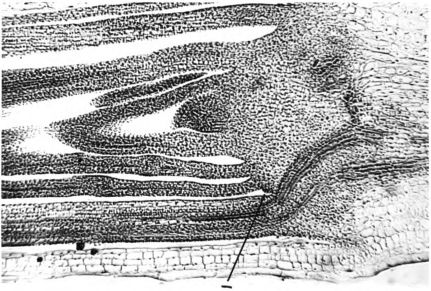
Table III. Differentiation of primary tillers*

Stage of development	No. of nodes on the main stem**	No. of axillary buds differentiated	No. of nodes differentiated on axillary buds					
			1st	2nd	3rd	4th	5th	6th
1st leaf stage	5.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0
2nd leaf stage	6.0	3.9	0.5	0.0	0.0	0.0	0.0	0.0
3rd leaf stage	7.0	5.0	2.1	1.1	0.0	0.0	0.0	0.0
4th leaf stage	8.0	6.0	3.5	3.0	1.7	0.0	0.0	0.0
5th leaf stage	9.4	7.2	5.0	4.8	3.7	0.0	1.7	0.0
6th leaf stage	11.0	8.9	6.8	6.7	5.6	2.0	4.0	0.0

*Data from 7-10 plants for each stage.
**Including coleoptile node.

Figure 3. Longitudinal section of Sudangrass seedling at the first leaf stage showing the primordium of tiller bud at the axil of the first foliage leaf.

Figure 4. Longitudinal section of Sudangrass seedling at the first leaf stage showing the primordium of tiller bud at the axil of the second foliage leaf.



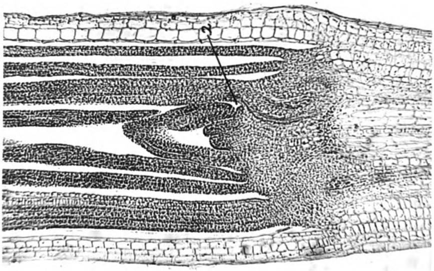
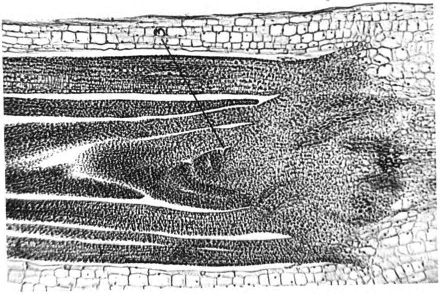
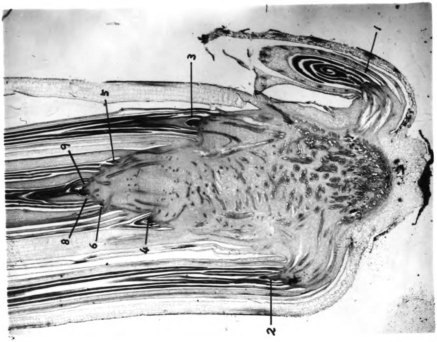


Figure 5. Longitudinal section of Sudangrass seedling at the first leaf stage showing the primordium of tiller bud at the axil of the third foliage leaf.

Figure 6. Longitudinal section of Sudangrass seedling at the sixth leaf stage showing young tillers, tiller buds and tiller bud primordia at the axils of first through ninth foliage leaves with bud primordium at the axil of seventh leaf missing in this section.




1
2
3
4
5
6
8
9

The development of secondary tillers was studied with longitudinal sections cut at planes perpendicular to that of the foliage leaves. It was found that secondary tillers started to differentiate at the fourth leaf stage. A maximum number of 2 secondary tiller bud primordia had been found on the first primary tiller and one on the second primary tiller. The leaf on the first node of the primary tiller was a protective sheath. No bud was found at this node.

The differentiation of secondary tiller buds followed the same pattern of that of the primary tiller buds. At the sixth leaf stage secondary tiller buds had been formed on the first four primary tillers (Table IV). The first and second tiller buds already had 2 and 1 leaves differentiated respectively (Figure 7).

Table IV. Differentiation of secondary tillers*

Primary tillers	No. of secondary tillers**		
	4th leaf stage	5th leaf stage	6th leaf stage
1st tiller	2	3	5
2nd tiller	1	3	4
3rd tiller	0	2	3
4th tiller	0	1	2
5th tiller	0	0	0

* Data from 5 plants for each stage.

** Maximum number found on single plant.

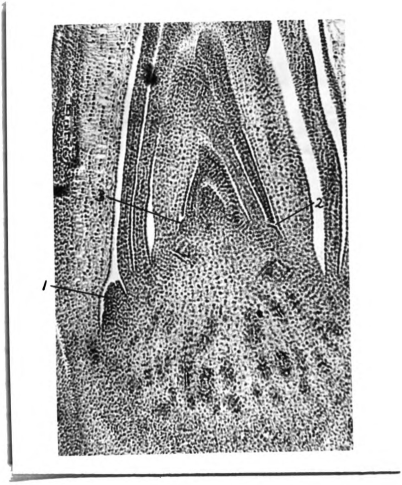


Figure 7. Longitudinal section of the first primary tiller of a Sudangrass seedling at the sixth leaf stage showing primordia of secondary tiller buds at the axils of first, second and third foliage leaves.

Experiment III. Effects of Shading on Tillering and Its Interaction with Ridging

MATERIALS AND METHODS

This experiment was conducted under controlled conditions in a growth chamber. Piper Sudangrass seeds were sown in 16 ounce cottage cheese cartons on February 19, 1964. A loamy soil was used. After germination, seedlings were thinned gradually to 3 plants per culture.

Temperature in the growth chamber was adjusted at 25°C. Plants were illuminated with fluorescent light. Light intensity at the level at the top of the pots was 2,000 f.c. The growth chamber was separated into 4 compartments with white paper boards on March 3 when plants were at the fourth leaf stage. Light intensity in each compartment was adjusted by shading with layers of cheesecloth. Four light treatments were applied as follows.

Full light -- 1,800 f.c.

Reduced light 1 -- 1,120 f.c.

Reduced light 2 -- 690 f.c.

Reduced light 3 -- 300 f.c.

The paper board septa were baffled to increase air circulation between compartments when air was blown across the chamber by the circulating system. Temperature in the chamber measured after light treatments had been applied varied with time between 22-24°C, however, no appreciable difference was found between compartments. During the light period, soil temperature at the surface was usually 1-2°C lower than the air temperature due to evaporation in the full light compartment. It was about 2.5°C lower in the 300 f.c. compartment than in the 1,800 f.c. compartment.

There were ten pots in each compartment, each with 3 plants. On March 4, plants in 5 pots were ridged by adding on another cottage cheese carton, with bottom removed, as a collar and filling in soil to 2 inches.

All treatments were harvested on March 27, 1964.

EXPERIMENTAL RESULTS

Non-ridged plants started tillering on March 9, 19 days after planting, under all light treatments except 300 f.c. For ridged plants, however, the appearance of the first tiller was delayed from 1 to 5 days by shading. Figure 8 shows the tillering process of ridged and non-ridged plants under different light intensities. Reduced light treatments only prolonged the process of tillering of non-ridged plants for a few days without decreasing the number of tillers per plant. The number of tillers on ridged plants at the end of the experiment were reduced at 1,120 and 690 f.c. at 5% and 1% levels of significance respectively (Table V). Significant differences in total length of tillers and total dry weight of tillers per plant were only found between ridged and non-ridged plants under 690 f.c. fluorescent light. The percentage of plants tillering also was reduced greatly by shading on ridged plants. Under 300 f.c.

light, neither non-ridged nor ridged plants tillered. Ridging increased the height and dry weight of plants slightly under all light treatments. The effect of shading on the dry weight of plants was significant at the 1% level.

The number of tillers shorter than 2 inches on non-ridged plants and those that had not emerged from soil on ridged plants were compared. A large proportion of differentiated tiller buds grew longer than 1/2 inch but failed to emerge when plants were ridged. This proportion increased with increased shading.

Roots were found in the ridged soil at the three higher light treatments.

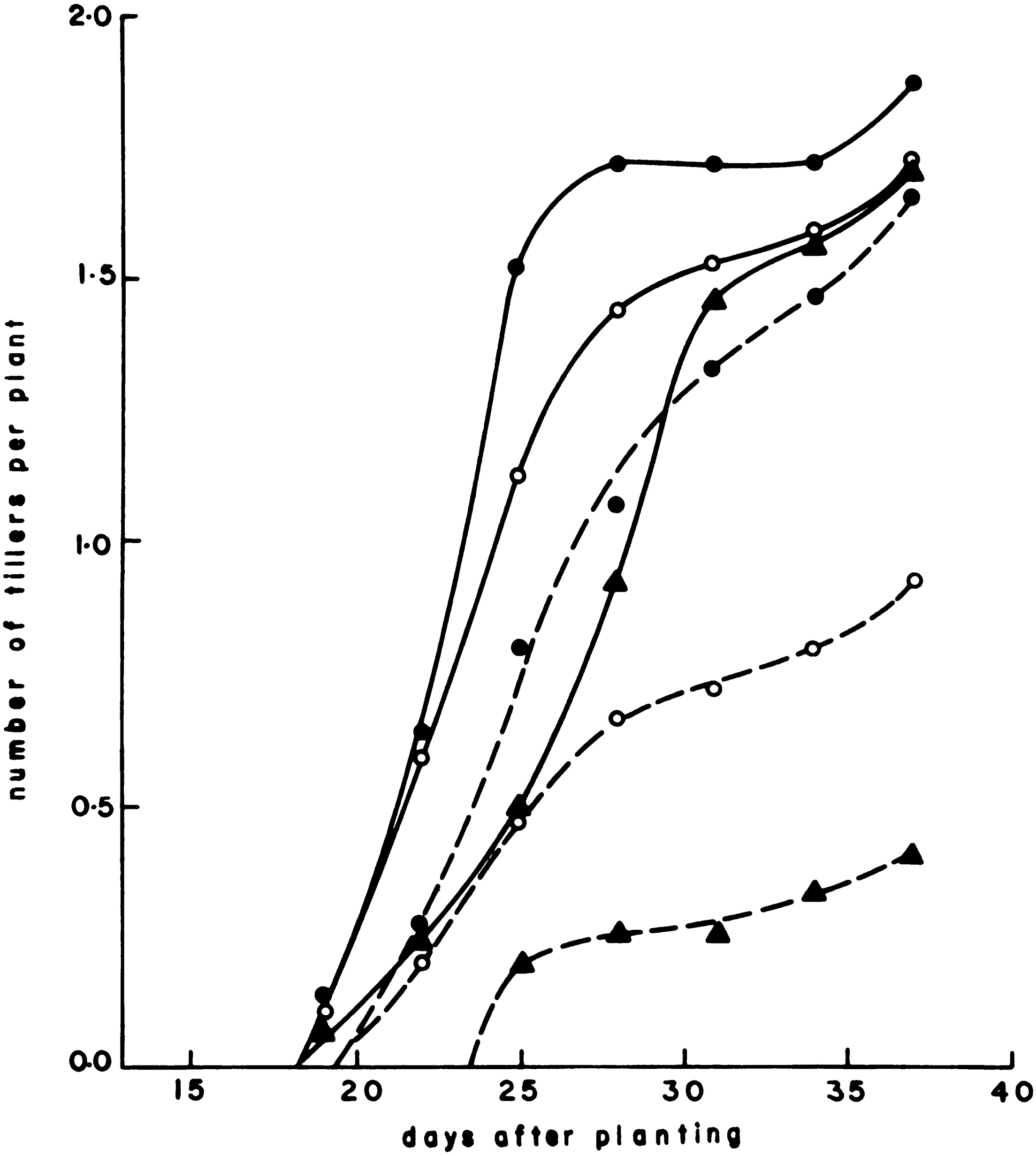


Figure 8. Effect of shading on tillering of Sudangrass under different light intensities. ● 1,800 f.c., ○ 1,120 f.c., ▲ 690 f.c., —— non-ridged, --- ridged.

Table V. Effects of shading on non-ridged and ridged Sudangrass

Treatment		Av. date of tillering (days after planting)	Percentage of plants tillered	Main stem		Tillers* per plant			No. of tillers under 2 inches or not emerged
				Height (cm)	Dry wt. (gm)	Av. no.	Total length (cm)	Total dry wt. (gm)	
1,800 f.c.	Non-ridged	22.4	100.0	78.60	1.09	1.9	37.07	0.10	0.07
	Ridged	23.1	80.0	81.50	1.17	1.7	43.17	0.12	0.80
1,120 f.c.	Non-ridged	22.7	100.0	83.17	0.89	1.7a**	36.17	0.06	0.27
	Ridged	24.0	53.3	84.10	0.89	0.9	22.17	0.05	1.07
690 f.c.	Non-ridged	25.0	93.3	79.13	0.49	1.7	31.43 a	0.04	0.07
	Ridged	27.0	26.7	83.13	0.55	0.4	9.67	0.02	0.73
300 f.c.	Non-ridged	---	0.0	53.00	0.14	0.0	0.00	0.00	0.20
	Ridged	---	0.0	61.23	0.18	0.0	0.00	0.00	0.27

* Counted as they appeared on ridged plants or when they attained two inches on non-ridged plants.

** Means in the same column with the same letter are different at 5 or 1% level.

Experiment IV. Effects of Fertility on Tillering of Ridged and Non-ridged Sudangrass Plants

MATERIALS AND METHODS

Growth Chamber Experiment

Piper Sudangrass seeds were sown in builder's sand in 16 ounce cottage cheese cartons on April 3, 1964. Two 6 inch glass tubes (1 inch in diameter) were one-third buried in the sand. More sand was added to the tubes to a level one inch above the outside sand surface. Two seeds were sown in each tube. After germination, seedlings were thinned to one per tube. Plants were illuminated 12 hours daily with fluorescent light of the intensity of 2,000 f.c. at pot level. Temperature in the chamber was controlled at 24–25°C. Plants were watered with modified Hoagland nutrient solution.

On April 17, 36 cultures were selected and separated into 3 groups. The 12 of the first group were used for full nutrient treatment and watered with nutrient solution A (full strength Hoagland nutrient solution) every two days. Each of the 12 cultures of the second group was leached discontinuously with a total amount of 500 ml tap water at the start of the treatment and was watered afterward with nutrient solution A every six days and with nutrient solution B (1/10 strength in macronutrients and full strength in micronutrients of modified Hoagland nutrient solution) on the days when nutrient solution A was applied on group 1 but not on group 2.

Each culture of the third group was leached with a total amount of 1,000 ml tap water at the start of treatment and was watered afterward with nutrient solution B every two days. Three days after the nutrients were applied, all plants of group 2 and 3 showed signs of insufficient nutrient supply.

On April 18, a simulated ridging treatment was applied on one of the two plants in each pot by adding 2 inches of greenhouse loamy soil into the glass tube as shown in Figure 9. The ridged soil was usually wet due to the capillary water arising from the sand.

All plants were harvested on May 11, 1964.

Greenhouse Experiment

Greenhouse loamy soil was screened through a 1/2 inch screen and was thoroughly mixed before planting. Ten to twelve seeds were sown in each of 64 10 inch clay pots on February 2, 1964. 15-15-15 fertilizer was applied at the rates of 0, 250, 500 and 1,000 pounds per acre and was mixed with the soil one inch below the seeds. Each fertility treatment consisted of 16 pots. After gemination, seedlings were thinned gradually to 3 plants per pot. Simulative ridging was made on 8 pots of each fertility treatment by adding 2 more inches of soil to each culture on February 18, when plants had attained 7-8 inches in height. At this time, plants were in the third leaf stage. Plant development was apparently retarded under the greenhouse conditions. The first cutting was made on April 16.

After the first cutting, the ridged soil was removed from 4 out of the 8 ridged cultures of each fertility treatment. Regrowth of the second crop and its yields were recorded. A second cutting was made on May 26.

EXPERIMENTAL RESULTS

Growth Chamber Experiment

Figure 9 and the height and the dry weight yields of plants in Table VI show that nutrient supplies were successfully controlled by the method used in this experiment. Analysis of variance showed that the effect of nutrient treatment on the total dry weight of plants was significant at the 1% level.

The development of tillers of non-ridged and ridged plants at different fertility levels is shown in Figure 10. Ridging delayed tillering and significantly reduced the number of tillers per plant of the full nutrient treatment at the time of harvest. However, no significant difference in the total length and total dry weight of tillers per plant was obtained (Table VI). Ridging treatment had less effect on plants of low nutrient treatment. Average number of tillers per plant was reduced from 2.08 of control plants to 1.75 of the ridged plants but the difference was not significant statistically.

Figure 9. Picture taken one week before harvest. From left to right, full nutrient, low nutrient and very low nutrient treatment. In each pot, left, ridged plant; right, non-ridged plant.

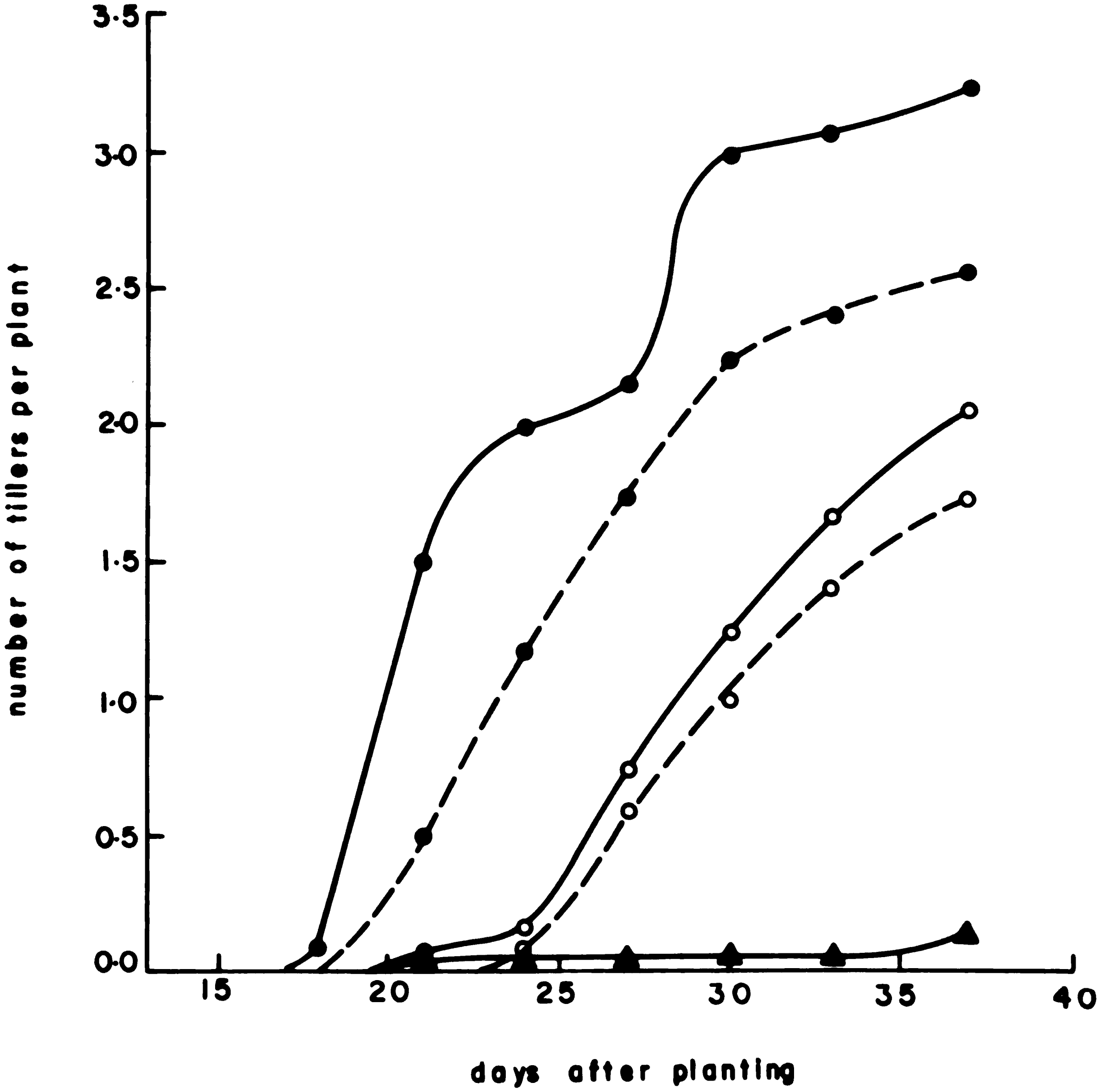


Figure 10. Effects of nutrients on the tillering of ridged and non-ridged Sudangrass. ● full nutrient, o low nutrient, ▲ very low nutrient, —— non-ridged, --- ridged.

Table VI. Effect of nutrient on the tillering of ridged and non-ridged Sudangrass Plants

Treatment		Av. date of tillering (days after planting)	Percentage of plants tillered	Main stem		Tillers* per plant			No. of tillers under 2 inches or non-emerged tillers
				Height (cm)	Dry Wt. (gm)	Av. no.	Total length (cm)	Total dry wt (gm)	
Full nutrient	Non-ridged	20.2	100.0	70.58	1.47 a**	3.3 a	77.73	0.36	0.16
	Ridged	21.3	100.0	74.98	1.93 a	2.6 a	65.47	0.35	0.42
Low nutrient	Non-ridged	26.4	83.3	59.29	0.86 b	2.1	28.87	0.09	0.50
	Ridged	27.3	83.3	62.16	1.12 b	1.8	26.14	0.09	0.67
Very low nutrient	Non-ridged	---	8.3	48.53	0.41	0.2	1.60	0.00	1.42
	Ridged	---	0.0	51.18	0.47	0.0	0.00	0.00	1.42

* Counted as they appeared on ridged plants or when they attained 2 inches on non-ridged plants.

** Means in the same column with the same letter are significant at 5 or 1% levels.

Ridged plants with full nutrient had an average of 0.42 non-emerged tillers per plant. This was much higher than the average number of tillers which were shorter than 2 inches on the non-ridged plants. At the low fertility level, ridged plants had an average of 0.67 non-emerged tillers per plant in comparison with 0.50 short tillers on each non-ridged plant. Percentage of plants tillered were the same between ridged and non-ridged plants at both high and low nutrient levels.

Only one plant of the very low nutrient treatment formed one tiller one week after the start of nutrient treatment. This tiller remained the same size for the duration of this experiment. At the end of the experiment another tiller on the same plant had attained a height of 2 inches. All other plants had either tillers under 2 inches in length or had non-emerged tillers only.

Greenhouse Experiment

I. First cutting

During early springtime, light intensity and temperature were very variable in the greenhouse. Temperature could be maintained at 75-80°F only on cloudy days when natural light intensity was low. On sunny days, light intensity increased to above 2-3,000 f.c. but it was usually accompanied by an increase in temperature to above 90-95°F. Sudangrass grown under these conditions elongated extensively, had tender leaves in an early stage of development and was retarded in tillering.

Tillering of ridged and non-ridged plants of 4 different fertility levels are shown in Figure 11. All ridged treatments tillered much later than the non-ridged ones. Higher fertility hastened tillering in both ridged and non-ridged plants.

Yield data are shown in Table VII. The soil used in this experiment contained enough nutrients that plants did not show signs of nutrient deficiency. Higher fertilities seemed to increase the dry weight of plants, however, statistical analysis showed that the effect was not significant. Number of tillers per plant was not affected by added fertility, however, the total dry weight of tillers per plant was affected at the 5% level. Ridging significantly reduced the number of tillers per plant in 0, 250 and 500 pound per acre treatments, but no significant difference among the total dry weights of tillers per plant could be attributed to the effects of ridging.

After the tillering stage only main stems grew to maturity while all tillers remained in their juvenile stage. This is shown by comparing the dry weight of the main stem and the total dry weight of tillers per plant in Table VII.

Ridged plants outyielded non-ridged plants in all cases. Significant differences were obtained in 0, 500 and 1,000 pound per acre treatments.

II. Second cutting

Tiller development of the second cutting is shown in Figure 12. Non-ridged plants sent out tillers faster than the ridged plants.

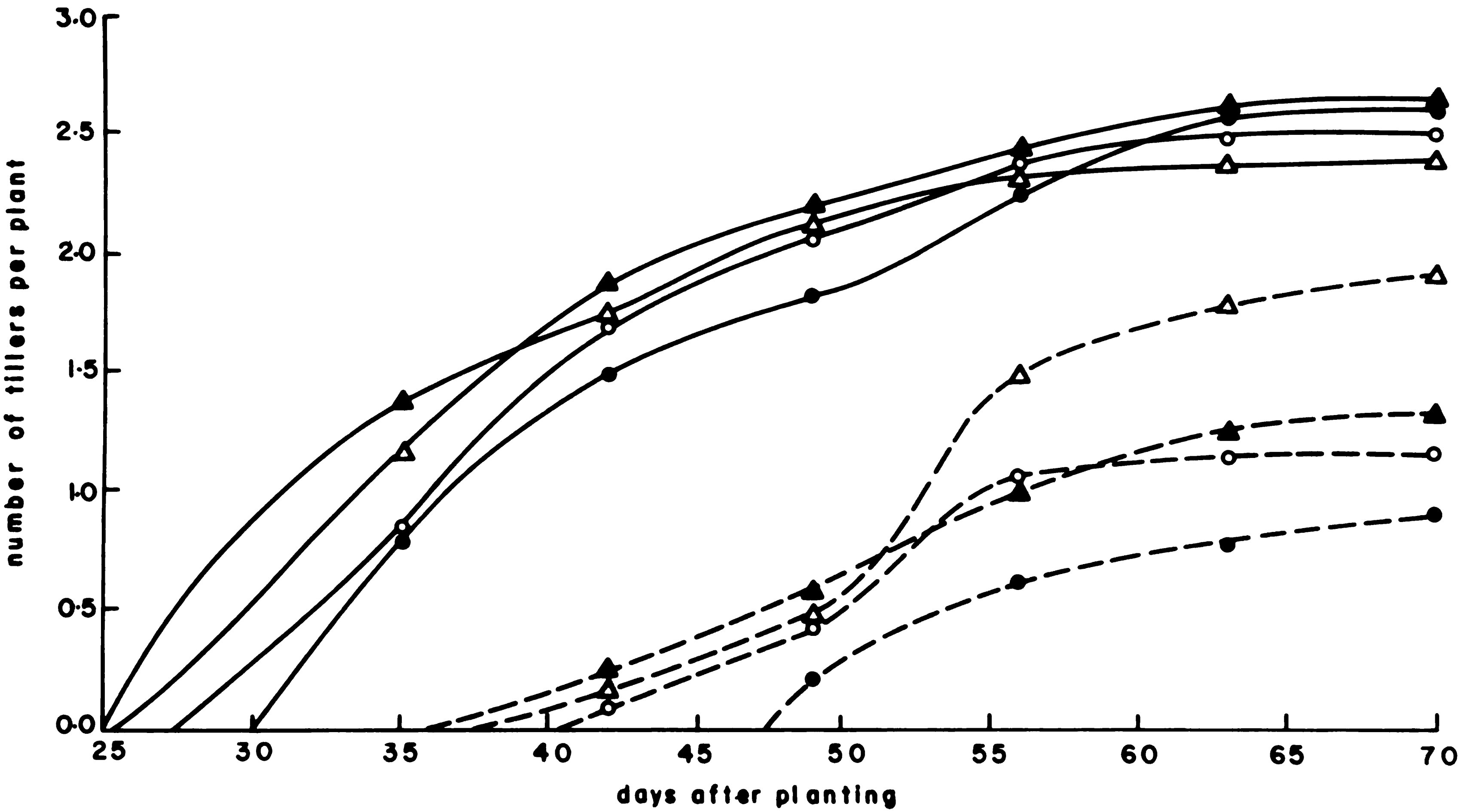


Figure 11. Effects of fertilizer application on the tillering of ridged and non-ridged Sudangrass. ● control, ○ 250 lbs/acre, △ 500 lbs/acre, ▲ 1,000 lbs/acre, —— non-ridged, --- ridged.

Table VII. Effect of fertilizer application on the tillering of ridged and non-ridged Sudangrass plants

Table VII. Effect of fertilizer application on the tillering of ridged and non-ridged Sudangrass plants

Treatment		Av. date of tillering (days after planting)	Percentage of plants tillered	Dry wt. of main stem (gm)	Tillers* per plant		Total dry wt. of shoot per plant (gm)
					Av. no.	Total dry wt. (gm)	
0 lbs per acre	Non-ridged	37.0	100.0	4.03	2.6 a**	0.27	4.30 a
	Ridged	51.4	58.3	6.36	0.9 a	0.15	6.51 a
250 lbs per acre	Non-ridged	37.6	100.0	5.65	2.5 b	0.29	5.94
	Ridged	48.4	66.6	6.91	1.2 b	0.56	7.47
500 lbs per acre	Non-ridged	32.5	100.0	4.63	2.6 c	0.26	4.89 b
	Ridged	45.0	66.6	7.43	1.3 c	0.31	7.74 b
1,000 lbs per acre	Non-ridged	30.2	95.8	5.61	2.4	0.56	6.17 c
	Ridged	48.3	91.6	7.92	1.9	0.74	8.66 c

* Counted as they appeared on ridged plants or when they attained 2 inches on non-ridged plants.

** Means in the same column with the same letter are significant at 5 or 1% levels.

Removing ridged soil also hastened tillering.

Yield data are shown in Table VIII. Ridged plants had the highest yield; plants with ridges removed in the second crop also outyielded the non-ridged plants though the latter had more tillers (Figure 13). Most of the differences in yields are significant at 1 or 5% levels.

The advantages in growth vigor and yields of ridged plants in either the first or second cutting may be attributed to the well developed crown parts of the plants. Non-ridged plants developed tillers and roots only from nodes near the soil surface. Ridged plants developed more roots from 2 or 3 nodes higher up when they were covered by soil (Figure 14). In the second cutting, non-ridged plants did not show any responses to fertilizer. Plants with ridges removed during the second crop were also paler in color than the ridged plants.

Table VIII. Dry weight (gm) of non-ridged and ridged plants grown at different fertility levels

Treatment	Fertilizer (lbs/acre)				
	0	250	500	1,000	Average
Non-ridged	2.50 a*	2.45 ab	2.14 ab	2.85 ab	2.50 ab
Ridge removed in second crop	6.26	6.63 a c	7.08 a c	9.80 a	7.44 a c
Ridged	9.37 a	11.11 bc	12.03 bc	9.92 b	10.61 bc

* Means in the same column with the same letter are different at 5 or 1% level.

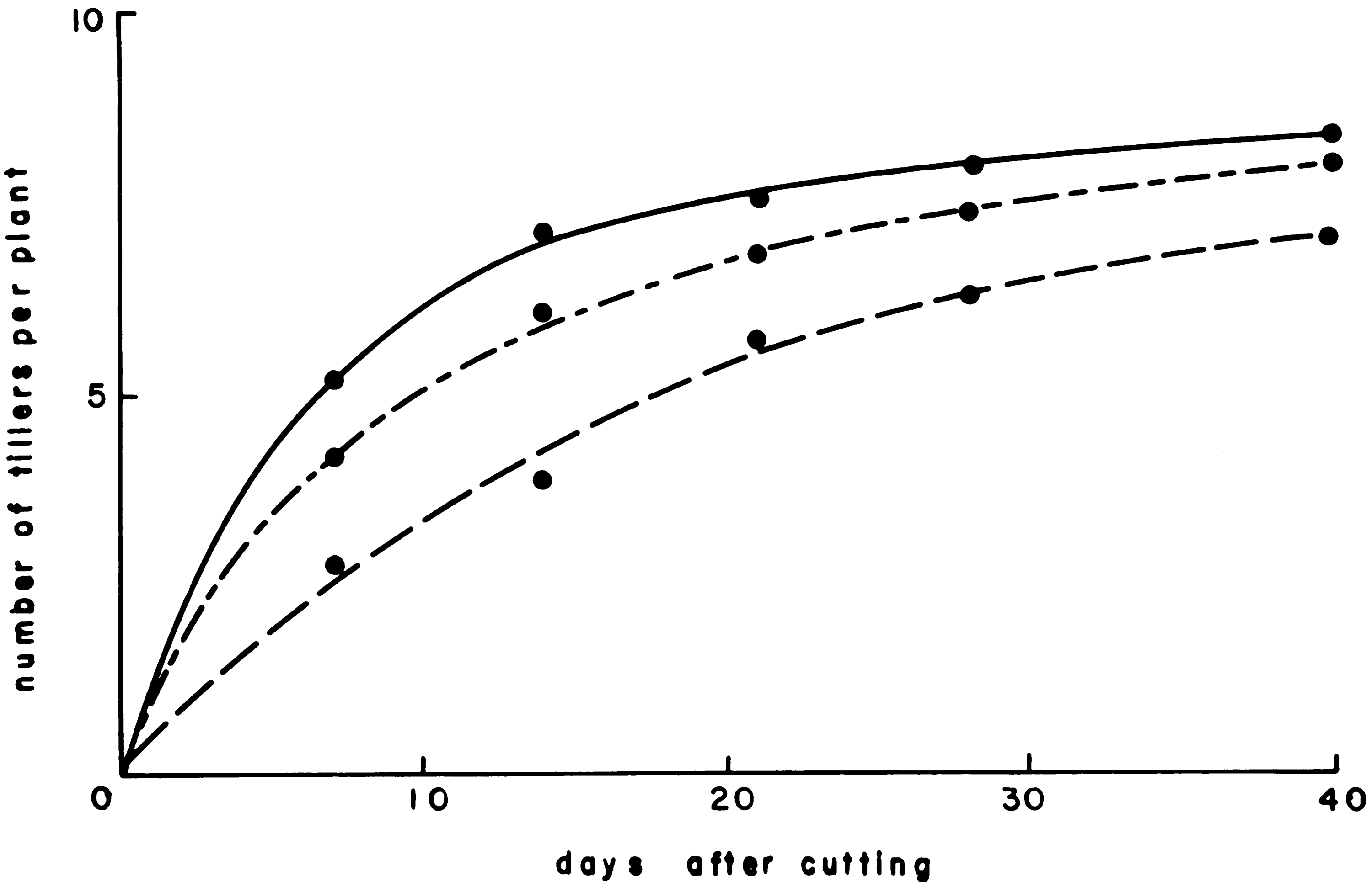


Figure 12. Tillering of second crop. —— non-ridged treatments, —·— ridged in first crop, ridges removed in second crop, --- ridged treatments.

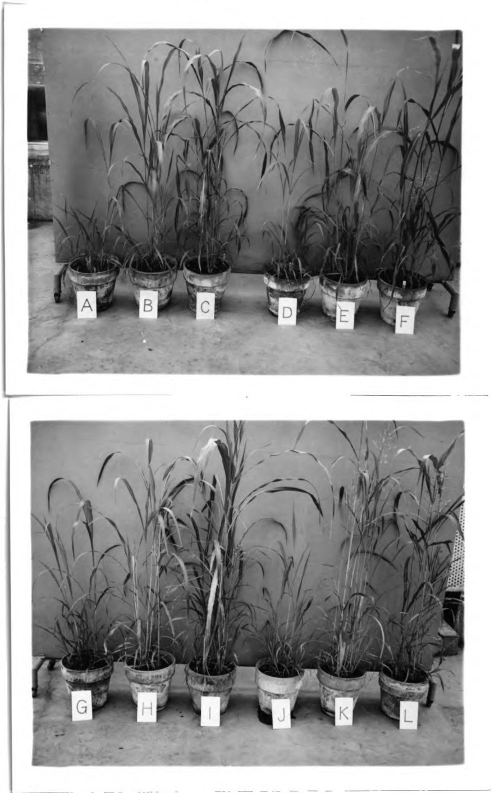


Figure 13. Plants of second crop. A-C, 0 lbs per acre; D-F, 250 lbs per acre; G-I, 500 lbs per acre; J-L, 1,000 lbs per acre. In each fertility group: left, non-ridged; middle, ridged with ridge removed in second crop; right, ridged plants.

Figure 14. Crown and root system of non-ridged (left), ridged with ridge removed in the second crop (middle) and ridged (right) plants of 500 lbs per acre treatment. Note difference in crown and type of root growth.

Experiment V. Effects of Peroxide Treatment and Ridging on Sudangrass

MATERIALS AND METHODS

Calcium peroxide[1] was used as an oxygen supplier. Information from the manufacturer[2] indicates that it decomposes slowly at a relative humidity of 80 percent and loses 11.7 percent of its active oxygen per week. Scott (13) reported that when being mixed in soil this chemical released oxygen at rather a constant rate over a period of 7 weeks.

One 6 inch glass tube (1 inch in diameter) was one third buried in the soil in a 4 inch clay pot. Soil was added in the tube and Sudangrass seeds were sown in the tube at 3 inches from the upper end. Two Sudangrass seeds were sown in each tube on May 23, 1964. After germination seedlings were thinned to 1. Plants were grown in the growth chamber at 25°C and with 12 hour illumination. Light intensity was 2,000 f.c. at the level of the top of the pot. On June 5, 60 uniform plants were selected and were divided into 3 groups. Plants of the first group were ridged by adding 2 inches of greenhouse loamy soil into the glass tube. Plants of the second group were ridged with the same kind of soil with 1% calcium peroxide mixed into it. A small glass tube (1/4 inch in diameter, 5/8 inch in length) filled with 0.13-0.15 gm calcium peroxide was put beside the basal part of the stem of each plant of the third group, then, these plants were ridged as group one.

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[1]Courtesy of Dr. E. A. Erickson, Department of Soil Science, Michigan State University.

[2]Buffalo Electro Chemical Company, Inc. Buffalo

Soil in the glass tube was kept wet by daily watering.

Light intensity was reduced to and was kept afterward at 1,000 f.c. after the ridging treatment was applied.

All plants were harvested on June 21.

EXPERIMENTAL RESULTS

The tillering of Sudangrass is shown in Figure 15 and Table IX. Plants of all treatments tillered at about the same time. 1% calcium peroxide mixed in the ridged soil seemed to increase the total length of tillers and the total dry weight of tillers per plant, but the differences were not significant statistically. Calcium peroxide applied in the small tubes which were buried in the ridged soil increased the number of tillers during the latter period of this experiment. It also increased the total length and dry weight of tillers per plant. However, only the difference of number of tillers between this treatment and the ordinary ridged plants was significant at the 5% level. A difference of 0.05 gm was obtained in the average dry weight of tillers per plant between this treatment and the ordinary ridged treatment. The number of non-emerged tillers was reduced by the peroxide treatments. Calcium peroxide applied in glass tubes had more effect than that mixed with the soil. Percentage of plants tillered was not affected by peroxide treatment.

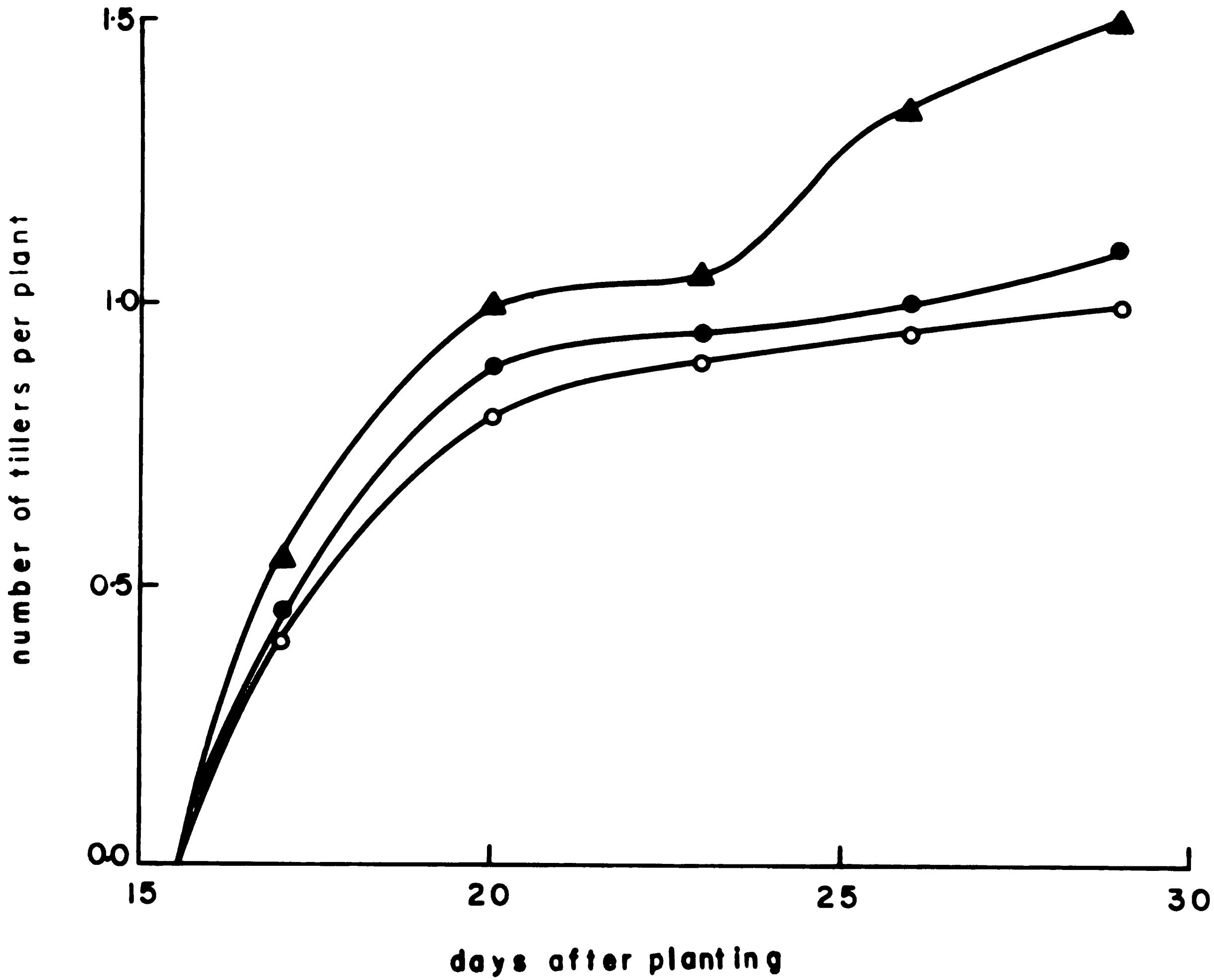

Figure 15. Effects of calcium peroxide on tillering of ridged Sudangrass. —o— ridged, —●— ridged + 1% CaO_2, —▲— ridged with CaO_2 in a glass tube.

Table IX. The effects of calcium peroxide on the tillering of ridged Sudangrass plants

Treatment	Av. date of tillering (days after planting)	Percentage of plant tillered	Main stem		Tiller* per plant			No. of non-emerged tillers per plant
			Height (cm)	Dry weight (gm)	Av. no.	Total length (cm)	Total dry wt. (gm)	
Ridged	18.41	85	112.16	2.13	1.0 a**	22.95	0.07	1.65
Ridged with 1% CaO_2	18.12	85	110.68	2.04	1.1	29.97	0.09	1.40
Ridged with CaO_2 in glass tube	18.41	85	111.20	2.02	1.5 a	36.60	0.12	1.05

* Counted as they appeared from the ridged soil.

** Means in the same column with the same letter are different at 5% level.

DISCUSSION

Anatomical studies showed that Sudangrass seedlings differentiated more than enough tiller buds for the normal tillering process under favorable conditions. The effects of light intensity, nutrition and ridging on tillering are thus a matter of influencing further development of these buds. The order of tiller bud formation is identical with that of rice plants reported by Nishikawa and Hanada (10). Buds of secondary tillers had been formed before the appearance of primary tillers. The formation of secondary tiller buds follows the same pattern as the formation of primary tiller buds.

Light intensity, probably combining with temperature, is the primary factor controlling tillering of young Sudangrass plants. Under suitable conditions, Sudangrass attained the tillering stage 20-27 days after planting as shown in the growth chamber experiments. Plants grown in the greenhouse under relatively low light and high temperature during early springtime attained the tillering stage 30-50 days after planting. Decreasing light intensity to 690 f.c. only prolonged the tillering process but did not reduce the number of total tillers per plant during the period of experimentation, though the dry weights of plants markedly decreased with decreased light intensities. At 300 f.c. light, tillering was almost completely suppressed. It seemed that a threshold existed between 300-700 f.c. for tillering under experimental conditions.

Low light intensity and relatively high temperature was also found to suppress further development of young tillers. Tillers stayed at their juvenile stage while only the main stems attained maturity. Sullivan (15) mentioned that 80°F was the temperature for highest yield of dry matter of Sudangrass under controlled conditions. Fukaki (3) reported that under high light intensity, the growth of tillers was greater than that of the main stem. Otherwise, under low light intensity, the growth of tillers was less than that of the main culm. This was also true in Sudangrass. A similar phenomenon was observed in the experiments conducted in growth chambers when shading developed because of the density of experimental plants. Under the experimental conditions, light intensity was sufficient for plant growth and tillering. However, during the late period of these experiments self-shading on tillers by the leaves of the main stem occurred. Tillers usually stopped growth under this condition. This may account for the fact that in Experiments III, IV and V significant differences between treatments were usually obtained in the number of tillers per plant but not in the total length or dry weight.

Experiment IV, conducted in the growth chamber, showed that at the tillering stage, low fertilities markedly reduced the number of tillers at time of harvest. This relationship was also clearly shown at the beginning of the tillering stage of the greenhouse fertilization experiment which lasted for a much longer time and was harvested at the flowering stage. In the later period of this experiment, not much difference was found in the total number of tillers of plants at the different fertility levels. Therefore, a low nutrient supply might only delay tillering or prolong the tillering process similar to the effect of low light intensities. It is interesting to compare the plants of the 300 f.c. light intensity treatment of Experiment III and those of the very low nutrient treatment of Experiment IV. Plants of these two treatments were of similar height at harvest time but were quite different in dry weight. Plants grown under low light intensity had very poor dry matter accumulation; on the other hand plants grown under very low nutrient supply had much more dry matter per plant. The latter had an average of 1.42 tillers per plant though they did not attain the 2 inch criterion for counting in these experiments. Plants under very low light intensity had only 0.20 such tillers per plant. This suggests that the effect of light intensity on tillering is more profound than that of nutrient supply.

Greenhouse and field experiments (Experiment I) showed that the ridging treatment reduced the number of tillers per plant and significantly reduced the number of stalks per unit length of row and the yield of Sudangrass at 10 pounds per acre seeding rate. These reductions in number of stalks in the row and yields were not found when the rate of seeding was increased to 20 pounds per acre. Ridgings applied after the appearance of primary tillers and before the appearance of secondary tillers also reduced the number of tillers per plant under greenhouse conditions when a single plant occupied enough space for development. Ridging treatment applied at a similar stage in the field did not have the same effect. This shows the possible use of a ridging practice in commercial crop production when spacing and time of ridging are controlled.

The primary effects of ridging on tillering may be considered to be the mechanical hindrance of soil on the emergence of tillers and the reduction of oxygen supply for the growth of tiller buds. Tillers of Sudangrass generally come out through the leaf sheaths and at the same time press it apart from the main stem. Young tillers usually form an angle from the main stem as shown in Figure 16. Tiller buds of ridged plants emerge from soil usually with difficulty. The first primary tiller usually cannot emerge from the ridged soil because the leaf sheath of the first leaf is shorter than 2 inches. Without its protection the first tiller bud generally becomes crooked in the soil as shown in Figure 17. Tiller buds at the axils of the second and third leaves have better protection from the leaf sheaths. However, difficulties in emergence may be caused by the close contact of the leaf sheath with the main stem. These young tillers were etiolated and also became crooked and were very often arrested in the ridged soil.

Low light intensities greatly enhanced the effects of ridging. Ridged plants had more non-emerged tillers than emerged ones under low light intensities (Figure 18). It shows that under higher light intensity, plants could overcome the unfavorable conditions caused by ridging and send out more tillers.

The interaction of nutrient deficiency with ridging is different from that of light and ridging. Figure 18 shows that ridging had a similar effect in suppressing tillering at these three quite different nutrient levels. Increase in the number of non-emerged tillers of ridged plants and tillers under 2 inches on non-ridged plants caused by nutrient deficiency are also nearly parallel to each other. These plants were grown under relatively strong (2,000 f.c.) light which was enough for normal tillering. The lack of interaction between the effects of low nutrient supply and ridging also suggested that light is the primary factor which affects tillering under both ridged and non-ridged conditions while the effect of nutrient on tillering may affect the general amount of growth and vigor of the plants.

Fertilizer addition under greenhouse conditions, however, showed interaction of fertility and ridging effects at the late period of the growing season. At harvest, not much difference in the total number of tillers per plant was found between different fertility treatments of non-ridged plants. However, higher fertilities increased the number of tillers per plant of the ridged plants. During the whole growing season, the effect of fertility on the total performance of plants apparently may be shown in part in overcoming the unfavorable conditions caused by ridging.

The observation of Krishnaswamy and Thangavelu (6) on the tillering of deep water rice led to a speculation that a low oxygen supply in the ridged soil may be a limiting factor for the development and emergence of tillers. In this research, 2 inch ridges were applied in most cases. Tiller buds were therefore buried at a depth of 2 inches from the soil surface. At this depth, the condition is usually suitable for the growth of roots. If oxygen supply is a factor which suppresses tillering of ridged plants, the oxygen requirement of developing tiller buds must be much higher than that of roots. Preliminary tests showed that calcium peroxide applied at a dosage as high as 1% in ridged soil did not have any harmful effect on the growth of Sudangrass plants and increased tillering under low (1,000 f.c.) light intensity which was known to be effective in enhancing the effect of ridging on tillering. However, the maximum effect in increasing tillers was obtained when calcium peroxide was applied in a small glass tube which concentrated the chemical in the vicinity of the basal part of the stem and prevented direct contact of this chemical with plants and soil. No calcium oxide was used as a check to balance the effect of calcium peroxide on the acidity of soil in this experiment because the rate of decomposition of calcium peroxide in soil and its solubility are not well known.

Figure 16. Ridged and non-ridged Sudangrass plants. From left to right: ridged plant having two tillers from the second and third foliage leaves; ridged plant without tiller; non-ridged plant with tillers from the axils of first three foliage leaves; and non-ridged plants having three tillers, the third one emerging from the leaf sheath.

Figure 17. Four ridged plants on left and a non-ridged plant on right. First three ridged plants showing different degrees of growth of etiolated tillers of the first and second nodes, none of them emerged from soil. The fourth ridged plant has one non-emerged first primary tiller, an emerged second tiller and a third tiller which is emerging through the leaf sheath of the third leaf. The non-ridged check has three well developed tillers.

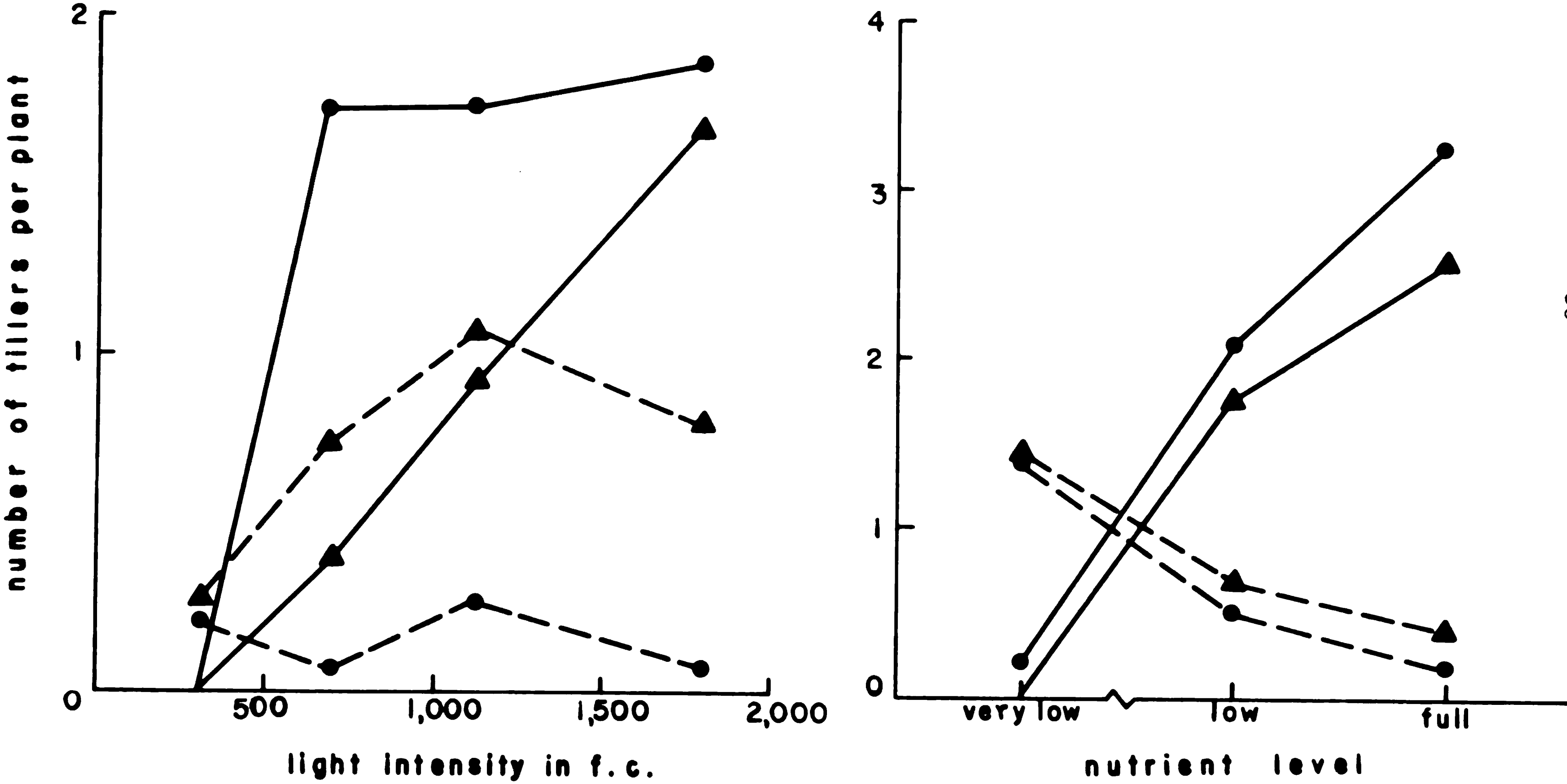

Figure 18. Comparison of interaction of light intensity and nutrient level with ridging.
● non-ridged, ▲ ridged, —— emerged tillers or tillers over 2 inches,
---- non-emerged tillers or tillers under 2 inches.

During the course of Experiment V, efforts were made to control the light intensity to give a critical condition for tillering for the ridged plants. However, it was not very successful. High light intensity applied before the ridging treatment apparently had its residual effect on tillering in the early tillering stage. Plants tillered much faster than expected. Calcium peroxide showed its effect only at the latter period of this experiment when the vigor of tillering was slowed down. Plants could not be maintained in the growth chamber any longer due to the limitation of space.

Sugarcane agronomists attributed the effect of ridging on increasing cane yield to preventing lodging, inhibiting the development of late tillers and accelerating the rate of elongation of stems. The author observed that roots come from the lower nodes of the main stem distributed in the ridged soil of Experiment III. The plant height and dry weight of ridged plants were generally higher than those of non-ridged plants. Efforts were made to prevent this effect in the nutrient experiment by minimizing the amount of ridged soil in the glass tubes. However, a significant difference in dry weight of plants between ridged and non-ridged plants was still obtained. The fertilizer experiment conducted in the greenhouse showed that plants reacted more to ridging than to the fertilizer treatments. A very marked effect of ridging was found in the second cutting. Better crown and root system development of ridged plants was observed in these cases and it may have accounted for the increased growth and yield of the shoot in Sudangrass. The additional root system developed within the ridge may have a possible significance in increasing yields of other crops of the Gramineae.

SUMMARY

Investigations were conducted to study the tillering process of Sudangrass, its reactions to light intensity, nutrition and more especially to ridging treatment.

1. An anatomical study showed that Sudangrass seedlings had differentiated more than enough tiller buds for the normal tillering process under favorable conditions before actual tillering began. Thus the effects of environmental factors and ridging on tillering are influencing further development of these buds.
2. Ridging treatments reduced the number of tillers per plant in all experiments conducted in the growth chambers and greenhouse. Early ridging applied before the tillering stage showed maximum effects. Under field conditions, the effect of ridging in reducing yield may be prevented by late application or increasing the rate of seeding.
3. The primary effects of ridging on tillering are attributed to the mechanical hindrance of soil on the emergence of tillers, subsequent etiolation and the reduction of the oxygen supply required by growing tiller buds.
4. Light intensity markedly affected tillering. Low light intensities delayed and prolonged the tillering period. Under 300 f.c. light intensity, tillering was almost completely suppressed.

5. Marked interaction between light and ridging treatment was observed. Low light intensities enhanced the effect of ridging.
6. Under low light intensity, the main stem grew fast while tillers remained in the juvenile stage.
7. Nutrient deficiency reduced the number of tillers but did not have an interaction with ridging treatments in the short term experiment. Under greenhouse conditions, higher rates of fertilizer application increased the number of tillers per plant of ridged treatments at the late period of the growing season.
8. Ridging generally increased the plant height, dry weight and yield of a single plant. These effects were attributed to the better developed crown parts and root systems of ridged plants.

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