RELATIVE YIELD EFFICIENCY AND SOME PRODUCTION PRACTICES ON PEARL MILLET [PENNISETUM TYPHOIDES (BURM.) STAPF AND HUBB.]

by

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INTRODUCTION

Pearl millet, *Pennisetum typhoides* [(Burm. f.) Stapf & Hubb.], is the staple food in the drier parts of tropical Africa, particularly in the northern countries of west Africa, and in India, where it is the fourth most important cereal after rice, sorghum and wheat. Pearl millet is usually grown as a rain-fed crop in semi-arid regions, although it is sometimes grown with irrigation in India. It is the most important food crop in the Sahel zone approaching the Sahara; in the Sudan zone to the south it is of equal status with sorghum.

There seems little doubt that tropical Africa is the home of pearl millet. It probably originated in western tropical Africa, where the greatest number of wild, and cultivated forms occur. Millet has great economic potential for grain production. No crop seems better able to supply the major food requirement for man in the dry, infertile lands of the tropics. Its yield potential appears to be similar to that of sorghum under good growing conditions. Millet would probably outyield sorghum under poorer soil moisture and soil fertility conditions.

Production practices for optimum pearl millet yields have not been extensively investigated. This study was intended to compare five plant densities and four nitrogen levels as they influence grain yield and components of yield. Yield efficiencies of two millet varieties, one sorghum variety and two corn varieties, were also compared under dryland conditions.

REVIEW OF LITERATURE

Cultural practices influence the production of pearl millet as well as that of corn and sorghum. However, little, if any, work has been reported on millet response to density and to nitrogen application. Studies with grain sorghum [Sorghum bicolor. (L.) Moench] would appear to be relevant to millet.

Effect of Plant Density on Grain Yield

Optimum rate of planting depends on soil moisture and soil fertility. It varies from location to location. Nielson (10), working with irrigated sorghum, showed that plant density can vary considerably from the normal stand without materially affecting grain yields. High densities are often necessary to fully utilize fertilizers or moisture, if other factors are not limiting.

Grimes and Musick (7) concluded from experiments with irrigated sorghum that in some instances densities ranging from 138,000 to 553,000 plants/ha did not differ significantly in grain yield. The remarkable constancy of grain yields from widely different stand densities was due to compensation among individual yield components, particularly heads/unit area and seeds/head.

Brown and Shrader (3) indicated that grain sorghum may respond differently to fertilization, row spacings, and plant density under dryland and irrigated conditions. Row spacings and plant density were of minor importance under irrigation but were very important in the experiment under severe dryland conditions. In extremely dry years, wide row spacing and low plant densities are desirable regardless of the amount of stored moisture. As seasonal rainfall increases, closer spacings and higher plant densities are indicated.

Significant decreases in panicles per plant and seeds per head occurred at each row width as the within-row plant density increased (2).

Robinson and Bernat (14) showed that density had little effect on grain sorghum yield, but panicle moisture decreased as density increased. The panicles per unit area and seeds per panicle increased with narrow row spacings whereas the seed weight decreased.

Duncan (5), studying the relationship between plant density and yield of corn, showed that there was apparently a linear relationship between the logarithm of the average plant yield and the plant density.

Response of Pearl Millet to Levels of Nitrogen

Investigations on the effect of nitrogen on pearl millet grain yield have been relatively few.

A nitrogen fertilizer trial conducted in India (4) showed that increasing level of nitrogen from 0 to 120 kg per ha increased the grain yield significantly. Levels of fertilizer above 120 kg decreased the yield. The protein concentration of the grain increased up to 120 kg N per ha and remained nearly constant at levels of 160 and 200 kg per ha. A significant positive correlation was observed between the protein concentration and the level of nitrogen fertilizer.

Protein concentration of a cereal crop varied with environmental factors, soil types, fertilization, genetic constitution, and moisture.

Nelson (9), working with grain sorghum, showed that the protein concentration of the grain increased with each increment nitrogen fertilizer applied under irrigated conditions.

Fernandez and Laird (13), working with wheat in Central Mexico, showed that the effect of applied nitrogen on grain yield was very largely dependent on soil moisture conditions. The increase in grain yield per unit of applied nitrogen under optimum soil moisture conditions was more than double the increase under the driest treatment.

Numerous workers have related maize yields to the nitrogen contents of soils and have indicated nitrogen was the dominant limiting factor in this respect (11). Burleson and Otey (11) observed in Texas that the yield of shelled corn increased from 949 kg per hectare to 1124 and 1233 kg per hectare by the application of 11 and 22 kg nitrogen per hectare, respectively. Ramirez and Laird (11) obtained maximum yield with 120 to 60 kg nitrogen per hectare, respectively, in irrigated and unirrigated maize with approximately 60,000 plants per hectare.

MATERIALS AND METHODS

Two varieties of pearl millet, 'Serere 3A' and 'Serere 3A x T239', were grown at Ashland (Manhattan) and Minneola, Kansas, during Summer, 1976. Response of the varieties to differences in plant density and nitrogen fertilization was determined.

'Serere 3A' is a variety from Uganda (Africa). Plants are tall and are early maturing compared to 'Serere 3A x T239'. The seeds used were from unbagged heads harvested at Ashland in 1973.

The short variety, 'Serere 3A x T239' was developed by Casady who transferred the dwarf gene, d2, from Tifton inbred 239 to 'Serere 3A' through a backcross program. The plants are very leafy and are more resistant to lodging than the tall variety 'Serere 3A'. The seeds used were from heads selected and bagged in 1973 at Ashland.

Planting was done with hand planters. Plants were hand thinned when they were 20 to 25 cm in height.

In the plant density study, different spacings of 15, 30, 45, 60, and 75 cm between plants were used in 75-cm rows. These spacings correspond to 87,120, 43,560, 29,033, 21,780, and 17,425 plants per hectare, respectively. At Ashland, the millet stand was established in plots of five rows 6 m long spaced 75 cm apart. At Minneola, 4-row plots were used.

The experimental design was a split-plot with varieties as main plots and densities as sub-plots. All treatments were replicated four times. Two border rows were used at Minneola;

the varieties were not randomized in the main plots.

In the nitrogen response study, a 15-cm spacing between plants in 75-cm rows was used. A split-plot design with varieties as main plots and nitrogen levels as sub-plots was utilized.

At Ashland, millet was planted June 7 on land which had been in soybeans the previous year; no fertilizers were applied. Available soil moisture was not very good at planting to allow good and uniform germination.

Millet was planted at Minneola June 3 on a sorghum-fallow-sorghum rotation field. Soil moisture conditions were good at planting time.

The plants were thinned four weeks after planting. The nitrogen fertilizer, nitrate ammonium, was applied July 15 at Minneola and July 20 at Ashland. Four nitrogen levels, 0, 60, 120, and 180 kg per hectare, were used.

Precipitation was below normal for the first 60 days after planting at Ashland (17 cm).

Rainfall at Minneola was different in amount and distribution from that recorded at Ashland. Only 5.85 cm of rain fell during the first 60 days after planting. This amount was below normal.

Millet was harvested October 8 at Minneola and October 13 at Ashland. At harvest, data were recorded on plant height, number of tillers per plant and head length. Only bordered plants were harvested in each plot. The samples were dried to a constant moisture level at 49 C for four days and then threshed. The grain yield of harvested plants was recorded. Samples of threshed grain were taken for Kjeldahl nitrogen (protein) analysis and for seed weight determination. Samples for nitrogen determination were oven dried at 60 C. Each sample was analyzed according to Macro-Kjeldahl method. Samples of 100 seeds from each plot were counted and then weighed. The weights were reported as per 1,000 seeds.

The statistical analysis of grain yield was expressed as g per plot. The data were analyzed according to a split-plot design. Analysis of variance and simple correlations between yield and the different variables were determined.

Yield Efficiency Study

Five different breeding populations and varieties or hybrids were used in the study. Two millet varieties 'Serere 3A x T239' and 'Serere 3A' were already described. One corn population, 'Amarillo Bajio', and one corn hybrid, 'Pioneer 3195A', were obtained from CIMMYT (International Maize and Wheat Improvement Center) and the Pioneer Seed Company, respectively. Amarillo Bajio is a temperate open-pollinated population developed in Mexico from Carribean and some USA cornbelt germplasm. One sorghum hybrid, 'RS 702', was used.

The experiment was undertaken at the Ashland Agronomy Farm, Manhattan, Kansas, during Summer, 1976. The field design was a randomized complete block with four replications.

Corn was planted May 14 in 4-row plots 6 m long with 0.75 m between rows and 0.25 m between plants (53,333 plants per ha). Sorghum and millet were also grown in 4-row plots with 0.75 m between rows but with 0.15 m between plants. Sorghum was planted May 28 and millet was planted June 4. Fertilizers were not applied prior to planting.

After flowering, four plants were selected randomly in each plot in all replications and the length and width of all leaves were measured. Area of individual leaves was calculated by multiplying leaf length x width x 0.75. Total leaf area per plant was obtained by summing the leaf area of all the leaves on a plant.

At maturity, ears were harvested from all corn plants in the two center rows; whereas, in millet and sorghum, four bordered plants randomly chosen were harvested in each plot. Corn ears and sorghum and millet heads were dried to a constant weight at 60 C and then threshed.

The plant yield efficiency was calculated by dividing the average kernel or seed weight per plant by the average leaf area per plant for each plot.

RESULTS

Density Effects on Grain Yield and Other Characters

Manhattan. Means of tiller numbers, plant height, head length, grain yield, protein and seed weight are shown in Tables I and II in the appendix.

The analysis of variance for effect of varieties and densities on number of tillers per plant is shown in Table 1. The effect of plant densities on number of tillers per plant was highly significant. Number of tillers per plant increased with decreasing plant density (Fig. 1). Differential variety responses to plant densities caused a highly significant variety x density interaction on number of tillers per plant. In 'Serere 3A X T239', mean tillers per plant ranged from 2.70 to 9.15, which were significantly different at the different densities. Mean tillers in 'Serere 3A' ranged from 1.95 to 4.80 and only the number of tillers at 45 cm and 60 cm were not significantly different. 'Serere 3A' tiller numbers increased linearly with increased spacing between plants (Fig. 2).

The variation in plant density did not significantly affect plant height (Table IX) and head length (Table X).

Protein concentration was not significantly affected by the variation in density (Table XI). However, the two varieties were highly significantly different. The short variety, 'Serere 3A X T239', had the higher protein concentration.

Seed weight was not significantly different at the different densities (Table XII). The seed weight of the tall variety was

Table 1. Analysis of variance for density effect on number of tillers per plant of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	3.46	1.15	0.72
Varieties	1	47.52	47.52	30.49**
Error a	3	4.68	1.56	
Densities	4	35.40	23.85	54.72**
Var. X Den.	4	14.69	3.67	8.43**
Error b	24	10.35	0.44	

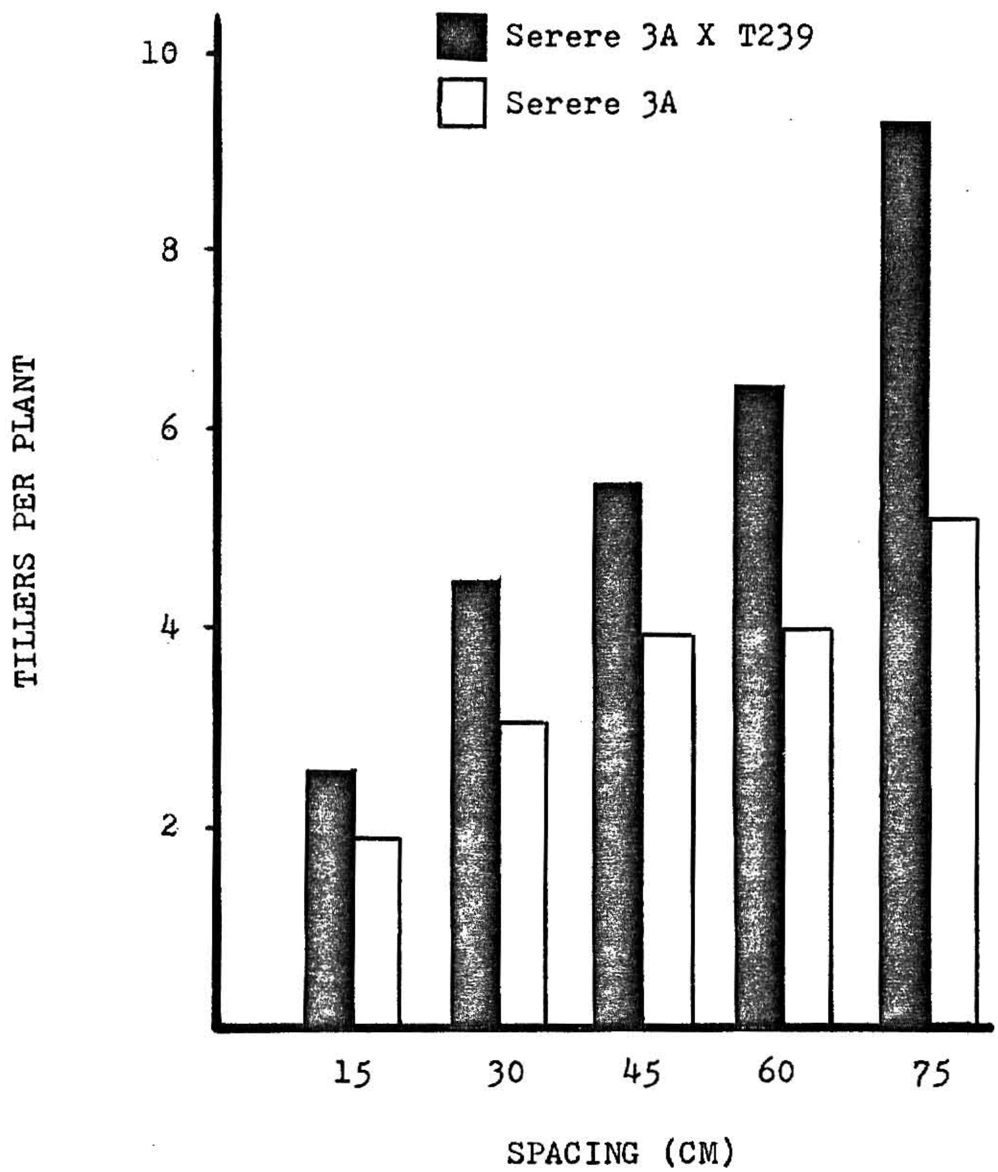
**significant at the 1% level.

Table 2. Analysis of variance for density effect on yield of two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	4,870,050	1,623,350	2.15
Varieties	1	51,104,773	51,104,773	67.59**
Error a	3	2,268,166	745,055	
Densities	4	86,222,479	21,555,619	11.69**
Var. X Den.	4	16,359,167	4,089,791	2.22
Error b	24	44,269,768	1,844,573	

**significant at the 1% level.

Fig. 1. Effect of density on number of tillers per plant at Manhattan.



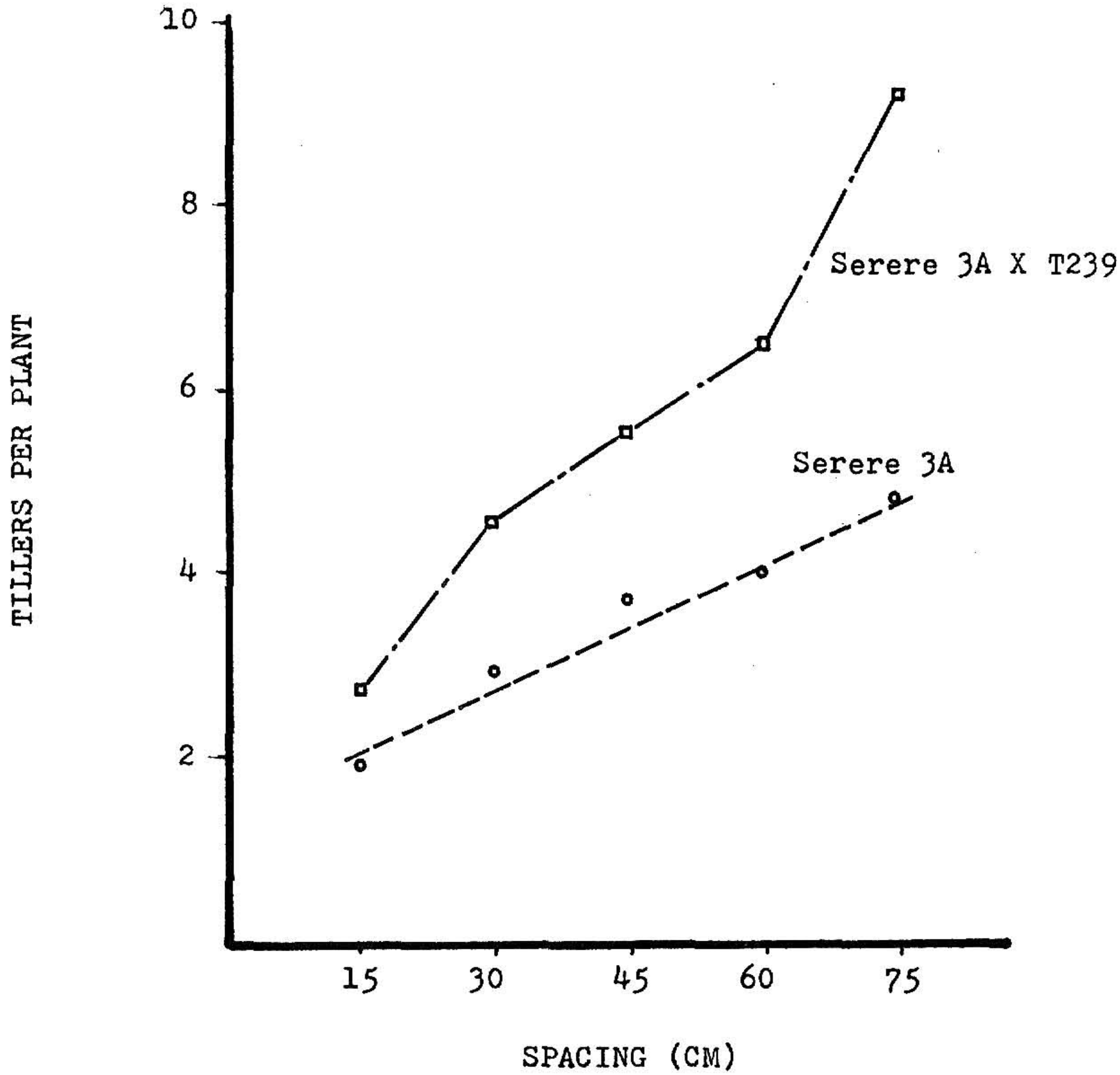


Fig. 2. Effect of density on number of tillers per plant of the two varieties at Manhattan.

highly significantly higher than the seed weight of the short variety.

Grain yields at the different densities were significantly different (Table 2). The mean yields of the pooled varieties (Table II) ranged from 5.00 kg to 9.11 kg per plot. The yield was higher at the highest density (Fig. 3). The 30-cm spacing gave a yield significantly higher than 60- and 75-cm spacings. The 45- and 60-cm spacings did not differ significantly in their yield. There was no significant difference between the yields of 60- and 75-cm spacings. The two varieties differed significantly in their yields. The tall variety gave the higher yield.

Table 3 shows the correlation coefficients among the different agronomic characters. The R^2 values ranged from .18 to .83. Yield per plot was positively correlated with plant height and seed weight but was negatively correlated with number of tillers per plant. The protein concentration was negatively associated with plant height and seed weight but was positively associated with number of tillers per plant. Plant height and number of tillers per plant were highly negatively correlated.

Minneola. The means of the different characters are shown in Table III and IV.

The effect of density on number of tillers per plant was significant (Table 4 and Fig. 4). The two varieties responded similarly to the density effect as shown by the non-significant variety x density interaction, whereas, this interaction was significant at Manhattan. Mean tillers per plant ranged from 2.4 to 5.05 for the highest and lowest densities, respectively,

Fig. 3. The effect of density on yield of the two varieties at Manhattan.

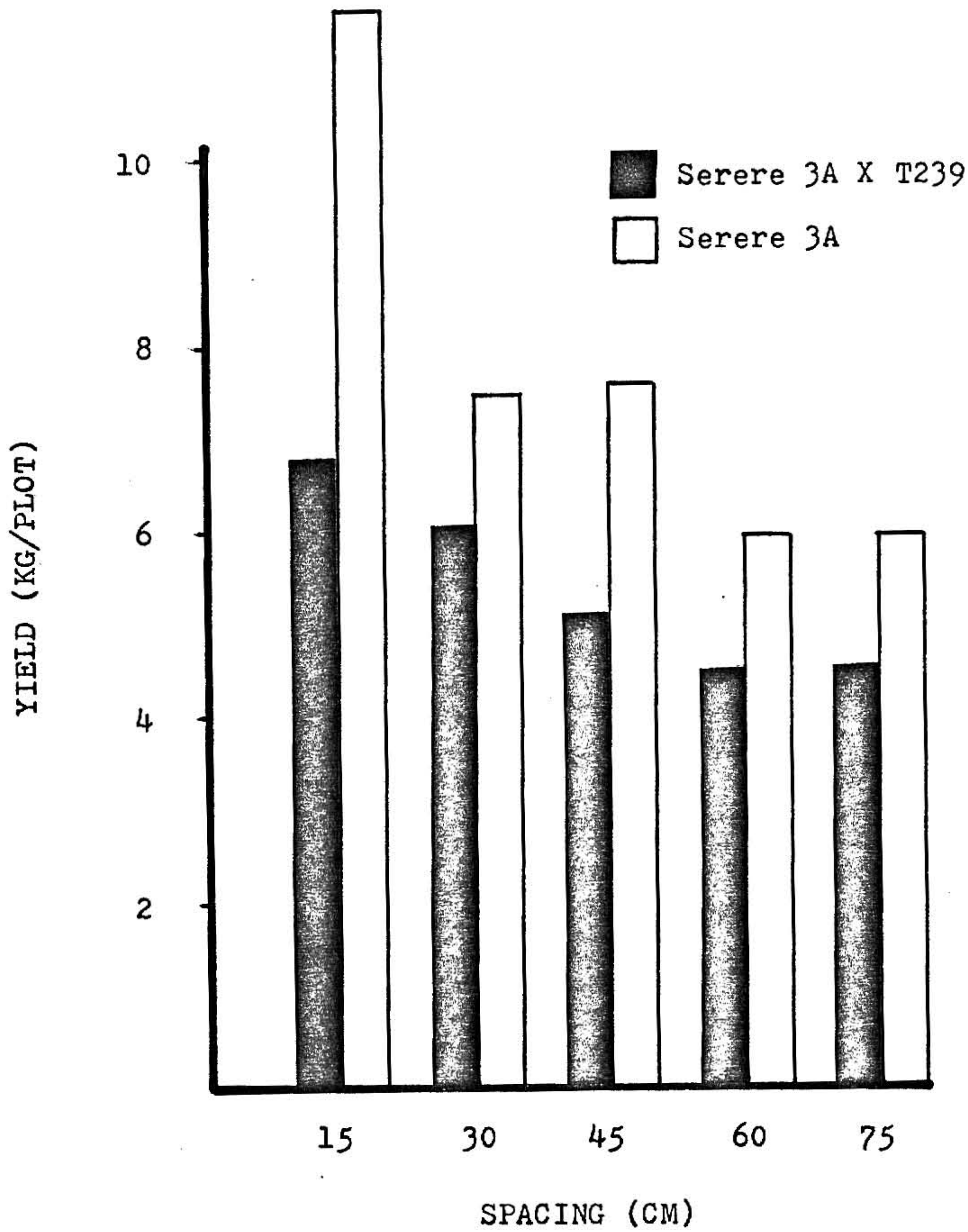


Table 3. Correlation coefficients between number of tillers per plant, plant height, percent protein and seed weight of the two varieties under density study at Manhattan.

	Tillers	Height	Seed Weight
Yield	-0.63**	0.55**	0.50**
Protein	0.40**	-0.55**	-0.43**
Seed Weight	-0.43**	0.91**	
Height	-0.55**		

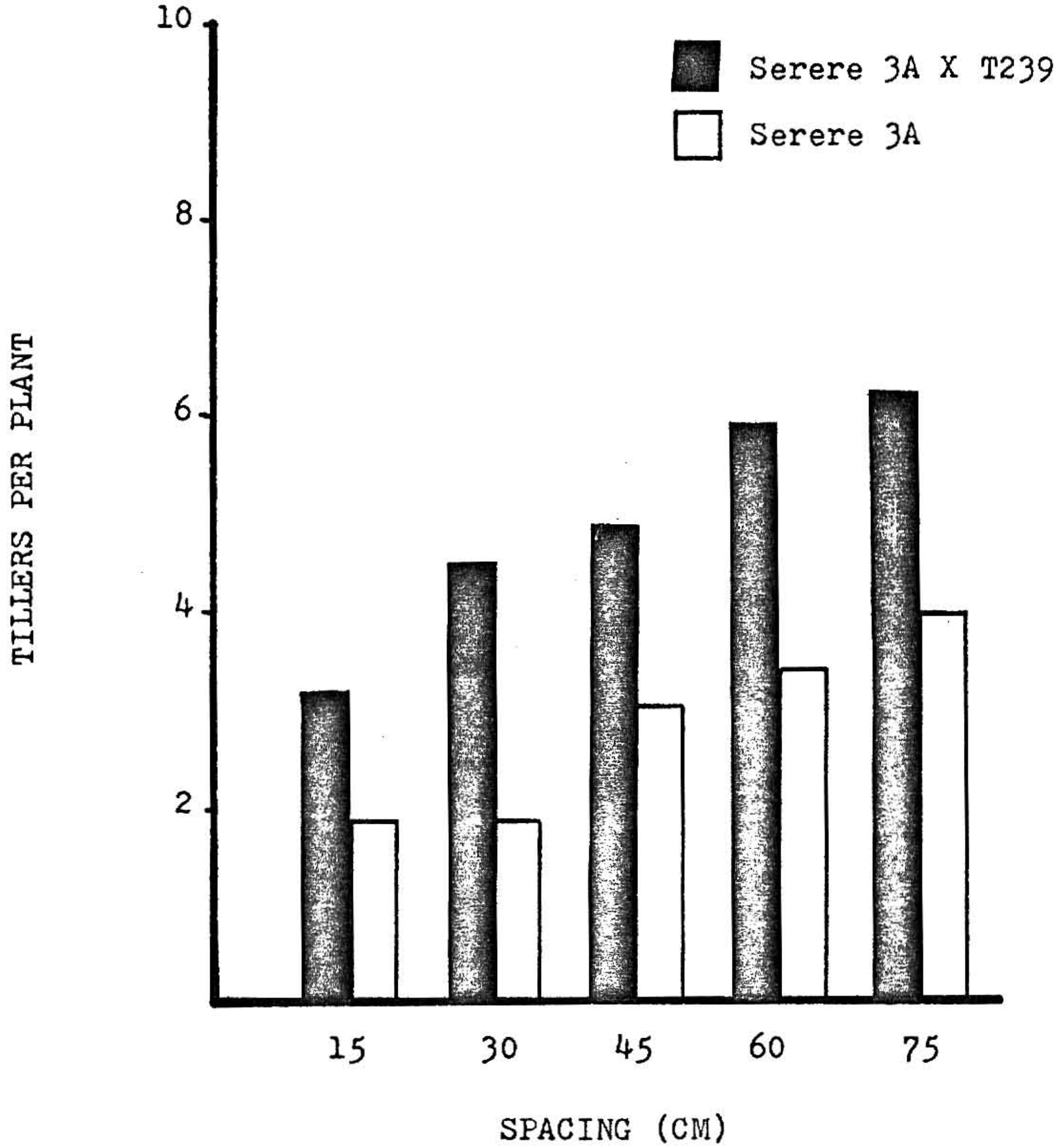
**significant at the 1% level.

Table 4. Analysis of variance for density effect on number of tillers per plant of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	3.52	1.17	1.25
Varieties	1	44.84	44.84	47.81**
Error a	3	2.81	0.94	
Densities	4	37.33	9.33	11.59**
Var. X Den.	4	1.72	0.43	0.53
Error b	24	19.32	0.80	

**significant at the 1% level.

Fig. 4. Effect of density on number of tillers per plant of 'Serere 3A X T239' and 'Serere 3A' at Minneola.



(Table IV).

Plant height was not significantly affected by plant density (Table XIII).

The head of the short variety was highly significantly longer than the head of the tall variety (Table 5 and Fig. 5). At Manhattan, there was no significant difference in head length between the two varieties. The 75-cm spacing gave the longest heads. The head lengths did not differ among 30-, 45-, and 60-cm spacings.

The varieties differed significantly in grain yields (Table XIV). The tall variety yielded better than the short variety. The yields at the different densities were not significantly different, whereas, the density had a highly significant effect on yield at Manhattan.

The two varieties differed highly significantly in grain protein concentration (Table XV). The short variety had the higher concentration. Protein concentration was not affected by plant density.

Seed weight was not significantly influenced by the different densities, but it differed highly significantly between the two varieties (Table XVI).

Grain yield was negatively and significantly associated with number of tillers per plant and with head length (Table 6). A positive and significant association occurred between yield, seed weight and plant height.

Table 5. Analysis of variance for density effect on head length of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	14.25	4.75	2.01
Varieties	1	102.88	102.88	43.63**
Error a	3	7.07	2.36	
Densities	4	72.53	18.13	5.12**
Var. X Den.	4	10.98	2.74	0.77
Error b	24	85.04	3.54	

**significant at the 1% level.

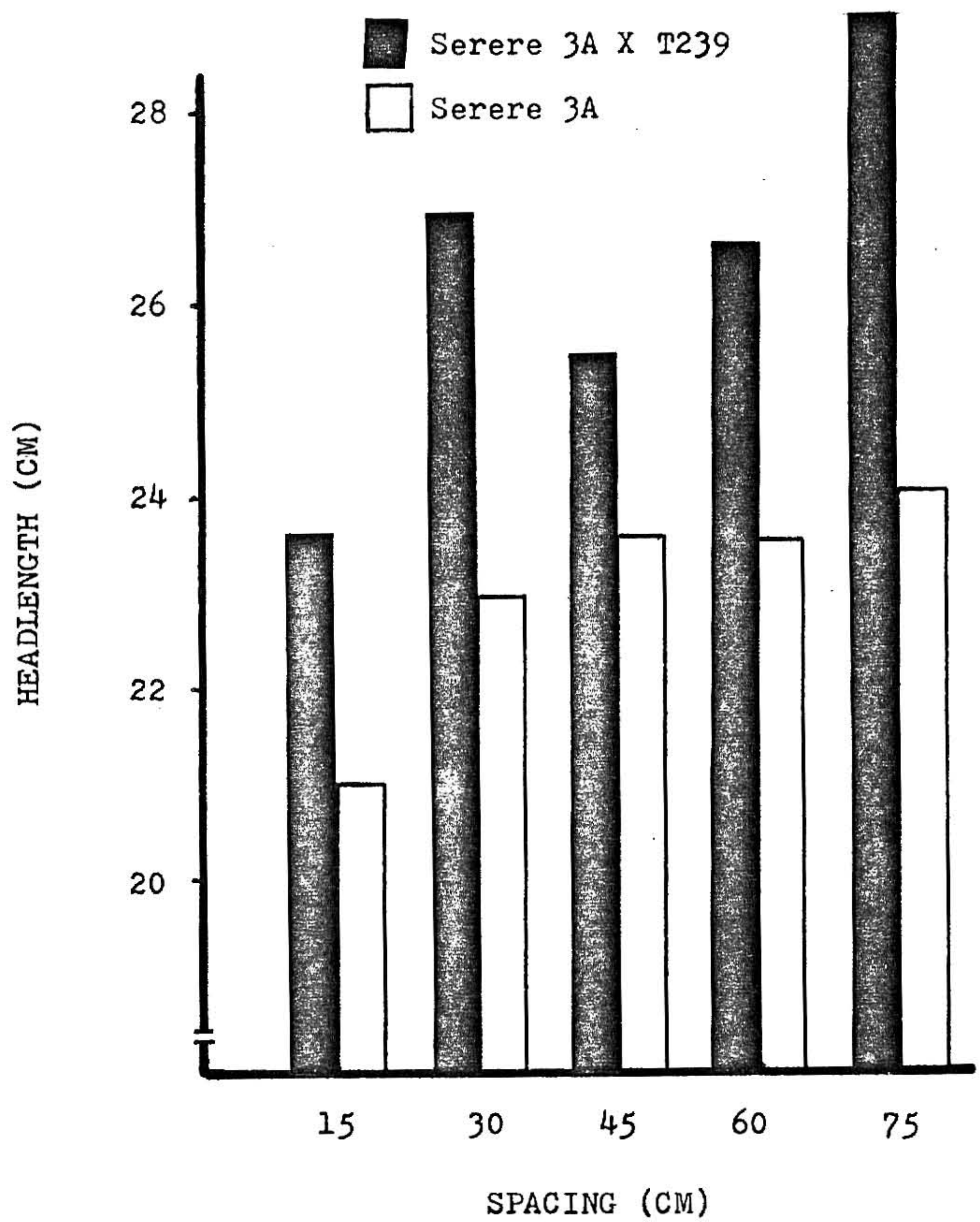
Table 6. Correlation coefficients between yield, percent protein, seed weight, tillers per plant, head length and plant height of the two varieties under density study at Minneola.

	Yield	Protein	Seed Weight	Tillers	Height
Seed Weight	0.63**	-0.64**			
Tillers	-0.40*	0.44**	-0.58**		
Height	0.67**	0.63	0.94**	-0.62**	
Head Length	-0.39*	0.35*	-0.55**	0.73*	-0.53**

*significant at the 5% level.

**significant at the 1% level.

Fig. 5. Effect of density on head length of 'Serere 3A X T239' and 'Serere 3A' at Minneola.



Response to Nitrogen Application

Manhattan. Tables V and VI show plant data means at the different nitrogen levels.

Nitrogen had no significant effect on number of tillers per plant and on plant height (Table XVII and XVIII, respectively). The differences in number of tillers per plant of the two varieties were highly significant. The short variety had more tillers per plant than the tall variety.

No significant effect of nitrogen or variety on head length was observed (Table XIX).

Yields of the two varieties differed greatly (Table XX). However, the yield was not affected significantly by the different nitrogen levels.

Nitrogen application significantly affected protein concentration (Table 7 and Fig. 6). The variety x nitrogen interaction was not significant, therefore, the overall means of the varieties were compared. Increased level of nitrogen increased the grain protein concentration. The short variety had significantly higher protein content.

Seed weight was not affected by nitrogen application (Table XXI). The tall variety had the largest seed weight.

Table 8 shows the significant correlation coefficients between the different characters. Grain yield was positively and significantly associated with plant height, seed weight and head length, but was negatively associated with protein. Protein concentration was positively correlated with number of tillers per plant, but was negatively correlated with plant height.

Table 7. Analysis of variance for nitrogen effect on protein concentration of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	0.928	0.309	1.07
Varieties	1	12.890	12.890	44.79**
Error a	3	0.863	0.288	
Nitrogen	3	27.139	9.046	15.36**
Var. X N	3	1.251	0.417	0.71
Error b	18	10.602	0.589	

**significant at the 1% level.

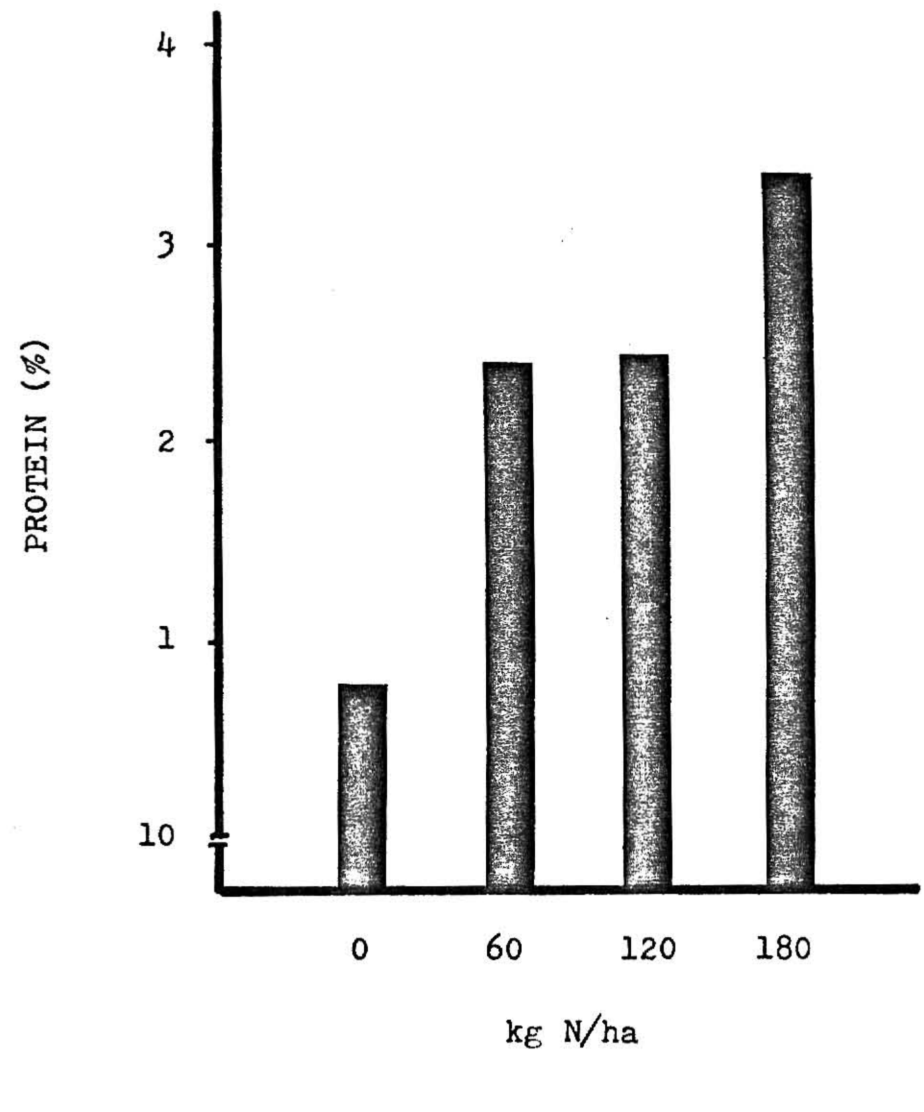
Table 8. Correlation coefficients between tillers per plant, plant height, yield, head length, seed weight and percent protein of the two varieties under nitrogen study at Manhattan.

	Tillers	Height	Seed Weight	Head Length	Protein
Yield		0.80**	0.81**	0.48**	-0.37*
Protein	0.37*	-0.45**			
Seed Weight	-0.42*	0.93**		0.37*	
Height	-0.55**				

*significant at the 5% level.

**significant at the 1% level.

Fig. 6. Effect of nitrogen application on percent protein of the two varieties pooled together at Manhattan.



<u>Minneola</u>. The different means are shown in Tables VII and VIII.

Nitrogen application did not influence plant height and number of tillers per plant (Tables XXIII and XXII, respectively). The short variety had the higher number of tillers per plant.

Nitrogen did not affect head length (Table XXIV), but heads of the short variety were significantly longer than heads of the tall variety.

Grain yield was not affected by nitrogen fertilizer (Table XXV). The yield of the tall variety was significantly higher than the yield of the short variety.

Nitrogen application significantly affected protein concentration (Table 9 and Fig. 7). The application of 180 kg per hectare gave the highest protein concentration, however, it was not significantly different from the application of 120 kg N per hectare. Protein concentrations at 60 and 120 kg N per hectare were not significantly different from the control (0 kg N per hectare).

Seed weight was not influenced by nitrogen application (Table XXVI). Larger seed weight was observed in the tall variety.

The significant correlation coefficients are presented in Table 10. Yield was positively and significantly correlated with seed weight and plant height, but was negatively associated with number of tillers per plant.

Table 9. Analysis of variance for nitrogen effect on protein concentration of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	7.919	2.64	0.42
Varieties	1	0.350	0.350	0.05
Error a	3	13.036	6.34	
Nitrogen	3	7.109	2.369	3.94*
Var. X N	3	0.941	0.314	0.52
Error b	17	10.217	0.601	

*significant at the 5% level.

There was one missing plot.

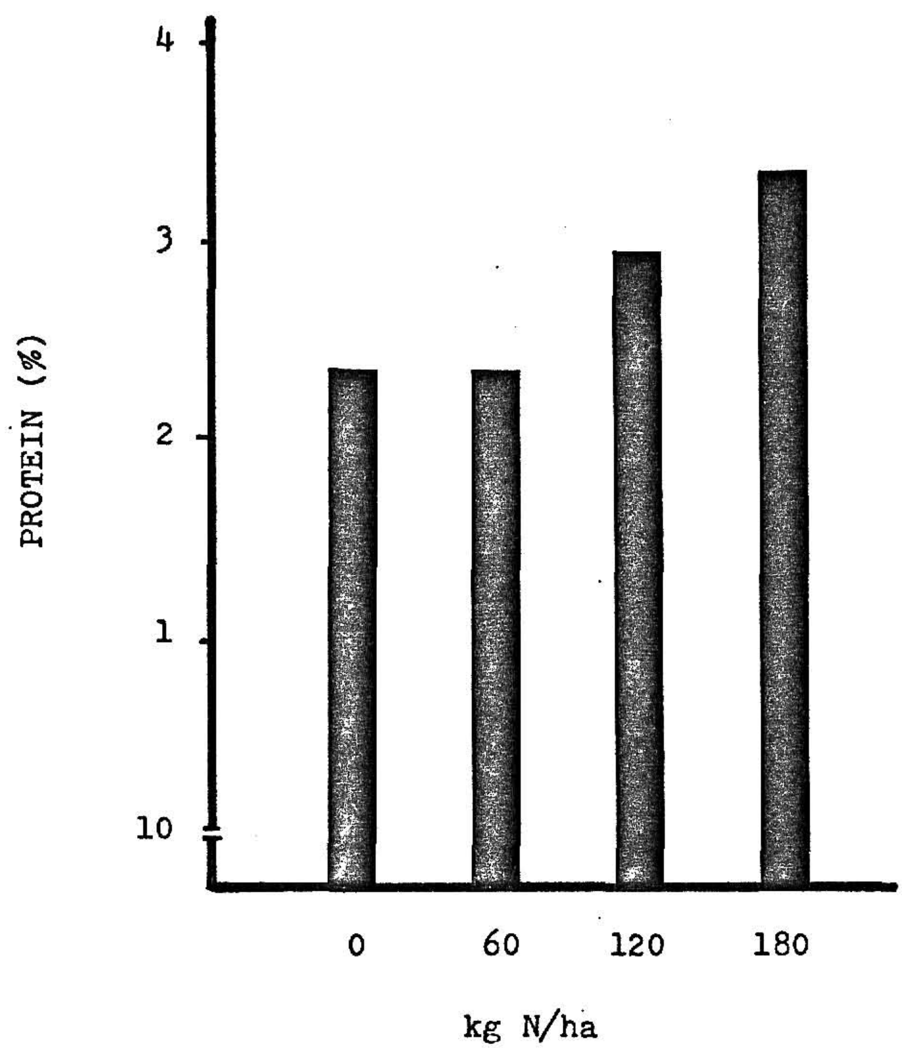
Table 10. Correlation coefficients between yield, tillers per plant, plant height, head length, seed weight and percent protein of the two varieties at Minneola.

	Yield	Seed Weight	Tillers	Head Length
Seed Weight	0.75**			
Tiller	-0.46**	-0.77**		
Height	0.79**	0.85**	-0.71**	0.37*

*significant at the 5% level.

**significant at the 1% level.

Fig. 7. Effect of nitrogen application on percent protein of the two varieties pooled together at Minneola.



Yield Efficiency Study at Manhattan

The yield efficiencies differed significantly with species and genotypes. The droughty conditions that prevailed during the growing season made water the first yield-limiting factor. Among the genotypes, Pioneer corn had the highest yield efficiency and A. Bajio had the lowest yield efficiency (Table 11 and Fig. 8). However, A. Bajio and sorghum did not differ significantly in their yield efficiency. No significant difference was observed between sorghum and the short millet variety. The tall millet variety, 'Serere 3A', had the second highest yield efficiency.

Yield per plant and total leaf area per plant had a significant effect on yield efficiency (Table 12). Higher yield per plant does not always imply a high yield efficiency. Compared to the tall millet variety, A. Bajio had the higher yield per plant but the lower yield efficiency.

Regression analysis indicated that yield per plant, seed weight, total leaf area per plant and protein were the best linear predictors of yield efficiency. More than 97 percent of the yield efficiency was accounted for by the model.

Yield efficiency was highly and significantly correlated with yield per plant (Table 13). Yield per plant was positively and significantly correlated with total leaf area per plant and seed weight, but was significantly and negatively correlated with protein.

Table 11. Means of protein, seed weight, yield, leaf area and yield efficiency (YE) of the two millet, one sorghum and two corn varieties under dryland conditions at Manhattan.

Varieties	Protein (%)	Seed Weight (g/1,000 seeds)	Yield (g/plant)	Leaf Area (m^2/plant)	YE (g/m^2)
Serere 3A X T239	11.74	8.71	32.75	0.1482	225.5
Serere 3A	12.00	12.48	56.94	0.1866	307.7
RS 702	9.50	16.96	50.81	0.2930	189.4
A. Bajio	10.11	239.35	88.55	0.5060	175.6
Pioneer 3195A	9.50	236.70	160.47	0.4623	348.2

Table 12. Analysis of variance for yield efficiency (YE) of the five varieties.

Source	df	SS	MS	F
Replications	3	6,829.8	2,276.6	3.81
Varieties	4	13,450.8	3,362.7	5.73*
Seed Weight	1	28.6	28.6	0.05
Protein	1	3,306.4	3,306.4	5.63*
Leaf Area	1	16,238.9	16,238.9	27.68**
Yield/plant	1	25,606.9	25,606.9	43.64**
Error	8	4,693.9	586.7	

*significant at the 5% level.

**significant at the 1% level.

Fig. 8. Yield efficiencies of the five varieties under dryland conditions at Manhattan.

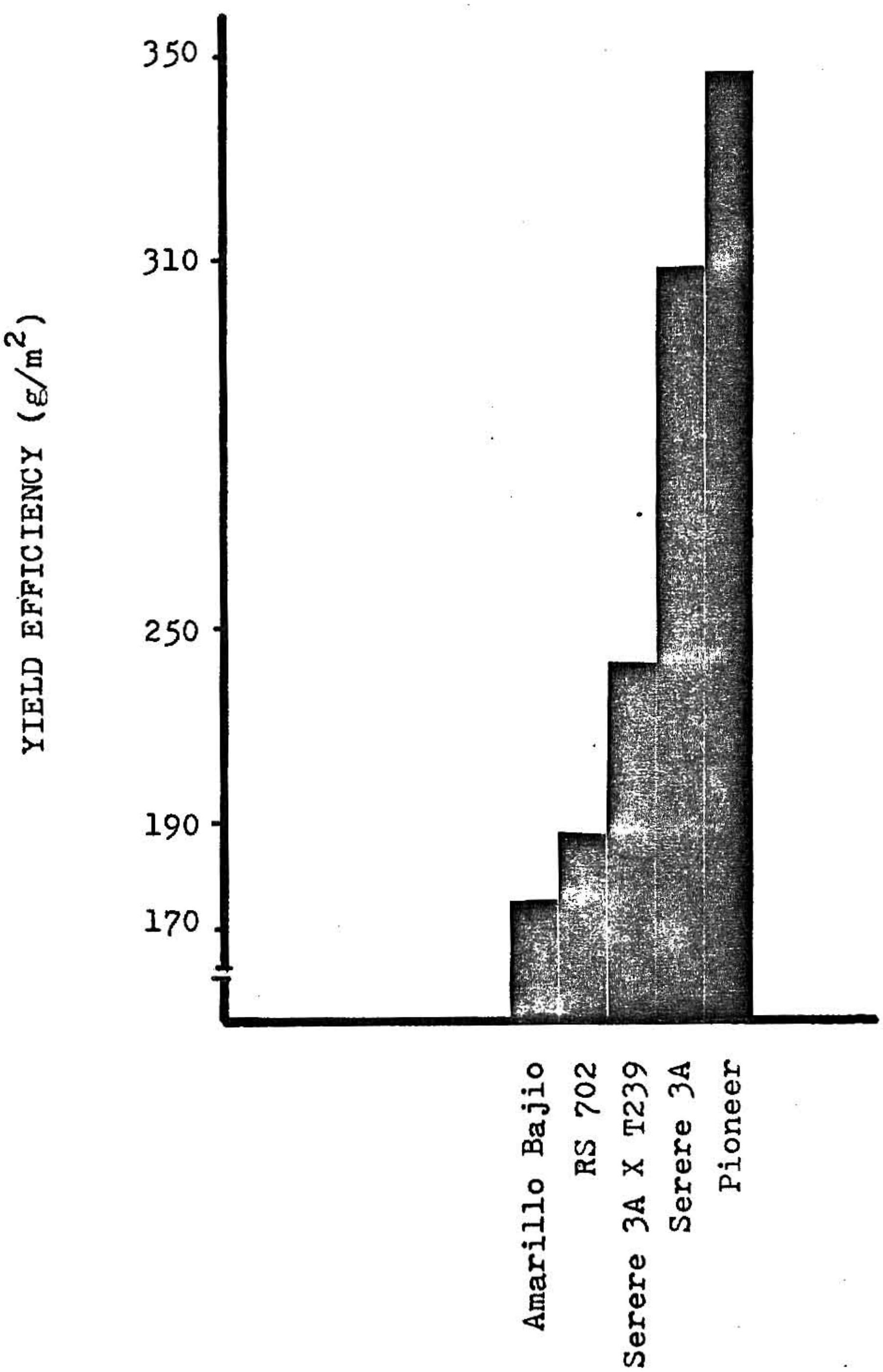


Table 13. Correlation coefficients among yield per plant, protein, seed weight, leaf area and yield efficiency of the 5 varieties.

	Protein	Seed Weight	Yield/Plant	Leaf Area
Seed Weight	-0.45*			
Yield/Plant	0.50*	0.80**		
Leaf Area	0.52*	0.88**	0.70**	
Yield Efficiency	-0.17	0.11	0.57**	-0.11

*significant at the 5% level.

**significant at the 1% level.

DISCUSSION

Yield and other agronomic characters were affected differently by increasing plant density at the two locations.

Increasing plant density increased grain yield significantly at Manhattan. These findings agree with those of Brown and Shrader (3), who reported that planting more plants per row increased plant competition within the row, reduced forage production, yet increased grain yield.

Increasing plant density did not affect grain yield at Minneola. Even though number of plants per unit area decreased greatly from the highest (87,120) to the lowest (17,425) density, tillering aided in equalizing grain yields of the five densities. Prevailing dry weather at Minneola evidently was responsible for the low yields.

At Manhattan, the variety x density interaction was caused by a greater increase in number of tillers per plant with increased spacing between plants for the short variety. Increasing spacing between plants increased number of tillers per plant in a highly significant linear trend with the tall variety, whereas, the trend was linear and cubic with the short variety. At Minneola, the non-significance of the variety x density interaction suggested that the two varieties responded uniformly to the density effect.

At both locations, the tall variety outyielded the short one, due in part to a larger seed weight and other factors. One possible factor was the number of seeds per head though this was not measured.

No increase in millet grain yield was obtained with higher nitrogen fertilizer application. The lack of response of millet to nitrogen application was probably caused by the low rainfall during the growing season and the date of application which was more than 40 days after planting. The results are in agreement with those of Fernandez et al. (12), who reported that the effect of applied nitrogen on grain yields was very largely dependent on soil moisture conditions. The 1976 growing season was exceptionally dry at Manhattan and Minneola.

The plant density did not affect the protein concentration of the grain. The amount of nitrogen applied was the only variable that affected grain protein concentration significantly. Similar results have been reported by Deosthale (4), who obtained a significant positive correlation between the protein concentration and the level of nitrogen fertilizer.

High protein concentrations were observed at Minneola. The low rainfall led to a low seed weight and high protein.

The results indicated that the ability of a single plant of a genotype to produce grain was positively and highly correlated with yield per unit leaf area. Only 32.6% of the variation in yield efficiency was due to yield per plant. Genotypes possessing a combination of high leaf area per plant and high yield efficiency should display a high yield per plant.

When screening genotypes for high yield efficiency, the first concern is not the actual leaf area of the genotype but the magnitude of genetic variation in yield efficiency within the materials under selection. The highest and lowest yield efficiencies were in corn, suggesting a large variagion in yield efficiency. Selection for yield efficiency of corn genotypes would be possible.

This study was based on one year's data, therefore, no definite conclusions on selection of yield efficiency could be drawn. For more information on yield efficiency, more genotypes within each species should be used.

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APPENDIX

Table I. Tillers per plant, plant height, head length, yield per plot, percent protein and seed weight of varieties at different plant spacings at Manhattan.

	Spacing (cm)	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
	15	2.7	125.5	25.9	6.75	12.53	7.63
	30	4.6	120.4	26.4	6.00	13.41	7.49
Serere 3A X T239	45	5.6	117.9	25.4	5.20	13.54	8.07
	60	6.5	117.5	27.7	4.43	13.27	6.58
	75	9.1	115.0	27.1	4.32	13.20	8.46
	15	1.9	217.4	27.0	11.46	11.67	12.1
	30	3.0	212.9	25.6	7.35	11.74	11.6
Serere 3A	45	3.8	219.9	27.0	7.54	18.17	11.5
	60	4.0	205.7	29.0	5.83	11.63	11.8
	75	4.8	209.7	30.0	5.81	12.30	12.3

Table II. Overall means of tillers per plant, plant height, head length, yield per plot, percent protein and seed weight at different plant spacings at Manhattan.

Spacing (cm)	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
15	2.3	171.4	26.3	9.11	12.10	9.86
30	3.8	166.7	26.0	6.68	12.57	9.53
45	4.7	168.9	26.2	6.37	12.86	9.99
60	5.3	161.6	28.3	5.13	12.45	9.37
75	7.0	162.4	28.6	5.01	12.75	10.39

Table III. Tillers per plant, plant height, head length, yield per plot, percent protein and seed weight of varieties at different plant spacings at Minneola.

Source	Spacing (cm)	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
	15	3.1	79.4	23.6	1.98	14.04	6.24
	30	4.3	68.8	26.8	1.20	13.68	5.51
Serere 3A X T239 (short)	45	4.8	67.0	25.4	1.08	14.54	6.16
	60	5.7	70.9	26.4	0.75	14.99	5.37
	75	6.2	78.1	28.9	0.98	14.45	6.10
	15	1.7	149.0	21.1	4.24	13.25	10.19
	30	1.8	150.4	22.9	2.83	11.3	10.77
Serere 3A (tall)	45	2.9	149.3	23.6	3.25	12.39	10.84
	60	3.3	147.1	23.4	2.33	12.35	10.92
	75	3.8	146.9	24.1	2.53	10.99	10.95

Table IV. Overall means of tillers per plant, plant height, head length, yield per plot, percent protein and seed weight at different plant spacings at Minneola.

Spacing (cm)	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
15	2.4	114.2	22.3	3.11	13.65	8.21
30	3.0	109.6	24.8	2.01	12.41	8.14
45	3.9	108.2	24.5	2.17	13.47	8.50
60	4.5	108.9	24.9	1.54	13.67	8.15
75	5.0	112.5	26.6	1.76	12.72	8.52

Table V. Tillers per plant, plant height, head length, yield per plot, percent protein and seed weight of varieties at different nitrogen levels at Manhattan.

	Nitrogen kg/ha	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
'Serere 3A X T239'	0	2.54	125.3	24.1	6.77	11.42	7.89
	60	2.96	127.6	24.5	8.48	12.75	7.13
	120	2.92	128.4	25.9	8.37	13.11	8.29
	180	2.92	129.8	24.6	9.17	14.29	8.96
'Serere 3A'	0	2.0	211.9	25.4	13.27	10.20	11.57
	60	2.1	218.3	25.9	13.90	12.03	12.79
	120	2.3	218.1	26.4	14.51	11.81	12.17
	180	2.0	219.2	25.0	13.61	12.46	12.27

Table VI. Overall means of tillers per plant, plant height, head length, yield per plot, percent protein and seed weight at Manhattan.

Nitrogen (kg/ha)	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
0	2.3	168.6	24.7	10.02	10.81	9.73
60	2.5	172.9	25.2	10.69	12.39	9.96
120	2.6	173.2	26.1	11.44	12.46	10.23
180	2.5	174.5	24.8	11.39	13.38	10.62

Table VII. Tillers per plant, plant height, head length, yield per plot, percent protein and seed weight of varieties at different nitrogen levels at Minneola.

	Nitrogen (kg/ha)	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
'Serere 3A X T239'	0	2.55	62.7	22.0	1.23	12.35	5.90
	60	2.55	65.0	22.4	1.22	12.69	5.92
	120	2.06	67.0	22.5	1.78	13.00	7.50
	180	2.45	75.6	23.2	2.84	13.40	7.46
'Serere 3A'	0	1.50	138.5	21.7	5.05	12.24	9.90
	60	1.50	133.2	21.9	4.97	11.87	9.71
	120	1.45	130.3	21.8	3.84	12.89	9.78
	180	1.35	133.2	20.4	3.93	13.45	9.48

Table VIII. Overall means of tillers per plant, plant height, head length, yield, percent protein and seed weight at different nitrogen levels at Minneola.

Nitrogen (kg/ha)	Tillers	Height (cm)	Head Length (cm)	Yield (kg/plot)	Protein (%)	Seed Weight (g/1,000 seeds)
0	2.02	100.6	21.8	3.13	12.29	7.90
60	2.02	99.1	22.2	2.10	12.28	7.82
120	1.71	103.2	22.1	2.96	12.94	8.80
180	1.90	104.4	21.8	3.39	13.42	8.47

Table IX. Analysis of variance for density effect on plant height of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	989.40	329.80	7.76
Varieties	1	88,096.99	88,096.99	2,071.96**
Error a	3	127.56	42.52	
Densities	4	567.47	141.87	1.36
Var. X Den.	4	210.69	52.67	0.50
Error b	24	2,506.10	104.42	

**significant at the 1% level.

Table X. Analysis of variance for density effect on head length of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	10.851	3.617	0.43
Varieties	1	14.641	14.641	1.72
Error a	3	25.491	8.497	
Densities	4	48.730	12.182	2.23
Var. X Den.	4	13.434	3.358	0.61
Error b	24	131.068	5.461	

Table XI. Analysis of variance for density effect on protein concentration of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	10.851	3.617	0.43
Varieties	1	14.641	14.641	1.72
Error a	3	25.491	8.497	
Densities	4	48.730	12.182	2.23
Var. X Den.	4	13.434	3.358	0.61
Error b	24	131.068	5.461	

Table XII. Analysis of variance for density effect on seed weight of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	5.075	1.692	1.40
Varieties	1	177.030	177.030	146.74**
Error a	3	3.619	1.21	
Densities	4	5.122	1.28	1.69
Var. X Den.	4	1.352	0.34	0.44
Error b	24	18.145	0.76	

**significant at the 1% level.

Table XIII. Analysis of variance for density effect on plant height of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	464.48	154.83	1.25
Varieties	1	57,369.26	57,369.26	464.77**
Error a	3	370.30	123.4	
Densities	4	209.37	52.34	0.61
Var. X Den.	4	325.24	81.31	0.95
Error b	24	2,044.15	85.17	

**significant at the 1% level.

Table XIV. Analysis of variance for density effect on grain yield of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	10,320,738	3,640,246	3.85
Varieties	1	33,736,717	33,736,717	35.64**
Error a	3	2,839,464	946,488	
Densities	4	11,630,135	2,907,534	2.08
Var. X Den.	4	979,736	244,934	0.17
Error b	24	33,507,244	1,396,135	

**significant at the 1% level.

Table XV. Analysis of variance for density effect on protein concentration of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	20.767	6.922	
Varieties	1	53.662	53.662	96.61**
Error a	3	1.666	0.555	
Densities	4	10.772	2.693	1.92
Var. X Den.	4	7.636	1.909	1.36
Error b	24	33.722	1.405	

**significant at the 1% level.

Table XVI. Analysis of variance for density effect on seed weight of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	4.342	1.447	
Varieties	1	235.710	235.710	155.35**
Error a	3	4.552	1.517	
Densities	4	1.171	0.293	0.22
Var. X Den.	4	2.989	0.747	0.57
Error b	24	31.258	1.302	

**significant at the 1% level.

Table XVII. Analysis of variance for nitrogen effect on number of tillers per plant of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	1.174	0.391	1.31
Varieties	1	4.014	4.014	13.44**
Error a	3	0.896	0.299	
Nitrogen	3	0.465	0.155	0.45
Var. X N	3	0.229	0.076	0.22
Error b	18	6.153	0.342	

**significant at the 1% level.

Table XVIII. Analysis of variance for nitrogen effect on plant height of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	120.34	40.11	0.24
Varieties	1	63,486.72	63,486.72	377.95**
Error a	3	503.92	167.97	
Nitrogen	3	157.84	52.61	0.96
Var. X N	3	18.46	6.15	0.11
Error b	18	980.71	54.48	

**significant at the 1% level.

Table XIX. Analysis of variance for nitrogen effect on head length of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	10.847	3.616	0.56
Varieties	1	6.125	6.125	0.95
Error a	3	19.403	6.467	
Nitrogen	3	9.826	3.275	2.23
Var. X N	3	1.549	0.516	0.35
Error b	18	26.458	1.470	

Table XX. Analysis of variance for nitrogen effect on grain yield of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	12,955,264	4,318,421	2.28
Varieties	1	230,981,668	230,981,668	121.91**
Error a	3	5,684,101	1,894,700	
Nitrogen	3	10,817,593	3,605,864	0.69
Var. X N	3	7,285,131	2,428,377	0.47
Error b	18	33,567,660	5,198,203	

**significant at the 1% level.

Table XXI. Analysis of variance for nitrogen effect on seed weight of the two varieties at Manhattan.

Source	df	SS	MS	F
Replications	3	2.94	0.98	0.98
Varieties	1	136.79	136.79	123.64**
Error a	3	3.32	1.11	
Nitrogen	3	3.48	1.16	0.27
Var. X N	3	6.58	2.19	0.08
Error b	18	14.78	0.82	

**significant at the 1% level.

Table XXII. Analysis of variance for nitrogen effect on number of tillers per plant of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	1.079	0.350	2.14
Varieties	1	6.197	6.197	36.77**
Error a	3	0.505	0.168	
Nitrogen	3	0.430	0.143	1.64
Var. X N	3	0.350	0.117	0.44
Error b	17	4.475	0.263	

**significant at the 1% level.

Table XXIII. Analysis of variance for nitrogen effect on plant height of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	1074.60	358.20	8.48
Varieties	1	31241.88	31241.88	739.98**
Error a	3	126.67	42.22	
Nitrogen	3	137.61	45.87	0.38
Var. X N	3	370.63	123.54	1.02
Error b	17	2060.97	121.23	

**significant at the 1% level.

Table XXIV. Analysis of variance for nitrogen effect on head length of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	34.01	11.337	42.46**
Varieties	1	10.30	10.30	38.58**
Error a	3	0.802	0.267	
Nitrogen	3	1.688	0.56	0.40
Var. X N	3	7.762	2.587	1.83
Error b	17	24.029	1.413	

**significant at the 1% level.

Table XXV. Analysis of variance for nitrogen effect on grain yield of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	11,586,203.7	3,861,434.2	9.09
Varieties	1	53,236,205.1	53,236,205.1	12.55*
Error a	3	1,273,810.5	424,603.50	
Nitrogen	3	1,399,842.1	466,608.04	0.40
Var. X N	3	10,181,676.7	3,393,892.25	2.94
Error b	17	19,614,640.1	1,153,802.71	

*significant at the 5% level.

Table XXVI. Analysis of variance for nitrogen effect on seed weight of the two varieties at Minneola.

Source	df	SS	MS	F
Replications	3	1.90	0.63	0.71
Varieties	1	61.53	61.53	69.13**
Error a	3	2.67	0.89	
Nitrogen	3	4.79	1.60	0.83
Var. X N	3	6.92	2.31	1.19
Error b	17	32.78	1.93	

**significant at the 1% level.

RELATIVE YIELD EFFICIENCY AND SOME PRODUCTION PRACTICES ON PEARL MILLET [PENNISETUM TYPHOIDES (BURM.) STAPF AND HUBB.]

by

BOTOROU OUENDEBA

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Pearl millet is an important food grain crop in India and many countries in Africa. It is used for forage in some parts of the United States and has considerable potential as a grain crop in the Great Plains.

Few data are available on production practices for optimum pearl millet grain yields.

Nitrogen and density effects on two millet varieties, 'Serere 3A' and 'Serere 3A X T239', were studied at Manhattan and Minneola, Kansas, during 1976. Four nitrogen levels (0, 60, 120 and 180 kg N per hectare) and five plant spacings (15, 30, 45, 60 and 75 cm in 75-cm rows) were used. Grain yield, number of tillers per plant, plant height, head length, seed weight and protein concentration were differently affected. At Manhattan, the highest density gave the highest grain yield per plot, whereas, grain yields were not significantly different at Minneola. Increasing plant spacing between plants increased number of tillers per plant but did not affect plant height, seed weight and protein concentration.

Grain yield was not affected by rate of nitrogen fertilizer application. The lack of nitrogen effect on grain yield can be explained by the low soil moisture that prevailed during the growing season. Increased level of nitrogen increased the grain protein concentration. Application of 180 kg N per ha gave the highest protein concentration.

Yield efficiencies of two millet varieties, one sorghum variety, and two corn varieties were studied under dryland conditions at the Ashland Agronomy Farm, Manhattan, during 1976.

The tall millet variety, 'Serere 3A', had the highest yield efficiency after 'Pioneer' corn. 'Amarillo Bajio' had the lowest yield efficiency. Yield efficiency was highly and significantly correlated with yield per plant.