FIRST DRAFT FOR PAPER TWO

An appraisal of irrigated temperate and tropical millet varieties in the semiarid region of Senegal

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SUMMARY

Millet constitutes a major food crop in the semiarid region of West Africa but yields are extremely low in peasant cropping systems because of inappropriate management and scarcity of water. The effects of fertilization, plant density and land preparation on yields of improved varieties were tested under irrigated facilities. Land preparation did not affect mean yields of the two millet varieties, 68 A x MLS from Nebraska (4025 kg/ha) and a local synthetic (4018 kg/ha). However, yield of the local synthetic variety increased by 60 % when planted on flat as opposed to ridges. Effect of fertilizer on yield of variety GB 87-35 yield was significant. In addition, method of land preparation and plant density increased yields of variety 68 A x MLS but not GB 87-35. Application of 100 kg/ha NPK+100 kg/ha urea gave the highest grain yield of variety 68 A x MLS. Neither frequency nor amount of irrigated water significantly affected yield of millet variety 68 A x MLS, but we noted that plots irrigated once per week with 75 % maximum water requirement of millet (526 mm) appeared most productive. Millet yields could be sustained in semiarid environments by ensuring a minimum and reliable water supply (526 mm/week during the dry season), optimum plant population (60 cm x 20 or 30 cm) as well as moderate fertilization (10 N, 9 P and 17 K kg/ha), and suitable land preparation method, depending on variety.

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Introduction

Yields of millet which constitute a major diet of people in northern Senegal is generally low because it is entirely rainfed and rainfall in this region is presently low (< 300 mm/year) and fluctuates from month to month and even within months (Dancette, 1973). Limited rainfall in northern Senegal is partly attributed to advancing desertification of the Sahara. Furthermore, soils of the semi-arid region are sandy, infertile and contain low levels of organic matter. Lack of improved varieties as well as poor crop and soil management also contribute to the low productivity under peasant conditions in this environment.

Research in Senegal, Niger and other semiarid countries have found that increased productivity of millet is possible with judicious management under favorable climatic conditions (Bationo, 1993). Management decisions under farmers' control include moderate application of manure and compost, a mixture of low doses inorganic fertilizers with manure or compost, rotation with legumes, varietal choices, appropriate land preparation techniques and proper sowing dates.

Farmers do not have any direct control on rainfall but indirectly they manipulate it through moisture retention strategies such as local irrigation canals, mulching and ditches. Added to that, in a move to intensify land use and boost cereal production in the light of growing human and livestock populations, the government has provided irrigation facilities on 240,000 ha northern Senegal. This study is designed to exploit this facility to assess whether or not millet production could thrive under the Sahelian environment. One millet variety from Nebraska (USA) and a local improved variety were tested under various cultural practices. The objective of the study was to determine the response of improved millet varieties to crop management (fertilization, plant population and land preparation) under irrigation.

Materials and Methods

The study was conducted in 1991 and 1992 with double cropping each year (i.e. four test periods) at the Thiago and Fanaye villages in north Senegal. The two villages belong to the Sahelo-Sudanian agroecological zone of Senegal. The soils are Alfisols (USDA, 1975) and generally deficient in major nutrients. Rainfall is low (250 to 300 mm) and uncertain; followed by a long dry season usually lasting about 8 months. Mean annual temperature is 20 to 35 °C. Additional information on the Sahelo-Sudanian agroecological zone of Senegal is provided by Sagna (1976).

Six field trials were conducted, four in 1991 and two in 1992. The design of the first trial in 1991 was a split plot with four replications. The main plots were millet varieties (68 A x MLS) variety from Nebraska, USA or a local synthetic (GAM 8201). Subplots were three land preparation techniques, flat, simple ridges (width=30 cm and height=40 cm) and double ridges (width=100 cm and height=30 cm). All treatments received 22 N, 21 P and 39 K kg/ha at planting and 67 Nkg/ha as top dressing after 2 weeks planting. The second trial in 1991 tested the same millet varieties with different fertilizer levels. The fertilizer treatments were 15 N, 14 P and 26 K kg/ha + 45 Nkg/ha as urea, 22 N, 21 P and 39 K kg/ha+77 kgN/ha as urea, 30 N, 28 P and 52 K kg/ha+ 90 kg N/ha as urea. The trial design was a split plot with four replications.

The third and fourth experiments in 1991 were modified to include plant density as an additional treatment and the synthetic variety GAM 8201 was replaced with variety GB 87-35. Research protocols of the third and fourth experiments were split-split-plot with four replications. Main effects were three fertilizer levels: 1)15 N, 14 P and 26 K kg/ha + 45 Nkg/ha as urea (divided into equal halves for top dressing at first weeding and 30 days later), 2) 22 N, 21 P and 39 K kg/ha at planting and 67 Nkg/ha as urea (divided into equal halves for top dressing at first weeding and 30 days later) and 3) 30 N, 28 P and 52 K kg/ha+ 90 kg N/ha as urea (divided into equal halves for top dressing at first weeding and 30 days later). Sub plots were land preparation on flat, simple ridges and double ridges. Sub-sub plots for variety GB 87-35 were plant spaced 80 x 80 cm, 80 x 60 cm, and 80 x 40 cm and sub-sub plot size was 11.52 m^2. Spacings for variety 68 A x MLS were 70 x 30 cm; 70 x 20 cm; 60 x 30 cm, 11 seeds/hole and 60 x 20 cm.

The 1992 studies examined the use of reduced levels of fertilizers on variety 68 A x MLS and frequency and quantity of water applied through irrigation. Fertilizer treatments were controlled with no fertilizer, 5 N, 4 P and 8 K kg/ha alone, 5 N, 4 P and 8 K kg/ha + 22 N kg/ha asurea, and 10 N, 9 P and 19 K kg/ha + 45 N kg/ha urea. Experimental design was a randomized block design with four replications. Treatments for the experiment consisted of an irrigation 693 mm water (maximum water used by millet) or 526 mm water (75 % of the maximum consumption) each of which was applied once or twice a week. The design was a 2 by 2 factorial in a randomized complete block with four replications. Maximum water consumption (Mc) was calculated as: Mc = Kc * Ev, where Kc = crop coefficient and *Ev* = evapotranspiration. Statistical analysis analyses were performed using SPSS (Norusis, 1997) and MSTAT-C (MSU, 1988).

Results and Discussions

Land preparation did not significantly *($P > 0.05$)* affect average yields of the Nebraska (68 A x MLS) and the local synthetic (GAM 8201) varieties (Table 1). However, mean yields of the local synthetic variety planted on flat increased by about 60 % and 26 %, relative to planting on simple and large ridges respectively. This finding is noteworthy, in view of time invested and labor costs in ridge construction.

On the contrary, the Nebraska variety performed on simple ridges, showing a 14 % increase over the flat. Average yields of both millet varieties, the Nebraska (4025 kg/ha) and the local synthetic (4018 kg/ha) were not significantly different *($P > 0.05$)* under irrigation, but yields of the two varieties were much higher than yields on farmers' fields under rainfed conditions (430-1230 kg/ha) in the semiarid environment (Bationo et al., 1993).

The effect of fertilizer was not significant ($P > 0.05$) nor was average varietal difference (Table 1), even though the yield of the local synthetic outperformed the Nebraska variety by 15 %. Doubling the fertilizer rate of 15 N, 14 P and 26 K kg/ha+45 Nkg/ha urea, resulted in about 20 % yield increase from 3295 kg/ha to 3911 kg/ha for the Nebraska variety whereas the local synthetic variety had a 10 % yield reduction. Apart from genetic differences of the two varieties, we cannot offer any agronomic argument to explain the behavior of the varieties; we suggest further research on this subject. Overall, the current yields were superior to what is obtained on farms in non-irrigated cropping systems in the Sahel as earlier indicated.

Results of yields for the new local improved variety (GB 87-35) and the Nebraska variety (68 A x MLS) in separate experiments are given in Table 2 and Table 3. Low yields in Tables 2 and 3 were principally due to infestation of stalk borers (*Coniesta ignefusalis*) and flower-sucking insects (*Psalydollita fusca* and *Cyliinrothorax dussaulti*). These insects pests caused about 30 % yield reduction.. Fertilizer affected yield of GB 87-35 ($P < 0.05$) but methods of land preparation and plant density did not *($P > 0.05$)* (Table 2). The yield of 1525 kg/ha with 22 N, 21 P and 39 K kg/ha and 67 Nkg/ha urea was not different from 1601 kg/ha with 30 N, 28 P and 52 K kg/ha +

90 N kg/ha as urea but these were significantly higher than 15 N, 14 P and 26 K kg/ha+45 Nkg/ha as urea. Thus, from this the recommended fertilizer rate is 22 N, 21 P and 39 K kg/ha and 67 Nkg/ha urea in combination with any of the planting arrangements and land preparation methods for variety GB 87-35.

Results of Table 3 indicate that fertilizer did not ($P > 0.05$) affect yields of the Nebraska variety but land preparation techniques and cropping patterns did ($P < 0.05$). Also, ridges, both simple and large improved yields of the Nebraska millet variety relative to planting on the flat, consistent with the earlier finding mentioned above. Yields of closer spacings between rows (60 cm x 30 cm or 60 cm x 20 cm) were superior to wider (70 cm x 20 or 30cm) spacings. It appears the best cultural practices to attain optimum yields of the Nebraska variety are ridges (large or small) and a high plant population density. Average yields were higher for Nebraska variety.

Results of the effect of reduced fertilizer rates on the Nebraska variety are presented on Table 4. Both grain and residue yields of millet responded to fertilizer ($P < 0.05$). Highest yields for grain (4880 kg/ha) and residues (6330 kg/ha) were obtained with the application of 10 N, 9 P and 17 K kg/ha+45 N kg/ha urea. The lowest yields came from 5 N, 4 P and 8 K kg/ha. This difference in yield between the control and the 5 N, 4 P and 8 K kg/ha plots (reduction by 36 %) which is (2440 kg/ha) and the control (3300 kg/ha) were not significantly different ($P > 0.05$).

Yields of the Nebraska variety in Table 1 compare favorably with the reduced yields in Table 4, thus, it may be safe to recommend less fertilizer (10 N, 9 P and 17 K kg/ha+45 N kg/ha as urea) to make this technology affordable to many farmers. Animal manure and compost could be tried alongside the use of mineral fertilizers. Recent and past experiences in the semiarid region of Senegal have demonstrated that a combination of mineral fertilizers and animal manure or compost improved millet and peanut yields better than either manure or fertilizer alone (Badiene et al., 1998; Ndiaye, 1998; Ganry, 1985; Charreau and Nicou, 1971).

Data on yield and yield components of the Nebraska variety as affected by frequency and amount of irrigation water are given in Table 5. Neither the frequency nor the amount of water significantly ($P > 0.05$) affected millet yield. However, plots irrigated with 75 % maximum water needed by millet tended to yield more than plots with full water dose. Millet is a dryland crop, so this finding is expected. Also, irrigation once per week yielded slightly higher than twice per week (Table 5). Governments and private organizations of the sub region should consider developing low level irrigation facilities to promote higher and more stable yields of millet and allied cereal crops. However, environmental impact assessment study should be done before implementing such program.

Table 1

Effects of land preparation and fertilizer on yields of irrigated millet varieties in the semiarid area of Senegal

Variety	Land preparation	Yield (kg/ha)	Fertilizer	Yield (kg/ha)
68AxMLS	Flat	3700	60 N, 14 P and 26 K kg/ha	3300
	Simple ridge	4230	90 N, 21P and 39 K kg/ha	3680
	Large ridge	4145	120 N, 28 P and 52 K kg/ha	3920
GAM 8201	Flat	4974	60 N, 14 P and 26 K kg/ha	4390
	Simple ridge	3146	90 N, 21P and 39 K kg/ha	4060
	Large ridge	3930	120 N, 28 P and 52 K kg/ha	3975
	Level of significance			
Variety		ns	Variety	0.079
Land prep.		ns	Fertilizer	ns
VxLP		0.043	Variety x fertilizer	ns

Table 2

Effect of fertilizer, land preparation and plant density on yields of irrigated millet (variety GB 87-35) in the semiarid area of Senegal.

Fertilizer	Density	Flat	Simple ridge	Large ridge
			Yield (kg/ha)	
60 N, 14 P and 26 K kg/ha	80cm x 80cm	1120	1170	1330
	80cm x 60cm	1290	1040	1590
	80cm x 40cm	1170	1250	1490
90 N, 21P and 39 K kg/ha	80cm x 80cm	1950	1410	1700
	80cm x 60cm	1490	1270	1610
	80cm x 40cm	1300	1660	1350
120 N, 28 P and 52 K kg/ha	80cm x 80cm	1770	1510	1800
	80cm x 60cm	1640	1460	1610
	80cm x 40cm	1630	1610	1370
Level of significance				
Density (D)	ns			
Fertilizer (F)	0.013			
Land preparation (LP)	ns			
LP x F	ns			
LP x D	0.047			
LP x D x F	ns			

Table 3

Effect of fertilizer, land preparation and plant density on yields of irrigated millet (variety 68 A x MLS) in the semiarid area of Senegal.

Fertilizer	Density	Flat	Simple ridge	Large ridge
			Yield (kg/ha)	
60 N, 14 P and 26 K kg/ha	70cm x 30cm	2030	2340	2030
	70cm x 20cm	2170	1790	2380
	60cm x 30cm	2060	2680	2420
	60cm x 20 cm	2730	2630	2330
90 N, 21P and 39 K kg/ha	70cm x 30cm	1850	2250	2200
	70cm x 20cm	1680	2170	2420
	60cm x 30cm	2370	2730	2830
	60cm x 20 cm	1890	2530	2280
120 N, 28 P and 52 K kg/ha	70cm x 30cm	1280	2650	2820
	70cm x 20cm	1790	2420	2680
	60cm x 30cm	2370	2680	2980
	60cm x 20 cm	1740	2630	3130
Level of significance				
Plant density (D)	<0.0001			
Fertilizer (F)	ns			
Land preparation (LP)	0.004			
LP x F	0.094			
LP x D	ns			
LP x D x F	ns			

Table 4

Effects of reduced rates of mineral fertilizer on grain and residue yields of irrigated millet (variety 68 A x MLS) in the semiarid zone of Senegal.

Fertilizer	Grain yield (kg/ha)	Residue yield (kg/ha)
Control (without fertilizer)	3300	4090
5 N, 4 P and 8 K kg/ha	2440	3020
27 N, 4 P and 8 Kkg/ha	3810	4740
60 N, 9 P and 70 K kg/ha	4880	6330
Level of significance		
Fertilizer	0.062	0.004

Table 5

Millet (var. 68 A x MLS) yield and yield components as affected by irrigation frequency and amount of water

Frequency	Amount	Yield (kg/ha)	Residue (kg/ha)	Non pro. tillers	Prod. tillers	Head (g/m^2)
			kg/ha	no of tillers/ha		
1/week	Maximum	3820	5423	172590	637135	3155
	75 %*maximum	4680	6915	274210	727465	3841
2/week	Maximum	3580	5202	220980	582290	2974
	75 % *maximum	4390	6472	196786	640361	3644
Level of significance						
Frequency (F)		ns	ns	0.17	0.13	ns
Amount (A)		0.12	0.02	ns	0.12	0.13
F x A		ns	0.05	ns	ns	ns