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AN APPRAISAL OF IRRIGATED TEMPERATE AND TROPICAL MILLET VARIETIES IN THE SEMIARID REGION OF SENEGAL

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ABSTRACT

Pearl millet (*Pennisetum glaucum* (L). R. Br.) constitutes a major food crop in the semiarid region of West Africa but yields are extremely low in subsistence cropping sysfems because of inappropriate management and scarcity of water. This study was designed to see if pearl millet could become a component of crop rotation in an irrigated scheme, and additionally, at a particular season (hot dry season - February to May when evapotranspiration levels are too high for other crops) when water supplies are low. The effects of fertilisation, plant density and land preparation on yields of improved varieties were tested under irrigation. Land preparation did not affect mean yields of the two very early dwarfmillet genotypes, hybrid 68 A x MLS from Nebraska (4025 kg ha-') and a local synthetic, variety GAM 8201 (4018 kg ha^{-1}). However, yield of taller, but early, local synthetic variety increased by 60% when planted on flat as opposed to ridges. Effect of fertiliser on yield of hybrid GB 87-35 was significant. In addition, method of land preparation and plant density increased yields of 68 A x MLS but not GB87-35. Application of 10 N, 9 P and 17 kg K ha^{-1} and 45 kg N ha^{-1} as urea gave the highest grain yield of variety 68 A x MLS. Neither frequency nor amount of irrigated water significantly ($P<0.05$) affected yield of pearl millet varlety 68 A x MLS, but we noted a trend ($P<0.12$) where plots irrigated once per week with 75% maximum, seasonal crop water requirement of millet (526 mm) produced higher yields. Millet yields could be sustained in semiarid environments by ensuring a minimum and reliable water supply (526 mm during the dry season), optimum plant population (60 cm x 20 or 30 cm) as well as moderate fertilisation (10 N, 9 P and 17 K kg ha^{-1} + 45 kg N ha^{-1} as urea), and suitable land preparation method, depending on variety.

Key *Words*: Agro-ecological zone, fertiliser use, irrigation, pearl millet, semi-arid

RESUMÉ

Le mil est la principale culture vivrière dans les régions semi-arides de l'Afrique Occidentale. Les faibles rendements enregistrés dans les systèmes de culture de subsistance sont le fait d'une gestion inadéquate et de la rareté de l'eau. Cette étude a pour but de déterminer l'aptitude du mil à s'intégrer dans une rotation avec d'autres cultures en culture irriguée, et particulièrement en contre saison (saison sèche chaude - de février à mai - quand l'indice d'évaporation est très élevé pour les autres cultures) durant laquelle les ressources en eau sont limitées. Les effets de la fertilisation, de la densité des plantes et de la préparation du sol sur les rendements des variétés améliorées ont été étudiés sous irrigation. La préparation du sol n'a pas affecté le rendement moyen des deux variétés du mil, l'hybride nain, 68 AX MLS de Nebrask'a et la variété synthétique locale de grande taille, GAM 8201 produisant respectivement 4025 kg ha^{-1} et 4018 kg ha-'. Cependant, le rendement de la variété synthétique locale a augmenté de 60% sur la culture à plat par rapport à la culture sur billon. L'apport d'engrais a un effet significatif sur le rendement de l'hybride GB 87-35. Par ailleurs, le mode de préparation du sol et la densité des plantes ont amélioré les rendements de la variété 68A X MLS, mais pas ceux de la variété GB 87-35. L'application de ION 9P et 17 kg K ha^{-1} et 45 kg N ha-' comme urée a produit le rendement le plus élevé chez la variété 68A

X MLS. Si la fréquence et les doses d'irrigation n'ont pas affecté d'une façon significative (P>0.05) le: rendement de la variété de mil 68A x MLS, les parcelles irriguées une fois par semaine et recevant un maximum de 75% dc leurs besoins en eau (526 mm) ont produit les rendements les plus élevés (P<0. 12). II ressort de l'ensemble des résultats obtenus que les rendement? du mil peuvent être sécurisés dans la zone semi-aride du Sénégal grâce à la satisfaction des besoins minimaux en eau, le semis à une densité optimale de 83 333 plants par hectare, l'efficacité d'itinéraires techniques appropriés tels que la préparation du sol, et une fertilisation raisonnée, adaptés aux variétés.

Mots Clés: Utilisation d'engrais, irrigation, mil, zone agroécologique semi aride

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L). R. Br.) is the main staple in the diet of people in northern Senegal. Yields are 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, 1974; INTSORMIL, 1993). Limited rainfall in northern Senegal is partly attributed to advancing desertification of the Sahelo-Sudanian region. Furthermore, soils of the semiarid 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.

Researchers in Senegal,Niger and other semiarid countries have found that increased productivity of millet is possible with judicious management under favourable climatic conditions (Bationo *et al.*, 1993). Management decisions under farmers' control include moderate application of manure and compost, a mixture of low doses of inorganic fertilisers 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 moistureretention strategies suchaslocal 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 in northern Senegal. Since millet has much lower waterrequirement than floodedrice, a much larger area of land could be cultivated with millet. 'This could be a more efficient way to use scarce irrigation water and provide significantly greater food production than flooded rice and utilise irrigation scheme resources at periods unfavourable for other crops. A millet hybrid from Nebraska (USA) and an early local improved variety were tested undervarious cultural practices. The objective of the study was to determine the response of improved millet varieties to crop management (fertilisation, 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 located in Senegal River Valley in north Senegal.. The two villages belong to the Sahelo-Sudanian agroecological zone of Senegal (Bèye, 1977). The soils are Alfisols (USDA, 1975) and generally deficient in major nutrients (Nicou, 1976; Ndiaye, 1989; Piéri, 1989). 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°C to 35°C. Additional information on the Sahelo-Sudanian agro-ecological zone of Senegal is provided by Sagna (1976).

Six field trials under irrigation were conducted, four in 1991 with two planted on 13 of February at Thiago (experiments 1 and 2) and two on 2 1 of August at Fanaye (experiments 3 and 4), and two in 1992,both planted on 11 of February (experiments 5 and 6). The design of the first tria1 in 199 1 was a split plot with four replications. The main plots were millet genotypes, early dwarf hybrid 68 A x MLS from University of Nebraska, Lincoln, Nebraska, USA and a local dwarf synthetic variety, GAM 820 1. Subplots were either three land preparation techniques or fertiliser at three levels. The genotype differences were important and were deliberately chosen, 68A x MLS and GAM 8201 were both dwarf and likely to respond to higher plant densities; GB87-35 is medium tall. All are shorter season, reaching physiological maturity in about 80 days, 10-15 days earlier than indigenous Senegalese varieties. Land preparation techniques were: 1) flat; 2) single ridges (width = 30 cm and height = 40 cm); and 3) double ridges (width = 100 cm and height=30 cm). All land preparation treatments received 22 N, 21 P and 39 K kg ha^{-1} at planting and 67 N kg ha-' urea as a top dressing 2 weeks after planting. The fertiliser subplot treatments applied in 199 1 were: 1) 15 N, 14 P and 26 K kg ha-'; 2) 22 N, 21 P and 39 K kg ha-' + 67 kg N ha-' as urea; and 3) 30 N, 28 P and 52 K kg ha-' + 90 kg N ha^{-1} as urea all applied at planting.

The third and fourth experiments in 199 1 minor season were modified to include plant density as an additional treatment and the synthetic variety GAM 820 I was replaced with variety GB 87-35. Research protocols of the third and fourth experiments were split-split-plot with four replications. Main plots werethreefertiliserlevels: 1)15 N, 14 P and 26 K kg ha^{-1} + 45 N kg ha^{-1} 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 N kg 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^{-1} + 90 kg N ha^{-1} as urea (divided into equal halves for top dressing at first weeding and 30 days later). Subplots were land preparation on flat, simple ridges and double ridges. Sub-sub plots for variety GB 87-35 were plants spaced 80 x 80 cm, 80 x 60 cm, and 80 x 40 cm and sub-subplot size was 11.52 m^2. Spacings for variety 68A x MLS were 70 x 30 cm; 70 x 20 cm; 60 x 30 cm, and 60 x 20 cm.

The rest of the studies conducted in 1992 examined the use of reduced levels of fertilisers on hybrid 68 A x MLS and frequency and quantity of water applied through irrigation. Fertiliser treatments were controlled with no fertiliser, 5 N, 4 P and 8 K kg ha^{-1}, 5 N, 4 P and 8 K kg ha-' + 22 N kg ha-' as urea, and 10 N, 9 P and 19 K kg ha^{-1} + 45 N kg ha^{-1} urea. Experimental design was a randomised block design with four replications. The weekly or twice weekly irrigation treatments consisted of a total of 693 mm water (maximum seasonal amount of water used by millet) or 526 mm water (75% of the maximum consumption). The design was a 2 by 2 factorial in a randomised complete block with four replications. Maximum water consumption (Mc) was calculated as: Mc = Kc * Ev, where Kc = crop coefficient and *Ev*=evapotranspiration. Statistical 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 varietyplantedontheflatincreased by about 58% and 26%, relative to planting on single anddouble ridges, respectively. This finding is noteworthy, because flat planting is cheaper than ridge planting. Conversely, the Nebraska variety performed better in single ridges, showing a 14% increase over the flat. Average yields of both millet genotypes, 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 main effect of fertiliser was not significant (P>0.05) nor was average varietal difference (Table 1), even though the yield of the local synthetic outperformed the Nebraska hybrid by 15 %. However, doubling the fertiliser rate of 15 N, 14 P and 26 K kg ha^{-1} + 45 N kg ha^{-1} urea, resulted in a significant (P<0.05) 20% yield increase of 3295 kg ha^{-1} to 3911 kg ha' for the Nebraska hybrid whereas the local synthetic variety had a 10% yield reduction. Apart from genetic differences of the two genotypes, reasons for the varietal differences are unclear; we suggest further research on this subject.

Results of yields for the new improved variety (GB 87-35) and the Nebraska hybrid (68 A x MLS) in separate experiments are given in Tables 2 and 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 *Cylindrothorax dussaulti*). These insect pests caused about 30 % yield reduction. Fertiliser affected yield of GB 87-35 ($P<0.05$) but methods of land preparation and plant density did not ($P>0.05$) (Table2). The yield of 1525 kg ha^{-1} with 22 N, 21 P and 39 K kg ha^{-1} and 67 N kg ha^{-1} urea was not different from 1601 kg ha-' with 30 N, 28 P and 52 K kg ha^{-1} + 90 N kg ha-' as urea but both of these were significantly higher than yields from 15 N, 14 P and 26 K kg ha-' + 45 N kg ha' as urea. Thus, from this the recommended fertiliser rate is 22 N, 21. P and 39 K kg ha^{-1} and 67 N kg ha^{-1} urea in combination with any of the planting arrangements and land preparation methods for variety GB 87-35.

TABLE 1. Effects of land preparation and fertiliser on grain yields of irrigated millet varieties in the semiarid area of Senegal (Experiments 1 and 2)

Variety	Land preparation	Yield (kg ha^{-1})	Fertiliser	Yield (kg ha^{-1})
68A x MLS	Flat	3,700	60 N, 14 P and 26 K kg ha^{-1}	3,300
	Simple ridge	4,230	90 N, 21 P and 39 K kg ha^{-1}	3,680
	Double ridge	4,145	120 N, 28 P and 52 K kg ha^{-1}	3.920
GAM 8201	Flat	4,974	60 N, 14 P and 26 K kg ha^{-1}	4,390
	Simple ridge	3,146	90 N, 21 P and 39 K kg ha^{-1}	4,060
	Double ridge	3,930	120 N, 28 P and 52 K kg ha^{-1}	3,903
		Level of significance		Level of significance
Variety (V)		ns	Variety	0.079
Land preparation (LP)		ns	Fertiliser	ns
V x LP		0.043	Variety x fertiliser	ns

TABLE 2. Effect of fertiliser, land preparation and plant density on grain yields of irrigated millet (variety GB 87-35) in the semiarid area of Senegal (Experiment 3)

Fertiliser	Density	Flat	Simple ridge	Large tidge
			Yield (kg ha^{-1})	
60 N, 14 P and 26 K kg ha^{-1}	80 cm x 80 cm	1,120	1,170	1,330
	80 cm x 60 cm	1,290	1,040	1,590
	80 cm x 40 cm	11,170	1,250	1,490
90 N, 21 P and 39 K kg ha^{-1}	80 cm x 80 cm	1,950	1,410	1,700
	80 cm x 60 cm	1,490	1,270	1,610
	80 cm x 40 cm	1,300	1,660	1.350
120 N, 28 P and 52 K kg ha^{-1}	80 cm x 80 cm	II ,770	1,510	1,800
	80 cm x 60 cm	1,640	1,460	1,610
	80 cm x 40 cm	1,630	1,610	1,370
Level of slgnificance				
Density (D)	ns			
Fertiliser (F)	0.013			
Land preparation (LP)	ns			
LP x F	ns			
LP x D	0.047			
LP x D x F	ns			

The results shown in Table 3 indicate that fertiliser 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 single and double, improved yields of the Nebraska millet variety relative to planting on the flat, consistent with the other study 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 30 cm) spacings. It appears that the best cultural practices to attain optimum yields of the Nebraska hybrid are ridges (large or small) and a high plant population density. Average yields were higher with the Nebraska hybrid.

Results of the effect of reduced fertiliser rates on the Nebraska variety are presented in Table 4.

TABLE 3. Effect of fertiliser, land preparation and plant density on grain yields of irrigated millet (hybrid 68 A x MLS) in the semiarid area of Senegal (Experiment 4)

Fertiliser	Density	Flat	Simple ridge	Large ridge
		kg ha $^{-1}$		
60 N, 14 P and 26 K kg ha $^{-1}$	70 cm x 30 cm	2,030	2,340	2,030
	70 cm x 20 cm	2,170	1,790	2,380
	60 cm x 30 cm	2,060	2,660	2,420
	60 cm x 20 cm	2,730	2,630	2,330
90 N, 21 P and 39 K kg ha $^{-1}$	70 cm x 30 cm	1,850	2,250	2,200
	70 cm x 20 cm	1,680	2,170	2,420
	60 cm x 30 cm	2,370	2,730	2,830
	60 cm x 20 cm	1,890	2,530	2,280
120 N, 28 P and 52 K kg ha $^{-1}$	70 cm x 30 cm	1,280	2,650	2,820
	70 cm x 20 cm	1,790	2,420	2,680
	60 cm x 30 cm	2,370	2,680	2,980
	60 cm x 20 cm	1,740	2,630	3,130
Level of significance				
Plant density (D)	0.0001			
Fertiliser (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 fertiliser on grain and stover yields of irrigated millet (hybrid 68 Ax MLS) in the semiarid zone of Senegal in 1992 (Experiment 5)

Fertiliser	Grain yield (kg ha'	Stover yield (kg ha $^{-1}$)
Control (without fertiliser)	3,300	4,090
5 N, 4 P and 8 K kg ha $^{-1}$	2,440	3,020
27 N, 4 P and 8 K kg ha $^{-1}$	3,810	4,740
55 N, 9 P and 25 K kg ha $^{-1}$	4,880	6,330
Level of significance		
Fertiliser	0.062	0.004

TABLE 5. Millet (hybrid 68 A x MLS) grain yield and yield components as affected by irrigation frequency and amount of water in 1992 (Experiment 6)

Frsquency	Amount	Yield	Stover	Non productive tillers	Productive tillers	Head g/m²
		kg ha⁻¹		(no. of tillers ha⁻¹)		
1/week	75%†	3,620	5,423	274,210	637,135	3,155
	maximum	4,660	6,915	172,590	727,465	3,641
2/week	75%†	3,590	5,202	220,980	562,290	2,974
	maximum	4,360	6,472	196,766	640,361	3,644
Level of signifkance						
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

†About 75 % of 693 mm water per year

Both grain and stover yields of millet responded to fertiliser ($P<0.05$). Highest yields for grain (4880 kg ha⁻¹) and stover (6330 kg ha⁻¹) were obtained with the application of 110 N, 9 P and 17 K kg ha⁻¹ + 45 N kg ha⁻¹ urea. The lowest yields came from 5 N, 4 P and 8 K kg ha-‘. The 36% difference in yield between the control (3300 kg ha⁻¹) and the 5 N, 4 P and 8 K kg ha⁻¹ (2440 kg ha-‘) plots is not significantly different ($P>0.05$).

Yields of the Nebraska hybrid in Table [compared favourably with the reduced yields in Table 4, thus, it may be safe to recommend less fertiliser (10 N, 9 P and 17 K kg ha-’ + 45 N kg ha⁻¹ as urea) to make this technology affordable to many farmers. Recent and past experiences in the semiarid region of Senegal have demonstrated that acombination ofmineral fertilisers and animal manure or compost improved rai.nfed millet and peanut yields betterthan either manure or fertiliser alone (Charreau and Nicou, 1971; Badiane, 1988). Additional research is needed on irrigated millet to determine whether adding organic amendments could further improve yield in the presence of inorganic fertiliser.

Data on yield and yield components of the Nebraska hybrid 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 witb ‘75% maximum water needed by millet tended to yield more than plots with full water dose. Millet is acrop adapted to low moisture conditions, particularly unsaturated soils, thus having lower water requirements (Vachaud et *al.*, 1978; Sarr et *al.*, 1998). Also, irrigation once per week yielded slightly higher than twice per week (Table 5). Govemments and private organisations of the sub region should consider developing low level irrigation facilities to promote higher and more stable yields of millet and other cereal crops. These crops may offer a more efficient way to use scarce irrigation water to produce more food per unit area than high water-requiring crops such as lowland rice. However, environmental impact assessment studies should be done before implementing such programmes.

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