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REGULAR ARTICLE

Yield performance and adaptation of four sorghum cultivars in Igunga and Nzega districts of Tanzania

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ABSTRACT

Sorghum plays a significant role for the smallholder farmers of Tanzania. It is the chief source of food and income for majority of Tanzanians but yields are low and crop management lacking leading to smallholder food and income insecurity. An experiment was conducted in the Nzega and Igunga districts of Tabora to compare improved cultivars Tegemeo, Pato and Macia to the commonly used landrace Wilu for adaptation and yield, assess farmers' preferences, and assess the economic potential of improved sorghum cultivars. Cultivar performance was measured for three seasons in a randomized complete block design with three replications per location. Tegemeo out-yielded other cultivars and had high average yields (2580 kg ha^{-1}). Wilu had the lowest yield (1460 kg ha^{-1}) but had consistent yields across environments. Ninety farmers developed seven criteria for cultivars assessments. Results of the farmers' rankings indicated Tegemeo was the best cultivar and recommended it be grown in the area. An economic analysis indicated the potential of doubling sorghum grain yield from 1000 to 2000 kg ha^{-1} and income from 525,600 to 928,800 TSh ha^{-1}. The combined statistical, farmers assessment and economic analysis showed changing order of importance of some cultivars which draws attention to breeders and policy makers on the importance of farmer's indigenous technical knowledge acknowledgement and participatory plant breeding in cultivars selection.

Key Words: *adaptation; economic analysis; farmer's assessment; Sorghum bicolour; yield.*

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is one of the five most important cereal crops in the world (Doggett, 1988). It is the major source of food in Africa and India. Sorghum has adaptive features that favor its growth in areas where other staple cereals such as wheat

(*Triticum aestivum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.) would not be suitable (Haussmann et al., 2000; Rami et al., 1998). According to Rohrbach et al. (2002), sorghum is the second most important staple food after maize, benefiting about 80% of Tanzanians. In Tanzania, sorghum is mostly grown under rainfed condition and has multiple uses including human food, animal feed, soil erosion control, thatching materials, brew preparation, and traditional ceremonial activities. In all African countries landraces are grown on 90-95 % of the sorghum growing areas, except in Sudan and Zimbabwe, where improved cultivars are used (Miller and Mann 1987). Tanzania is the largest producer of food grain sorghum in Southern Africa, which occupies 663,000 ha in the southern region and covers 21 % of the total cereal area in the country SADC/ICRISAT SMIP (1998).

The average sorghum yield for Tanzania is estimated to be approximately 1000 kg ha^{-1}, too low to sustain an average farm family for 12 months (FAO, 2008). Over the last 20 years average sorghum grain yield in Tanzania have ranged from 442 kg ha^{-1} in 2003 to 1310 kg ha^{-1} in 1996 (Fig. 1). The low average sorghum yields can be attributed to low soil fertility, bird feeding damage, striga, weed infestation, use of cultivars with low yield potentials, and socio-economic factors.

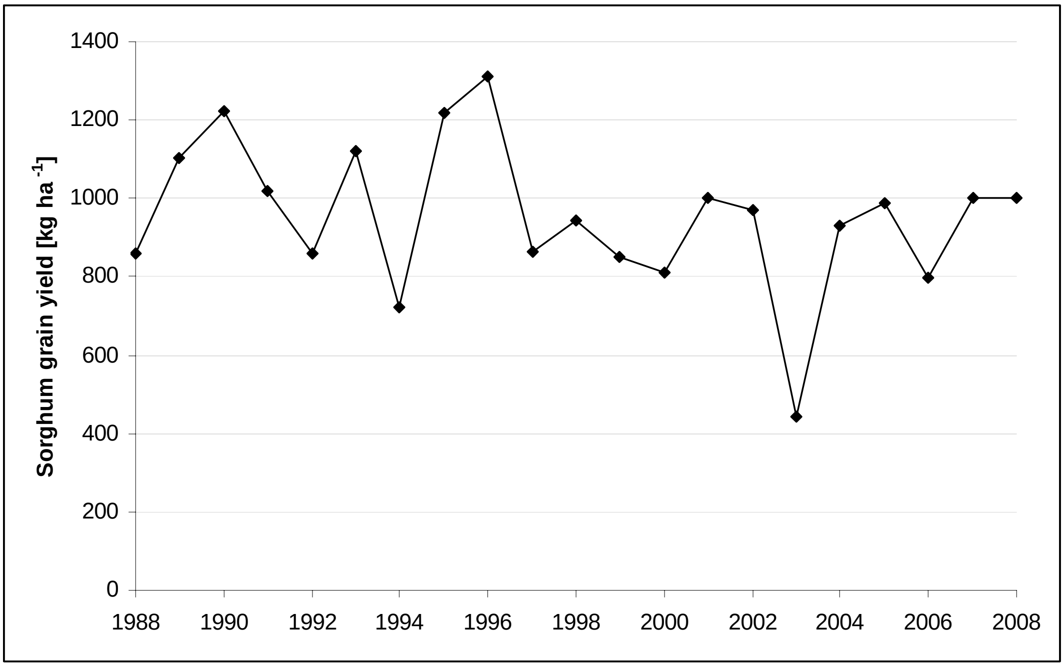

Figure 1. Average sorghum grain yield (kg ha^{-1}) for Tanzania 1988-2008. (FAOSTAT, 2008)

The rate of adoption of new sorghum cultivars in Tanzania is low and many farmers still prefer landraces. Although landraces are late maturing and photoperiod-sensitive, they are well adapted to local stresses, have high quality stover, good fuel properties, good properties for the production of local fermented beverages, good grain qualities, good cooking qualities, as well as acceptable yield under sub-optimal conditions. Furthermore, landraces have the preferred white seed and pearly white endosperm.

Improved cultivars such as Tegemeo, Pato and Macia, developed by the Tanzania sorghum breeding program in collaboration with the Southern African Development Community/ International Crop Research Institute for the Semi- Arid Tropics Sorghum and Millet Improvement Programme (SADC/SMIP) had high yields in on research station tests and possess preferred traits such as cooking quality and pearly white endosperm. Research station small-plot trials are vital tools for evaluating cultivar performance but on-farm trials are needed to evaluate farmer opinions that may enhance or hinder adoption of improved cultivars. A combination of field trial data alongside with farmers' assessments and economic analysis has shown potential to increase the rate of cultivar adoption elsewhere (Kaizzi et al., 2006). Therefore, yield performance and adaptation studies were carried out in the Igunga and Nzega districts of Tanzania.

The objectives of this study were to (1) evaluate sorghum cultivars for adaptation and yield, (2) assess farmers' preferences, and (3) assess the economic potential of sorghum cultivars.

MATERIALS AND METHODS

On-farm sorghum yield trials were conducted in the Nzega and Igunga districts of the Tabora region for three seasons from 2002-2005. Three sites (Isanzu, Shila, Mhembe) were located in the Nzega district and three (Ziba, Mbutu, Majengo) in the Igunga district for a total of 18 location x year combinations. Cultivars Wilu (a local landrace check), Tegemeo, Pato and Macia were planted in a randomized complete block design (r = 3 per location); an individual farm was considered a complete block. Cultivars were evaluated on 22.5 m^2 plots (075 x 5 rows x 6 m), which gives a plant population of 88,888 plants ha^{-1}. Fertilizer at the rate 46 kg N ha^{-1} and 18.4 kg P_2O_5 ha^{-1} was used. The center three rows of each plot were harvested for yield but no end trimming of the plots occurred. Trials were managed according to recommended agronomic practices. To control stalk borers, 175 g ha^{-1} of Phoskill (Monocrotophos 36 SL) was applied in 500 L H_2O ha^{-1} at each location.

Sorghum grain yield was recorded at harvest and analyzed using Genstat (2006) statistical computer software. We considered location, year, variety and all their interactions to be fixed effects. Farm within location x year was the sole random effect. The homogeneity of variance assumption held true for the pooled residual error term and, hence, there was only a single error term.

To reveal farmers preferences on sorghum cultivars, 90 farmers selected seven criteria for ranking the cultivars: bird attack resistance, plant height, days to maturity, panicle size, grain size, grain color, stalk borer tolerance and grain yield. A scale of 1-5 was used to assess these traits with the definition as follows: 1 = not preferred, 2 = less preferred, 3 = moderately preferred, 4 = highly preferred and 5= excellent. Farmers were given 5 grains and asked to place 1, 2, 3, 4 or 5 grains into a container representing a given trait and cultivar according to the abovementioned definitions. Seeds were counted to get totals for each trait per cultivar; the largest total count was assigned first rank. An economic analysis to assess the economic viability of cultivars was done according to procedures described by CIMMYT (1988) by using prevailing market prices of inputs during planting while outputs were assessed at harvesting time (field price).

A yield adjustment of 20% was applied to reflect the yield achievable under real farming conditions. According to Shiluli et al. (2003), this is done to reflect the presence of researchers and extension agents in farmers' field during on-farm trials execution. Gross field benefit analysis was used to reveal feasibilities of introduced cultivars in the area (CIMMYT, 1988). It was calculated from adjusted yield (plot yield x 0.80) x field price. In this analysis, a field price of 450 Tanzanian Shilling (Tsh) per kg was used. Field price comprises of average price at crop harvest. This estimation is based on the price of crops during harvesting period. It is not fixed and varies from season to season (CIMMYT, 1988).

RESULTS AND DISCUSSION

YIELD TRIALS

Among the interactions, only the village x cultivar interaction was significant (P < 0.001; Table 1). This interaction was due almost entirely to changes in magnitude among location and not to changes in cultivar rank among locations. Tegemeo was the top-ranked cultivar at all locations and Wilu was the bottom-ranked, except for one location (Ziba), where it switched the 3rd rank with Pato (data not shown). Macia occupied 2nd rank at all locations and Pato 3rd, except for the abovementioned location. Hence, yield data may be discussed on the basis of location and cultivar main effects.

There were statistically significant ($P < 0.0001$) differences among test locations (Table 1). The highest average yield (3569 kg ha^{-1}) was recorded at Majengo, whereas Mhembe had the lowest average yield of 904 kg ha^{-1} (Table 2). This ranking was not altogether unexpected as Majengo is located on a montmorrillonite fertile soil, while Mhembe is located on a rather infertile sandy soil (TRIDEP, 1985). Indeed, all locations in the Nzega district share this sandy soil attribute.

Cultivar differences also were significant ($P < 0.0001$, Table 1), where Tegemeo had the highest average yield (2580 kg ha^{-1}) and Wilu the lowest (1466 kg ha^{-1}; Table 4). Similar yield trends were observed across all environments, where Tegemeo had the highest yield in 17 and Wilu the lowest yield in 16 out of 18 location x year combinations (data not shown). The improved cultivar Tegemeo was thus at least as stable in performance as the landrace Wilu. Improved cultivars have a high inherent (genetic) yield potential. While the yield of Wilu increased at the more fertile locations, it never even came close to the yield of Tegemeo. Thus, the deployment of improved sorghum cultivars in Tanzania could raise the nationwide average sorghum yield substantially above the current average nationwide yield of approximately 1000 kg ha^{-1} (FAOSTAT, 2008).

Table 1. Analysis of variance on grain yields of four sorghum cultivars analyzed across 18 environments in Nzega and Igunga districts

Source of variation	d.f.	MS	*F*-value	*P*-value
Location (L)	5	47094930	413.22	<0.0001
Year (Y)	2	181284	1.59	0.207
Cultivar (C)	3	11612013	101.89	<0.0001
L x Y	10	30466	0.27	0.987
L x C	15	436593	3.83	<0.0001
Y x C	6	87022	0.76	0.600
L x Y x C	30	94986	0.83	0.714
Residual	144	113970		
Total	215			

Table 2. Six testing sites description and mean sorghum grain yields evaluated for three seasons (2002-2005) in Nzega and Igunga districts

Location	District	Altitude (m)	Latitude	Longitude	Grain yield (kg ha^{-1})
Majengo	Igunga	1067	04°14′ N	033°55′ E	3569
Mbutu	Igunga	1071	04°15′ N	033°54′ E	3156
Ziba	Igunga	1231	04°14′ N	033°28′ E	2399
Shila	Nzega	1206	04°14′ N	033°07′ E	1034
Isanzu	Nzega	1220	04°15′ N	033°05′ E	1312
Mhembe	Nzega	1241	04°15′ N	033°02′ E	904
SED					73

SED – Standard error of the difference

Table 3. Matrix of ranking of sorghum cultivars across three seasons (2002-2005) in Nzega and Igunga districts

Year/Criterion	Tegemeo	Pato	Wilu	Macia
2002/2003				
Bird damage	2	2	1	2
Plant height	3	3	2	2
Days to maturity	3	3	1	3
Panicle size	3	2	1	3
Grain size	3	2	3	2
Grain color	3	3	2	3
Stalk borer tolerance	3	2	3	2
Grain yield	3	3	1	2
Total	23	20	14	19
Rank	**1**	**2**	**4**	**3**
2003/2004				
Bird damage	3	2	3	3
Plant height	2	2	2	1
Days to maturity	3	2	3	1
Panicle size	2	1	3	1
Grain size	3	3	2	3
Grain color	2	3	3	2
Stalk borer tolerance	3	2	3	3
Grain yield	2	3	3	1
Total	20	18	22	15
Rank	**2**	**3**	**1**	**4**
2004/2005				
Bird damage	1	1	2	1
Plant height	3	2	2	2
Days to maturity	3	2	2	3
Panicle size	2	2	3	1
Grain size	1	3	2	3
Grain color	2	2	2	3
Stalk borer tolerance	2	1	1	1
Grain yield	3	3	3	2
Total	17	16	17	16
Rank	**1**	**2**	**1**	**2**

Table 4. Estimated economic returns of four sorghum cultivars evaluated for three seasons (2002-2005) in Nzega and Igunga districts

	Preference ranking based on		Grain yield			
Cultivar	All eight criteria	Grain yield only	Research plots (kg ha^{-1})	Farmer achievable (kg ha^{-1})	Rank	Gross field benefit (Tsh ha^{-1})
Tegemeo	1	2	2580	2064	1	928 667
Pato	2	1	2003	1602	3	721 067
Wilu	3	3	1466	1173	4	527 933
Macia	4	4	2200	1760	2	792 000
SED			46	37		16 539

SED – Standard error of the difference

FARMER ASSESSMENT AND ECONOMIC ANALYSIS

Farmers ranked Tegemeo either at the first or the second position across all three seasons (Table 3). The overall preference ranking of cultivars based on eight criteria for three crop years was in the order Tegemeo > Pato > Wilu > Macia. The preference rating based on the single criterion yield also revealed that farmers assigned a much higher preference to the landrace cultivar Wilu than was warranted based on the objective yield criterion. Familiarity seems to play a large role in subjective yield rankings. Furthermore, farmers prefer sorghum cultivars that meet multiple objectives Mekbib (2006). This means that Tegemeo and newer improved cultivars could easily be introduced and incorporated in the farming systems based on multiple subjective preference criteria.

The economic analysis revealed that a farmer would have earned 400,734±16,539 Tsh ha^{-1} more by growing Tegemeo instead of the landrace Wilu (Table 4). The income difference illustrated by this study could be used to pay for capital and other incentives to sorghum growers in the region.

COMPARISON OF YIELD, FARMERS' ASSESSMENT AND ECONOMIC ANALYSIS

Statistical and economic analysis resulted in the same sorghum cultivars rankings Tegemeo > Macia > Pato > Wilu. This is due to the assumption that the variable cost (seed, fertilizer, labor) will be the same for all cultivars (Shiluli et al., 2003). Cultivar ranking based on a subjective assessment of yield potential were quite different Pato > Tegemeo > Wilu > Macia, assigning a much greater preference to Wilu than was warranted on the basis of the objective yield criterion. Cultivar ranking based on all eight farmer-developed criteria was also quite different from yield-based ranking with Tegemeo > Pato > Wilu > Macia. This indicates that among the three improved cultivars, Tegemeo was most preferred for multiple uses. Wilu (Local landrace cultivar) occupying 3rd rank in farmer assessment reflects farmers' different criteria for cultivar selection, yield potential under sub-optimal condition, and multiple uses other than grain yield per se. But our trial also shows that the implicit subjective assumption of landraces having higher yield stability may not be warranted. While local knowledge is important for policy makers and breeders alike it has to be tempered by objective criteria.

CONCLUSIONS

Results showed yield advantages of three improved sorghum cultivars over a landrace sorghum cultivar. Tegemeo, in particular, was top-ranked based on objective yield trials, gross field returns, and multiple criteria subjective preference rating. These subjective preference ratings could be used as a tool to increase rate of adoption of improved cultivars. Based on yield performance, farmers' assessment and economic returns, Tegemeo was recommended to be grown in Nzega and Igunga districts of the Tabora region. Plant breeders could use such regional trials to fine-tune the area of adaptation of new improved cultivars. Stakeholders can use the information from such trials to improve their income by growing more productive cultivars.

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