MUARIK BULLETIN, Vol. 7. pp. 30-37, 2004
Printed in Uganda.
ISSN 1563-3721

Sorghum yield response to kraal manure combined with mineral fertilisers in eastern Uganda

G. Olupot, J. Etiang, J. Aniku, H. Ssali† and M. Nabasirye††
Department of Soil Science, Makerere University, P.O. Box 7062, Kampala, Uganda
†Kawanda Agricultural Research Institute, P.O. Box 7065, Kampala-Uganda
††Department of Crop Science, Makerere University, P.O. Box 7062, Kampala, Uganda

Abstract

Sorghum [*Sorghum bicolor* (L.) Moench] is a strategic food security crop in the drought prone areas of Uganda. However, farmers' yields are much lower than what is reported in research stations. Low soil fertility is identified as a major contributor to the low grain yields but little has been done to address this problem. The use of kraal manure obtained from cattle that are an integral component of the farming systems in sorghum growing areas is not being exploited probably due to farmers reluctance to take advantage of synergistic relationships between crop and livestock production units. The yield responses of sorghum to kraal manure and mineral fertiliser applications are largely unknown in Uganda and besides, application rates have not been determined. This study was conducted to evaluate sorghum yield response to kraal manure (KM) combined with mineral nitrogen (N) and phosphorus (P) fertilisers in Kumi district, eastern Uganda. On-farm experiments were conducted for three rain seasons; from August 2000 to December 2001. We found that combining 2.5 t KM with 22.5 kg N and 8.5 kg P ha^{-1} gave the highest grain yields (2.1 and 4.0 t ha^{-1}) for the first and second seasons of 2001, respectively. Further studies are, however, needed to establish the feasibility of this input combination for increased and sustained sorghum production.

Key words: Drought prone areas, food security, grain yield, nitrogen, phosphorus, *Sorghum bicolor*

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench.] is a staple cereal in the drought prone areas of Uganda. Such areas are found in the eastern, northeastern and southwestern parts of the country and are the areas where sorghum production is concentrated (Esele, 1988). However, farmers' get on average 700 kg ha^{-1} of the grain, compared to 4000 kg ha^{-1} reported in research stations. Use of low-yielding varieties (Cox *et al.*, 1984), poor soil fertility (Esele, 1988), low soil moisture (Seetharama, 1995), and pests and diseases (Esele, 1995a) are the major contributors to the low farmers' yields.

Earlier, FAO (1981) had projected that higher yields per unit area would account for 60 % of sorghum yield increases by the year 2000. Accordingly, World Bank (1982) sounded calls for increased research in neglected areas of rain fed crops, particularly coarse grains, such as sorghum and millet (*Elusine coracana* L. Gaertn) in drought prone areas. In particular, World Bank (1982) stressed the need to develop location-specific technologies that would increase grain production while maintaining high quality of the soil. Recognizing its strategic importance in the drought prone areas of Uganda, NARO (1991) re-sounded calls by World Bank (1982) by ranking sorghum third after maize (*Zea mays* L.) and finger millet, in order of research priorities within the framework of the country. Significant scores have since, been made from breeding for drought tolerance (House, 1995; Seetharama, 1995; Omanya *et al.*, 1996), grain quality improvement (Asante, 1995) and higher yields (Cox *et al.*, 1984; Esele, 1995b). These concerted efforts saw Esele (1995b) release varieties like sekedo with a yield potential of 3 to 5 t ha^{-1}. However, farmers have not yet realised this yield potential, owing to the inherently low soil fertility in the areas where sorghum is produced. Since cattle are an integral component of the farming system in Kumi district, we conducted this study to evaluate sorghum grain yield response to KM combined with modest quantities of mineral N and P fertilisers.

Materials and methods

This study was conducted in Kanyum parish, Kanyum sub-county, Kumi district, in eastern Uganda. Kumi lies in the agro ecological zone where the Teso Farming System (TFS) is practiced (Wortmann and Eledu, 1999). The landscape is gently undulating, with occasional inselbergs. Kumi lies on latitude 1^0 43' N, longitude 33^0 37' E and on elevation ranging from 1030-1127 m above sea level (Yost and Eswaran, 1990).

The climate is mainly tropical, with a bimodal type of rainfall, averaging 900-1200 mm yr^{-1} (Yost and Eswaran, 1990). First rains start from March, peaking in April, and subsiding in June. The second rains start from August, peaking in September, and subsiding in October, or persisting up to November. The intervening periods are dry. Prolonged dry spells may be experienced in the east and northeastern parts of the district, especially areas bordering Karamoja. Annual temperature ranges from 15 to 36 °C, with a mean temperature of 25 °C (Yost and Eswaran, 1990).

The typical farming system comprises of cotton (*Gossypium hirsutum L.*)-finger millet system. Other major crops are sweetpotatoes (*Ipomoea batatus* L. Lam), cassava (*Manihot esculenta* Crantz) and sorghum (Mugisha, 1996). These are often cultivated in a crop rotation sequence with legumes like groundnuts (*Arachis hypogaea* L.) and cowpeas (*Vigna ungiculata* L. Walp.) on light-textured soils, ranging from sandy loam to loam. In addition to cultivation, cattle were an integral component of the TFS before they were rustled away in 1987 (Walaga *et al.*, 2000). However, some farmers have managed to restock kraals.

On-farm experiments were conducted with farmers who had access to KM either from their own cattle or from neighbours for three planting seasons; second rains of August - November 2000, first and second rains of March-June and August-November 2001, respectively. Different plots were used during each planting season. Each season, 20 farmers each as a replicate, were involved in the execution of on-farm trials.

Farmers' fields where soil samples had been analysed (Olupot *et al.*, 2003 unpubl.) were ploughed twice using oxen, as practised by the farmers. The plough depth was about 0-15 cm. Second ploughing was done two weeks after the first ploughing, to turn the decomposing plant materials. This also helped to pulverise the soil to produce a suitable tilth for the relatively small sorghum grain.

The fields were marked into experimental units of dimension 5 m x 5 m. Each of the plots within a block was separated by 0.5 m alleys. Each farmer had 7 treatments arranged in a randomized complete block design. The treatments included: T_0 (P_0+N_0+KM_0), T_1 (2.5 t KM), T_2 (17 kg P + 2.5 t KM), T_3 (45 kg N + 2.5 t KM), T_4 (8.5 kg P + 22.5 kg N + 2.5 t KM), T_5 (8.5 kg P + 2.5 t KM) and T_6 (22.5 kg N + 2.5 t KM) ha^{-1}.

Field dry KM was broadcast and mixed with the soil before planting. Five to ten seeds of the Sekedo variety of sorghum were planted at a recommended spacing of 60 cm x 20 cm (Obuo, 1995). The rationale for the choice of sekedo variety was based on its drought tolerance, resistance to birds and higher yield potential (3-5 t ha^{-1}) (Esele, 1995b).

Phosphorus as single super phosphate (7.9 % P), was spot applied once at planting, 5 cm deep and 5 cm away from the seed holes. Nitrogen as calcium ammonium nitrate (26.6 % N) was split into two doses. The first dose (25 % of the total dose) was spot applied at planting as for P, to supply some starter nitrogen (de Geus, 1967). Thinning to one seedling per hole was done during the first weeding, to give 83,400 plants ha^{-1}. The second dose of nitrogen was top-dressed at anthesis. According to de Geus (1967) and Clegg (1996), these are the critical stages for nutrient demand for grain filling in sorghum.

The crops were sprayed with Fenkil and Ambush whenever necessary, to control particularly shoot flies and stalk borers, the common pests of sorghum. The purpose was to minimize as much as possible, the influence of external factors on the yield of sorghum. The experiments were closely monitored by both the farmers and the researchers.

Total above ground biomass of sorghum was determined at harvest, by cutting whole plants at ground level for each plot. Field dry biomass was weighed in kg per plot. The sorghum heads were then cut off from the stover and weighed in kg per hectare. The heads were then threshed per plot, and the grain weights determined in kg per hectare. The moisture content in the stover and grain were standardised by oven drying sub-samples in the oven at 70 °C for 48. The threshing percentage (TP) was calculated as the fraction of grain expressed as the percentage of sorghum head weights (HW) in kg ha^{-1} (equation 1).

$$TP = \frac{GY}{HW} * 100 \qquad (1)$$

Where: GY = Sorghum grain yield (kg ha^{-1})

The harvest index (HI) under each treatment was estimated from equation 2 below.

$$HI = \frac{GY}{AGB} * 100 \qquad (2)$$

Where: AGB = above ground biomass (kg)

The data collected were subjected to ANOVA using the GenStat computer programme version 6.1. The significantly different means were separated using Fischer's LSD (Steel *et al.*, 1997).

Results and discussion

Effect of combining kraal manure with mineral N and P on above ground biomass of sorghum

The second season experiment for August - November 2000 failed because of late planting which coincided with drought, coupled with devastation of the crop by the smut fungus *(Sporisorium sorghi)* (Esele, 1995a). The above ground biomass (AGB) yields of sorghum for the first and second rain seasons of 2001 in response to KM combined with mineral N and P are presented in Figure 1. All the treatment combinations influenced AGB of sorghum variably ($P < 0.05$) in both seasons. Treatment T_3 gave the highest AGB (14.21 t ha^{-1}). This yield was as good ($P > 0.05$) as 13.66 t obtained when 2.5 t KM was combined with 22.5 kg N and 8.5 kg P ha^{-1} (T_4). These yields were close to the 13.33 t ha^{-1}, which Omanya *et al.* (1996) got as a mean of 20 sorghum genotypes at the University of Nairobi Dry Land Research Field Station during the second season of their experiments. The control treatment, T_0 gave the lowest AGB (9.65 t ha^{-1}). The second season AGB was generally higher in all the treatments than during the first season. Again T_3 and T_4 significantly ($P< 0.001$) outperformed the other treatments. Application of nitrogen and phosphorus fertilisers was also instrumental in increasing the AGB yield of maize in the south-east lowveld of Zimbabwe (Nyakatwa *et al.*, 1996).

Nitrogen stimulates the vegetative growth of a plant whereas phosphorus encourages root growth and uptake of nutrients like nitrogen. These two factors contributed to the higher AGB of sorghum. Vegetative and root growth also helped both rice and wheat to attain higher straw yields in the Sudan (Ayoub, 1986; Kolar and Grewal, 1989).

Attainment of higher AGB is desirable for more utilisation of available water and uptake of nutrients. This, according to Seetharama (1995) enables a crop to thrive in drought prone areas through a mechanism known as drought avoidance. High AGB enables the crop to accumulate assimilates that kg N (T_3) and with 22.5 kg N and 8.5 kg P ha^{-1} (T_4), respectively. The KM and mineral N and P rates used were much lower than the levels used by Clegg (1996) in the USA, Gono (1996) and Zengeni (1996) in Zimbabwe. The manure rate used was also lower than the 8 t ha^{-1} that Ikombo (1984) recommended for maize grain yield of 5 t ha^{-1} in eastern Kenya. The results highlight the crucial importance of both N and P in increasing sorghum grain yields in Kumi district.

Nutrient transfer to the grain is important in terms of the physiology of grain filling, yield and nutritive value of the grain. Mengel and Kirkby (2001) reported that the transportation of nutrients from xylem to the grain appears to be strongly influenced by the availability of water and plant nutrients in the root environment. The role of manure in moisture and nutrient retention could have accounted for the more than doubling of the grain yields obtained under the farmers' practice (T_0) during the first season, where 2.5 t KM alone (T_1) was applied. The poor quality of the manure used (1.1 % N, and 0.6 % P) (Olupot *et al.*, 2003 unpubl.), however, highlights the need to supplement it with modest quantities of mineral N and P fertilizers. This was evidenced by the more superior grain yields ($P < 0.05$) obtained where 2.5 t KM was combined with 22.5 kg N and 8.5 kg P ha^{-1}.

Nitrogen and phosphorus play a key role in increasing the leaf area index (LAI) as well as chlorophyll content in leaves of plants. These factors enabled rice and wheat to trap more photosynthetically active radiation (PAR), which increased the number of ear-bearing shoots, grains per panicle, grain weight and yield (Kolar and Grewal, 1989). Nitrogen is particularly important in determining grain number and quality, and hence yields. Its deficiency results in abortion of the initial florets, production of a small panicle with fewer primary and secondary branches, and fewer visible florets. These factors reduce yields, depending on the on-set of the deficiency. Asher and Cowie (1974) found that N deficiency between floral initiation and anthesis caused between 16 to 30% of the florets to abort whereas N stress following anthesis had little effect on grain yield, but greatly reduced grain N concentration. Phosphorus was, on the other hand, found to promote extensive lateral and fibrous root development (Hajabbasi and Schumacher, 1984). Ayoub (1986) found that phosphorus applied to irrigated rice increased uptake of soil- fertiliser-nitrogen, resulting in higher straw and grain yields. The synergistic relationship between nitrogen and phosphorus was the reason for the superior performance of sorghum where they were jointly applied.

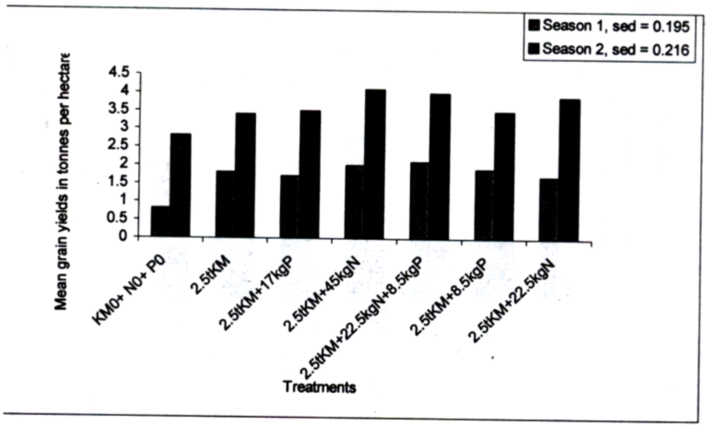

Figure 2. Sorghum grain yield response to N- and P-enriched KM for seasons 1 and 2.

Effect of KM with N and P on the threshing percentage and harvest index of sorghum

The results of threshing percentage (TP) and harvest index (HI) of sorghum are presented in Table 1. The T_0 treatment gave the poorest ($P < 0.05$) TP (51.3 %) during the first season. During the second season, none of the treatments influenced the threshing percentage of sorghum ($P > 0.05$). The results indicate that application of soil inputs is more critical in increasing the proportion of the grain in sorghum heads during the first season than during the second season.

Some farmers planted sorghum in fields where groundnuts had been harvested. Groundnuts is usually grown during the first season, whereas sorghum is mainly a second season crop. The symbiotic association between the *Rhizobia* and legumes like groundnuts was found to fix substantial quantities of N (22.5 kg ha^{-1}) Olupot *et al.* (2003 unpubl.). The symbiotically fixed N may have benefited the sorghum crops particularly in the control treatment.

The harvest index (HI) of sorghum was highly influenced ($P < 0.001$) by the various treatments. Again T_4 gave the highest harvest indices ($P < 0.001$) of 0.153 and 0.229 for the first and second seasons, respectively. Combining KM with small doses of mineral N and P fertilisers increased the proportion of nutrients that ended up in the economic (grain) yield of sorghum.

One of the major factors constraining the use of mineral fertilisers in Uganda (Bekunda and Woomer, 1996) is their high costs. Reduction in costs of sorghum production is important because the crop is grown mainly for food security reasons. Besides, the people who produce this crop in Kumi district are small scale farmers who are already resource constrained, and can not therefore, afford use of higher rates of mineral fertilisers. Interventions that minimise the costs of producing sorghum such as combining KM with small quantities of N and P may receive wide acceptance in Kumi district.

Conclusions and recommendations

Kraal manure has a potential of enhancing productivity and thus bridging the wide gap between farmers' and research station grain yields. Farmers are advised to apply 2.5 t KM ha^{-1}, if they are to benefit from its yield advantages. The poor quality of the manure suggests the need to combine it with mineral N and P fertilisers. For this particular study, combined application of 2.5 t KM with 22.5 kg N and 8.5 kg P ha^{-1} resulted in grain yields comparable to those reported in research stations.

Table 1. Sorghum threshing percentage and harvest index as influenced by the inputs.

Treatment	TP_1	TP_2	HI_1	HI_2
	— (%) —			
T_0 (P_0+N_0+KM_0)	51.3a	75.2	0.071a	0.185a
T_1 (P_0+N_0+2.5 t KM ha^{-1}	63.7	76.5	0.137bc	0.235b
T_2 (17 kg P+N_0+2.5 t KM)	65.2	77.3	014bc	0.219a
T_3 (P_0+45 kg N+2.5 t KM)	62.9	76.8	0.137bc	0.227
T_4 (8.5 kg P+22.5 kg N+2.5 t KM)	64.6	77.7	0.153bc	0.229
T_5 (8.5 kg P+N_0+2.5 t KM)	63.2	78.2	0.141bc	0.242
T_6 (P_0+22.5 kg N+2.5 t KM)	59.1	78.4	0.132c	0.243
CV (%)	12.4	6.5	21.7	19.3

Means followed by the same letter (s) or without any letter (s) within each column were not significantly different ($P > 0.05$). 1 & 2 (first & second seasons).

Agronomic practices should aim at ensuring timely maximum production of above ground biomass, since this later translates into higher grain yields. Further studies to establish the feasibility of this input combination and to provide plausible explanations for the more superior performance of sorghum during the second rain season than during the first season are recommended.

Acknowledgement

We are grateful to the Rockefeller Foundation Forum for Agricultural Resource Husbandry for funding this study under grant # 2000 FS 039; and for sponsoring the Fifth Regional Meeting held in Entebbe, Uganda where this work was presented in 2002.

References

Asher, C.J. and Cowie, A.M. 1974. Grain sorghum-high yield, satisfactory protein content or both? Proceedings of the Agronomy Society of New Zealand 4: 79-82.

Ayoub, A.T. 1986. N-labeled urea recovery by different crops in the Sudan Gezira. Fertilizer Research 9: 213-221.

Bekunda, M.A. and Woomer, P.L. 1996. Organic resource management in banana based cropping systems of the Lake Victoria basin, Uganda. Agriculture Ecosystem and Environment 59:171-180.

Clegg, M.D. 1996. Crop Management: Nutrients, Weeds and Rain. pp. 91-97. In: Leuschner, K. and Manthe, C.S. (eds.). Drought-tolerant crops for Southern Africa: Proceedings of the SADC/ ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana.

Cox, T.S., House, L.R. and Frey, K.J. 1984. Potential of wild germplasm for increasing yield of grain sorghum. Euphytica 33:673-684.

de Geus, J.G. 1967. Fertilizer Guide for Tropical and Subtropical Farming. Centre d'Etude de l'Azote, Zurich. 727pp.

Esele, J.P. 1988. Current status of Sorghum and Millets Research in Uganda. pp. 318-335. *In* Guiragessian, V. and S.Z. Mukuru (eds.). East African Research on Sorghum and Millets: Proceedings of the Sixth Regional Workshop, 20-27 July 1988, Mogadishu, Somalia.

Esele, J.P. 1995a. Foliar and Head Diseases of Sorghum. African Crop Science Journal 3 (2):185-189.

Esele, J.P. 1995b. Technology generation and transfer of sorghum in Uganda. *In* Mukuru, S.Z. and G. Ejeta (eds.). Sorghum and Millets research in Eastern and Central Africa. Proceedings of a Conference Organized to Re-establish a Sorghum and Millets Research Network in the Region 6-9 November 1995, Kampala, Uganda. pp. 177-184.

Food and Agriculture Organisation (FAO). 1981. Agriculture: Toward 2000. Rome, Italy. FAO.

Food and Agriculture Organisation (FAO). 2000. Guidelines for on-farm plant nutrition and soil management trials and demonstrations, Food and Agricultural Organization of the United Nations, Rome Italy. Roy, R.N., H. Nabhan and W. Burbos (eds.). AG/MISC 26/2000. 71pp.

Gono, L.T. 1996. Deriving fertilizer recommendations for grain sorghum in Zimbabwe with a simple production function. In: Leuschner, K. and Manthe, C.S. (eds.). Drought-tolerant crops for Southern Africa: Proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 July 1994, Gaborone, Botswana. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for Semi-Arid Tropics. pp. 105-111.

Hajabbasi, M.A. and Schumacher, T.E. 1984. Phosphorus effect on root growth and development on two maize genotypes. Plant and Soil 158:39-46.

House, L.R. 1995. Sorghum: One of the world's great cereals. African Crop Science Journal 3 (2):135-142.

Ikombo, B.M. 1984. Effects of farmyard manure and fertilizers on maize in Semi-Arid areas of eastern Kenya. East African Agriculture and Forestry Journal 44:266-274.

Kolar, J.S. and Grewal, H.S. 1989. Phosphorus management in a rice-wheat cropping system. Fertilizer Research 20:27-32.

Mangombe, N., and Mushoga, J.N. 1996. Sorghum and pearl millet on-farm research work in Zimbabwe. In: Leuschner, K. and Manthe, C.S. (eds.). Drought-tolerant crops for Southern Africa: Proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 July 1994, Gaborone, Botswana. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for Semi-Arid Tropics. 81-90pp.

Mengel, K. and Kirkby, E.A. 2001. Principles of Plant Nutrition. Kulwer Academic Publishers. 849p.

Mugisha, O.R. 1996. Uganda Districts Information Handbook. Fountain Publishers Ltd. Kampala, Uganda. 105p.

NARO. 1991. National Agricultural Research Organization/Serere Animal and Agricultural Research Institute. National Agricultural Research strategy Plan. Vol. 1: Strategy, Organization and Management. Uganda Working Group 9A-Agricultural Policy Committee. Ministry of Animal Industry and Fisheries, Kampala, Uganda

Nyakatwa, E.Z., Brown, M. and Maringa, D. 1996. Maize and sorghum yields under tied ridges of fertilized sandy soils in semi-arid south-east lowveld of Zimbabwe. African Crop Science Journal 4 (2): 197-206.

Obuo, J.E. 1995. A study of cowpea/sorghum intercrop with special emphasis on plant spacing and weeding frequency. MSc. Thesis, Makerere University.

Olupot, G., Etiang, J., Aniku, J., Ssali, H. and Nabasirye, M. 2003. Assessment of of nutrient inflow and outflow in Kumi district, eastern Uganda. African Crop Science Journal (unpublished).

Omanya, G.O., Ayiecho, P.O. and Nyambundi, J.O. 1996. Variation for adaptability to dry land conditions in sorghum. African Crop Science Journal 4 (2):127-138.

Seetharama, N. 1995. Biotechnology and sorghum improvement for drought and temperature stress tolerance. African Crop Science Journal 3 (2):223-229.

Steel, R.G.D., Torrie, J.H. and Dickey, D.A. 1997. Principles and Procedures of Statistics: A Biometrical Approach. Third Edition. McGraw-Hill Book Company Inc., New York, USA. 666pp.

Walaga, C., Egulu, B., Bekunda, M. and P. Ebanyat. 2000. Impact of policy change on soil fertility management in Uganda. In: Hilhorst, T. and F.M. Muchena (eds.). Nutrients on the move- soil fertility dynamics in African farming systems. International Institute for Environment and Development, London. pp. 29-44.

World Bank, 1982. World Development Report 1982. (Published for the World Bank). New York, USA: Oxford University Press.

Wortmann, C.S. and Eledu, C.A. 1999. Uganda's Agro ecological Zones: A Guide for Planners and Policy Makers. Kampala, Uganda: Centro International de Agricultura tropical (CIAT).

Yost, D. and Eswaran, H. 1990. Major Land Resource Areas of Uganda. World Soil Resources, Soil Conservation Service; USDA, Washington D.C.

Zengeni, S.B. 1996. Preliminary evaluation of ICRISAT sorghum varieties at Sigaro, Zimbabwe. In: Leuschner, K. and Manthe, C.S. (eds.). Drought-tolerant crops for Southern Africa: Proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 July 1994, Gaborone, Botswana. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for Semi-Arid Tropics. pp. 303-304.