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Evaluation of yield performance of sorghum (*Sorghum bicolor* L. Moench) varieties in Central Tanzania

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Abstract

The study was conducted to determine the performance of local and improved varieties in Central zone, Tanzania. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications, one local variety (udo) and two improved varieties (NACO-1 and macia) were used. Results indicated significance variation at $p < 0.05$ among sorghum tested in terms of plant height, leaf area, and leaf length. Out of three sorghum varieties tested, variety macia was the shortest in plant height (122.37 cm) while variety udo showed the highest plant height (279.8 cm). There was no significance variation in yield, number of tillers, leaf width, total leaf area, leaf area index and moisture content among three varieties tested. However, improved variety NACO-1 yielded the highest (1870.83 g) followed by macia (1412.7 g) while local variety udo yielded the lowest 914.43 (g) respectively. Such results indicate that, there is a difference in genetic bases with variation in the gene action expressing phenotypes among varieties tested. The variety NACO-1 could contains QTLs expressing high yielding compared to the rest varieties. Moreover, varieties respond different in the level of tolerant during dry spell period. This may be one factor that has favoured high yielding in improved varieties in addition to high stay green ability than udo. From this study, we recommend variety NACO-1 for adoption by farmers to enhance high production of sorghum, considering that this variety has performed better in most sorghum production areas in Tanzania.

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Introduction

Globally sorghum (*Sorghum bicolor* L. Moench) is a fifth cereal staple food crop after wheat, rice, maize and barley (FAOSTAT, 2013). United States of America is the highest producer in the world next by Nigeria and India respectively. In Africa, sorghum is cultivated in Southern Africa, Eastern Africa and Western Africa. The production of cereals in Eastern and Southern Africa (ESA) is led by maize with 70% next by sorghum and millet with 7% and 2% respectively (Mitaru *et al.*, 2012). The report by ICRISAT indicates that, in the period of 30 years ago, the production of sorghum has been decreasing in Southern Africa with increasing in East Africa of which Ethiopia is the top producer (Mitaru *et al.*, 2012). Sorghum ranks the second priority staple crop after maize which helps smallholder farmers to prevent hunger. Over 64% of sorghum products is used for food, 14% is used as processed food and 19% as non-processed food. Animals consume about 3% of the total sorghum products (Orr and Mwema, 2016). It is projected that sorghum production is going to increase three times from 6.6 to 19.5 million tonnes in 2015-2050 in ESA thus, triggering the increase of exportation of 2.5 million tonnes. Sorghum has dropped worldwide by 0.8% per year, contrary to Africa which report shows an increase by 2.2%. Nonetheless, the crop does not given priority compared to other cereals like maize, rice and wheat (Macauley, 2015).In Tanzania, sorghum ranks fourth after maize, rice and wheat with average yielding of less than 1 tonne per hectare. However, sorghum is the basic food in Central zone (Msongaleli *et al.*, 2017). In 2016/2017 cropping season, farmers were searching sorghum seeds due to poor rainfall distribution where most crops fail to adapt. Sorghum is the major crop in Central Tanzania which is drought prone with erratic rainfall and long dry spell ranging from 10-20 days during production seasons (Munishi, 2009). Some of white sorghum grain varieties like NACO-1 is used by Tanzania Breweries Limited for production of beer called eagle lager due to failure of barley production (INTSORMIL, 2007). Furthermore, the National Food Reserve Agency in Tanzania allocates funds for buying sorghum grain for storing national food (Mpangwa, 2011). It is used as a staple food for human and animal feed. The grain is used to process wax, starch and local alcohol (Agrama and Tuinstra, 2003). Sorghum grows in the annual rainfall ranging from 400-800 mm (Bibi *et al.*, 2012). The average annual rainfall in Central zone is 589 mm with poor distribution such that, it fails to sustain crops from planting to harvesting (Msongaleli *et al.*, 2017). The adoption of improved varieties is emphasized by farmers who still dwell on landraces with poor yield (Mpangwa, 2011). Authors of studies on sorghum point out that, improved varieties like Tegemeo, Macia, Pato, Wahi, Hakika and recently NACO -1 are high yielding and food secure compared to landraces (Saadan *et al.*, 2000). Most farmers adopt improved sorghum varieties simply because of early maturity and high yielding ability. On top of that, most improved varieties have high grain quality, attractive colour and good market. While climate change is continuous, there is need to increase effort on researches to develop new drought tolerance sorghum, millets and other crops which will withstand the harsh environment in future to secure food for the people (Msongaleli *et al.*, 2017). While emphasizes is for farmers to adopt improved sorghum seeds still the availability of seed has been poor (Mpangwa, 2011). Regarding efforts made by researchers the production of sorghum remain low or increase insignificantly, though improved varieties performed better than local. The technologies do not reach farmers on time thus; participatory demonstration plots should be emphasized for farmers to see. Most farmers in Tanzania utilize local sorghum than improved. Therefore this study aims to determine the yield performance among preferred local sorghum in response to improved varieties in central zone, Tanzania.

Materials and methods

Study area

The study was conducted at Tanzania Agricultural Research Institute (TARI) - Makutupora Centre located at 25 km North of Dodoma municipality in Dodoma region (Longitude: 35°, 46.093'E and Latitude: 05°, 58.669'S) (Altitude: 1080 m).

The centre is characterized by annual rainfall from 300-500mm, temperature varies from 15-35.1^{O}C (Tanzania Meteorological Agency- 2014).The area is classified as semi-arid with mono-modal rainfall pattern. Rainfall commences in December to the first week of April with dry spell of at least two weeks per year.

The trial was planted in January, 2017 on the Complete Randomized Block Design (CRBD) with three replications and spacing of 0.75 m between rows and 0.5 m from plant to plant. In this study, three treatments, one local (udo) sorghum and two improved varieties (Macia and NACO- Mtama 1) were involved. The improved varieties were collected from TARI- Hombolo Centre in Dodoma region- Tanzania. The trial depended on rain fed from planting to harvesting. The regular agronomic management like weeding, fertilizer application and pest and disease control were employed.

A total of 20 kg N ha-1 and 20 kg P ha-1 was applied as basal dressing. Thinning was conducted three weeks from emergency remaining with one plant per hole. Data were collected from five plants per replication. Phenotypic parameters collected in this study include plant height, flowering date, date of physiological maturity, leaf length, leaf width, moisture content, and 100 seed weight yield.

Statistical data analysis

Data were analysed using Gen Stat version 12.1, the mean separation was determined using Least Significance Difference (LSD) at 5%.

Results

From the study conducted, results indicated significance variation of plant height of which local sorghum genotype showed the highest plant height of 279.8 cm while improved variety Macia showed the smallest of 122.4 cm. The local varieties grow longer than improved varieties (Table 1).

Table 1. Traits contributing to yield in sorghum.

Variety	P (cm)	Ll (cm)	Lw (cm)	LA (m^2)	G (m^2)	T (m^2)	LAI	Nt	Df
NACO 1	155.33	74.9	10.04	0.08	1.88	0.23	0.12	0.33	65
Local (Udo)	279.8	80.17	9.3	0.08	1.88	0.25	0.13	0.33	79
Macia	122.37	77.53	10.67	0.07	1.88	0.21	0.11	0.13	63

Continued

Variety	Dm	Mc (%)	100 w (g)	Yield (g)
NACO 1	96.67	14.17	3.13	1870.83
Local (Udo)	112.33	13.63	2	914.43
Macia	104.5	13.9	2.4	1412.7

P - Plant height, Ll - Leaf length, Lw - Leaf width, LA - Leaf area, G - Ground area, T - Total leaf area, LAI - Leaf area index, Nt - Number of tillers, Df - 50% days of flowering, Dm - 50% days of maturity, Mc - Moisture content, w - weight.

The leaf length among the sorghum genotypes tested showed no significance differences however, the highest leaf length was observed in the local genotype (udo) 80.2 cm and improved variety NACO-1 showed the lowest of an average leaf length of 74.9 cm. The variety macia indicated the medium length of 77.5 cm (Table 1). No significance difference attained in leaf width among sorghum tested, the improved variety macia showed the highest leaf width compared to other sorghum genotypes while the local genotype sorghum showed the lowest leaf width with 9.3 cm (Table 1). The varieties NACO -1 and Udo had the highest (0.08 m^2) leaf area. There was no significance variation of days to flowering; the improved varieties flowered earlier than local (Udo) variety with the difference of 14-16 days. Significance difference at 5% was observed in the tested sorghum varieties of which, the earliest maturing variety was NACO – 1 (97 days) from planting while Udo (112 days) was the last maturing variety.

Little variation experienced in the moisture content among sorghum planted. Leaf area varied with the highest from NACO – 1 and Udo while macia showed the lowest on a constant ground area per variety (Table 1). All sorghum varieties showed little number of tillers although macia had the smallest. Moisture content during harvesting varied from 96.67% (NACO – 1) to 112% (Udo).

Discussion

From the results above, many traits have contribution to the final grain yield. For instance, plant height has significant contribution to the final grain yield in sorghum. Extremely high plant height and low sorghum height reduces impact of the final yield. High plant height results into poor stand ability of the plant thus easily fall down under high wind blowing. Agronomic management for instance chemical spraying may not be achieved. Medium plant height ranging between 100 – 200 cm is favourable for stand ability which reduce falling of plants due to wind. May *et al.* (2014) in his study concluded that plant height varies from one variety to another due variation in adaption of weather condition or may be due to genetic differences. In our study, NACO- 1 with high yielding than the rest proves differences of plant height in the final yield. Notwithstanding, Ghosh *et al.* (2015) in his study reported the highest yielding on the sorghum variety with the highest plant height among 20 varieties tested. For animal feed purposes, tallest sorghum varieties are recommended because of high biomass of above ground (Abduselam *et al.*, 2018). Such findings emphasize the importance of plant height as one of the importance of plant height in determining final yield of the crop. Number of tillers plays major role in the determination of yielding in sorghum. The varieties with high number of tillers gain more weight compared to varieties with few number of tillers per plant. Nevertheless, it depends on the agronomic management, genetic gain and gene action expressing the phenotypes. Sorghum plant with many tillers may have less weight under poor genetic gain, gene action which affects yielding. Although sorghum varieties tested indicated low number of tillers, still yield per variety varied from NACO-1 to Udo implying that, high yielding may be expressed in sorghum varieties with low number of tillers (Yoseph and Sorsa, 2014). The number of tillers formation in sorghum is triggered by a number of factors such, spacing, high soil fertility, application of fertilizers and high soil moisture content (May *et al.*, 2014). Varieties with tillers have inconsistent growing stages and maturity compared to varieties without tillers. Varieties with tiller may sprout after resumes of rainfall from drought spell period where for varieties without tillers may dry at all ending with 100% loss. Days of flowering is one of the traits which account suitability of the variety, the early flowering sorghum is preferred to counterpart shortage of rainfall especially in drought prone areas where sorghum is common cultivated (Belay and Meresa, 2017). In our study, there was no statistical significance differences at 5% among sorghum tested nevertheless, local (udo) variety flowered late which may not be of interest due to high association with drought. Days to flowering predict maturity; early flowering varieties have high possibility of maturing first. This was observed in our study where improved varieties flowered and matured first. Similar findings have been reported by Saadan *et al.* (2000) where, out of four improved varieties tested, three had no significance difference on 50% days to flowering. Yielding- most local sorghum varieties delay maturity, they may produce high yield when there is rainfall but they are affected by dry spell occurs for 10 days and above (Msongaleli *et al.*, 2017). For areas where there is sufficient rainfall least significance difference means among local and improved varieties may not be seen, Although there are early flowering and maturing local varieties adopted by farmers. In our study no statistical significance difference reported for sorghum tested. The variety NACO-1 yielded the highest of all varieties tested. Report by Kotu and Admassie, (2015) has indicated high yielding of improved sorghum varieties than landraces under constant agronomic management suggesting farmers to adopt. Improved variety NACO-1 is high yielding and early maturity nonetheless the variety is sensitive to birds' attack. However, udo is cultivated by farmers in Tanzania regarding low yielding ability due to low susceptibility to birds attack; it is good for local alcohol processing and unavailability of improved varieties where needed. Further improvement of new varieties which perform better than landraces is inevitable under continuous climate change to ensure food security in small holder farmers (Matiru *et al.*, 2012).This is in agreement with views of other studies which recommend that, local varieties are very important for maintaining wide genetic base in the next breeding programmes (Muui *et al.*, 2013). Keeping in the gene bank is suggested to ensure genetic diversity of sorghum. Yield is an important trait to consider for most crops as important output, varieties with high yielding are taken into consideration for adoption by farmers and further studies. In our study, there was no significance differences among varieties tested. Nevertheless, variety NACO-1 yielded promising weight than the rest. The local variety udo which produced the lowest weight could be due to poor genetic composition which does not favour genes for high yielding. Yield is contributed by different Quantitative Trait Loci depending on the variety and crop. Varieties with high yield like in our study variety NACO-1 could be due to high association with high yielding QTLs. Previous studies reported QTLs (qPH-1,qTN-2,qFW-3,qFW-2, qSD-10 and *Ma1*) for plant height, tiller number, fresh weight, stem diameter and flowering as the determiner of high yielding in sorghum (Felderhoff, 2011; Zou *et al.*, 2012). Thus, suggesting that such QTLs can be introgressed into varieties lacking to develop new line by marker assisted backcrossing. This technology transfer QTLs of interest from the donor parent to the elite sorghum varieties. QTLs from variety NACO-1 may be introgressed into poor yielding variety udo for yield enhancement. However, success depends on high compatibility of gene action among parents crossed. On the other hand, variation in yielding among sorghum varieties tested could be due to dry spell that occur when rainfall stop especially at flowering growth stage. Varieties with high tolerant to water stress have high stay green with some mapped QTLs (Stg 1, Stg 2, Stg 3 and Stg 4) triggering phenotypic expression and little leaf rolling which sustain plant to produce many grains (Vadez *et al.*, 2013). In addition, variation in yield is contributed by efficiencies of root biomass for water absorption from the soil (Borrell *et al.*, 2000).

This has significance determination to the final yield; studies show that high biomass of the root produce high yield due to high efficiency of water absorption from the soil. On top of that, varieties with high biomass adapt well in the drought prone locations. Similarly root to shoot ration is high suggesting that, varieties with such traits should screened for further studies and adoption (Borrell *et al.*, 2000).

Conclusion

In our study, improved variety NACO- 1 performed the best in term of yield of all varieties tested. This variety may be introgressed into varieties lacking trait of high yielding to produce new improved sorghum lines. There is need to study at molecular level to map for QTLs expressing phenotypes of the best performing varieties. Such results may provide easy approaches of incorporating traits of interest to the parents lacking such traits. Therefore, we recommend NACO-1 variety for farmers' practices and further breeding programmes.

Declaration

Authors declared no conflict of interest among them.

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