EVALUATION OF *CENCHRUS CILIARIS* ECOTYPES FOR SEED YIELD AND RELATED TRAITS

Kirwa, E.C.[*]; Kidake, B.K.[#]
[*]KALRO-Genetic Resources Research Institute; [#]KALRO-Arid &Rangeland Research Institute

Key words: [*Cenchrus ciliaris*; ecotypes; germination]

Abstract. *Cenchrus ciliaris* is widely promoted as a choice grass species for reseeding Arid and Semi-arid Lands (ASALs). Due to the high variability in ASAL environments, there is need to evaluate ecotypes of *C. ciliaris* with potentially higher seed yield and germination that may possibly be selected and promoted for rangeland reseeding initiatives. Nine ecotypes of *C. ciliaris* collected from selected sites in Kenyan ASALs were evaluated for seed yield and related traits at three KALRO centres (Kiboko, Buchuma and Mtwapa). Buchuma site (208.4 kg ha^{-1}) had higher ($p \leq 0.05$) mean seed yield than Kiboko and Mtwapa with 87.3 and 104.2 kg ha^{-1}, respectively. Seed yield varied among ecotypes at Mtwapa and not at Kiboko and Buchuma. Seed yield was significantly and positively correlated with caryopsis per spikelet ($r = 0.78$) and, significantly and negatively correlated with percent empty spikelets ($r = -0.75$). KLF1 ecotype, a high seeder, had the highest mean germination capacity at 71 % and MGD3 had the least with 22.5%. Ecotype MGD3 collected from a seasonally flooded preserved grazing area in agro-ecological zone six recorded the poorest germination characteristics across all sites. Adaptation to the prevailing environmental conditions and management and utilization of grazing lands at sites of ecotype collection may have influenced the observed seed characteristics.

Introduction

Cenchrus ciliaris, is a perennial grass among the species preferred by farmers for grass reseeding in the Southern rangelands of Kenya and beyond. Due to the challenges of seed availability, approaches such as the community based forage seed system (CBFSS) were established to aid in seed bulking and increase access of quality seeds through farmer trainings (Kimitei et al. 2010). Seed bulking of *C. ciliaris* in the rangelands is opportunistic mainly targeting wild establishments. Due to high spatial variability of rangelands particularly in moisture availability, there is a likelihood of existence of ecotypes among the indigenous grass species due to adaptations to local environmental conditions (Jorge et al. 2008). This could result in variation in seed yield and quality among the ecotypes that could compromise the success of programmes such as the CBFSS.

Seed production in terms of quantity and quality is of major interest in successful establishment of *C. ciliaris* grass species in reseeding programmes. Seed yield is affected by both genetics, environment and their interactions. It is necessary to establish the potential relationship between seed yield and related traits such as seed number per spikelet, seed weight and seed germination that may influence seedling establishment and hence rangeland rehabilitation. The traits could be used in indirect selection for seed yield. Seed weight has been found to affect seed yield and seed germination in Buffelgrass (Rajora et al. 2011). Grass seed germination is also affected by prevailing environmental conditions such as rainfall and temperature that may lead to development of adaptive traits such as seed dormancy. High seed dormancy has been blamed for poor stand establishment in *C. ciliaris* during the first year in CBFSS initiative although with more seedling recruitment during the subsequent year. Seed dormancy due to seed coverings allows for accumulation of a persistent soil seed bank. Thus, the objective of the study was to evaluate the performance of *C. ciliaris* ecotypes for seed yield and the related traits in different environments.

Methods

The study involved nine ecotypes of *Cenchrus ciliaris,* namely, KBK1, KBK3, KLF1, KLF2, KLF3, TVT1, TVT3, MGD1 and MGD3 collected from Kenyan rangelands in 2012. The study was conducted in

three sites, Kiboko, Buchuma and Mtwapa research stations of the Kenya Agricultural and Livestock Research Organization (KALRO). Mtwapa and Buchuma stations are in the coastal Kenya and located in agro-ecological zones III and V, at 15 and 400m a.s.l, respectively. Rainfall is bimodal in distribution at all sites with the short rains occurring in October-December. The long rains occur in March-August in Mtwapa and in March-June in Buchuma and Kiboko. The long-term annual rainfall for Kiboko, Mtwapa and Buchuma is 575, 1200 and 560 mm, respectively. The experimental design was randomized complete block design with three replicates. The plots consisted of five rows of four metres long with a distance of one metre between plots. Planting was done during the short rains in October 2012 in Kiboko and the long rains, May 2013 for Mtwapa and Buchuma through seedling transplant or use of splits in cases where there was shortage of seeds. Supplementation with irrigation was done during establishment stages for Kiboko and Buchuma but data collection season was rainfed in all sites. Standardization by cutting of herbage to 5 cm stubble was done at the beginning of short rains in early November 2013.

Seed harvesting was done by stripping all the seeds on a seed head per plot at the end of the short rains season in January 2014 from three study sites and taken to KALRO Kiboko station for processing. all seeds harvested per plot was weighed using an electric balance (Scout Pro SPU601, Ohaus Corporation, USA). Four replicates of 25 caryopses each were placed on moistened filter papers in plastic petri dishes and germinated at room temperature for germination capacity studies. Germination, defined as the appearance of a root, was counted daily from day 1 to 14. Germination capacity was expressed as the percentage of the total number of germinated seeds relative to the total number per replicate. Counting of caryopsis number per spikelet was done by picking four samples of 25 spikelets each and scarifying each spikelet then counting the number of caryopsis contained. Analysis of variance and means separation was done using Least Significant Difference (LSD) at $p \leq 0.05$ in Genstat 15th edition.

Results and discussions

Buchuma with 208.4 kg ha^{-1} had higher mean seed yield than Kiboko and Mtwapa with 87.3 and 104.2 kg ha^{-1}, respectively ($p<0.001$, CV=11.34 %) (Table 1). The high seed yield at Buchuma could be associated to variation in rainfall amounts between sites during the study period. Higher total rainfall amounts were received in the month of December (140.1 mm) at Buchuma compared to the Kiboko (84.5 mm) and Mtwapa (45.5 mm). Flowering of the plots occurred in December when there were adequate amounts of rainfall that could have supported better seed setting at Buchuma than the other sites. Although heavier rains have been found to depress seed yield in Marvel grass (Kumar et al. 2008), the amounts at Buchuma may have just been adequate. Studies by Koech et al. (2014) indicated that addition of soil moisture increases seed yield in grasses where depressed seed yield in *C. ciliaris* under rainfed conditions (21.6 kg ha^{-1}) was recorded compared to irrigation to 80, 50 and 30 % field capacity soil moisture content that yielded 150.5, 136.6 and 156.6 kg ha^{-1}, respectively. Significant difference in seed yield was recorded at Mtwapa site only where ecotype KLF2 with 160.3 kg ha^{-1} had significantly higher yield than the rest of the ecotypes except KLF1 with 144.2 kg ha^{-1}. There were no differences between ecotypes at Kiboko and Buchuma sites ($p \geq 0.05$). There was lack of differences in seed yield across sites for KLF2 and KBK3 which could imply stability to environmental effect. The two ecotypes successfully established in the three study sites.

Table 1. Mean seed yield (kg ha^{-1}) for Cenchrus ciliaris ecotypes at Kiboko, Buchuma and Mtwapa

Site/Ecotype	KLF1	KLF2	KBK3	MGD3	KBK1	KLF3	TVT3	TVT1	MGD1	**Mean**	P_value	CV (%)
Kiboko	199.1	142.6	113.2	109.1	88.1	60	65.9	54.8	44.4	**87.3**	ns	13.6
Buchuma	-*	220	139.9	227	-	-	381.1	207	149.3	**208.4**	ns	8.8
Mtwapa	144.2	160.3	79.4	-	88.5	104	85.9	92.7	-	**104.2**	0.01	4.8
All sites' mean	169.4	171.4	107.9	157.4	88.3	79.1	129.6	101.6	81.7	**120.6**	ns	11.9

**missing values for unestablished plots; Key: ns – not significant at p≥0.05; CV – coefficient of variation*

All ecotypes had overall mean of less than one caryopsis per spikelet except MGD3 (1.39), KLF1 (1.14) and KLF2 (1.08) (Figure 1a). The caryopsis per spikelet ranged from 1-2 (KBK1, KBK3 and MGD1), 1-3 (KLF2, KLF3, TVT1 and TVT3) and 1-4 KLF1 and 1-7 for MGD3 (Figure 1b). Ecotype KBK1 (0.33) had the lowest mean number of caryopsis per spikelet and the highest percent empty spikelets (70 %). The ecotype ranked among the lowest in seed yield and was among the robust types. This result is supported by correlation results where seed yield per hectare was positively and significantly correlated with number of caryopsis per spikelet (r = 0.8) and negatively with percent empty spikelets (r = -0.8). The ecotype was found to be late flowering with the lowest percent fertile tillers (22 %) compared to others like KLF1 with 78 % during field characterization. Delayed head emergence and lower density of flowering tillers was found to contribute to low seed yield in grasses (Boonman, 1993). Awad et al. (2013) observed a significant positive correlation (r=0.55) between grain yield and number of panicles per plant with Sudangrass (*Sorghum sudanense*). Similarly, spike density per unit area had positive and significant influence on seed yield in Buffelgrass for three different seasons (Rajora et al. 2011).

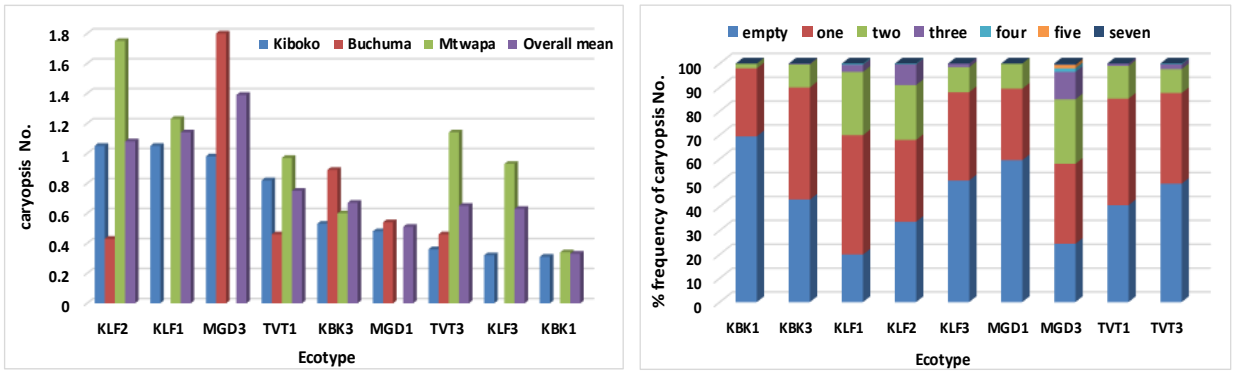

Figure 1. a) Mean caryopsis number per spikelet at Kiboko, Buchuma and Mtwapa and b) mean percent frequency of caryopsis occurring per spikelet in Cenchrus ciliaris ecotypes

Mean percent germination capacity varied between ecotypes and sites (Figure 2). KLF1 was the highest in germination capacity at Kiboko (67 %) and Mtwapa (75 %), the only sites that the ecotype successfully established. MGD1 recorded the highest germination capacity at Buchuma at 69 %. The overall mean germination capacity ranged from 22.5 % for MGD3 to 71.0 % for KLF1 ((p <0.001; 21.8% CV and average $LSD^{0.05}$ of 10.2 %).

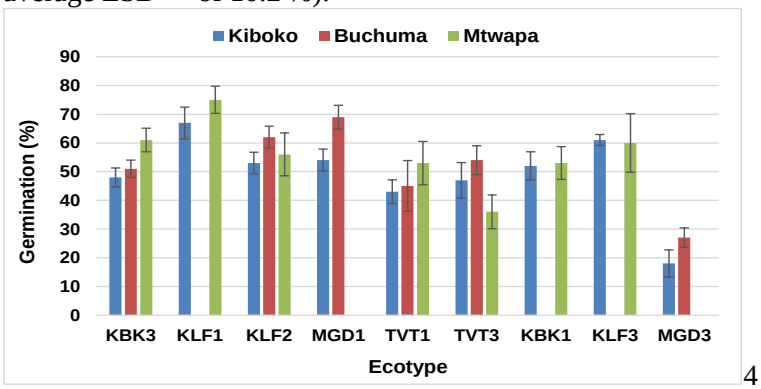

Figure 2. Mean percent germination capacity ± SE (P<0.001) of seeds of Cenchrus ciliaris ecotypes harvested from Kiboko, Buchuma and Mtwapa study sites

The low germination attributes of MGD3 could be due to the low caryopsis weights of the ecotype. The ecotype recorded the lowest seed weight (0.4 g) against a total mean of 0.7 g when seeds harvested from Kiboko were analysed. Bigger or heavier seeds are known to have more rapid germination (Casler and Santen, 2010). Also, the low germination capacity in some of the ecotypes could be attributed to dormancy characteristics that adapted them to the climatic conditions of their origin. MGD3 results may

be attributed to adaptation to the flooding conditions and controlled grazing at the site of collection, near Lake Magadi. Species found in frequently flooded areas require alternating temperatures to germinate which is associated with detection of end of floods and successful establishment of seedlings is achieved when flooding and grazing conditions are followed by high moisture seasons (Cornaglia et al. 2009). The high seed dormancy in MGD3 could have been selected for by the normally succeeding long dry seasons. The controlled grazing also allowed time for the plants to develop sufficient foliage during wet-flooded seasons resulting in lower mortalities of mature plants unlike the continuous grazing of KLF1 necessitating recruitment. Higher number of smaller plants in grazed lands compared to few large ones in ungrazed areas have been observed (Sala, 1988). This was observed during collections where KLF1 was characterized by very many small sized plants less than 30 cm tall while MGD3 had tall robust sparsely spaced plants. The observed germination capacity was not influenced by the new establishment sites. The mean germination capacity of the seed lot under the study (GC2014) positively correlated (r = 0.8) with germination capacity of the seeds collected from the wild at the time of germplasm collection.

Conclusion

Ecotype KLF1 presented better seed quality based on the measured germination attributes and the higher seed yield and may have greater potentially in successful establishment during range reseeding initiatives. Seeds of MGD3 had very poor germination characteristics across all sites. The seasonal flooding and controlled grazing at the site of collection may have induced the observed characteristics.

Acknowledgements

The authors acknowledge funding support from the EU through ASAL APRP Programme and are grateful to the Director General KALRO and the staff for logistical assistance.

References

Awad, A., Salah, H., Mohammed, S.H., Azza, E., Salah, E. 2013. Grain yield production of Sudan grass (Sorghum sudanense (Piper) Stapf) as influenced by cutting numbers, potassium rates, and intra-row spacing in a semiarid environment. *Turkish Journal of Agriculture and Forestry*., 37: 657-664.

Boonman, J.G. 1993. *East Africa's grasses and fodders: Their ecology and husbandry*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Cornaglia, P.S., Schrauf, G.E., Deregibus, V.A. 2009. Flooding and grazing promote germination and seedling establishment in the perennial grass *Paspalum dilatatum*. *Austral Ecology*., 34: 343-350.

Jorge, M.A.B., van de Wouw, M., Hanson, J., Mohammed, J. 2008. Characterization of a collection of Buffelgrass (*Cenchrus ciliaris*). *Tropical Grasslands*., 42: 27–39.

Kimitei, R., Kirwa, E., Kidake, B., Kubasu, D., Manyeki, J., Mnene W.N. 2010. Community based forage seed system approaches in Southern Kenya rangelands. Presented during the 12th KARI Biennial Scientific Conference in Nov. 2010 at KARI HQ.

Koech, O.K., Kinuthia, R.N., Mureithi, S.M. Karuku, G.N., Wanjogu R.K. 2014. Effect of varied soil moisture content on seed yield of six range grasses in the rangelands of Kenya. *Universal Journal of Agricultural Research*., 2(5): 174-179.

Kumar, D., Seth R., Natarajan, S., Dwivedi, G.K., Shivay, Y.S. 2008. Seed yield response of marvel grass (*Dicanthium annulatum*) to cutting management and nitrogen fertilization in Central India. *Agronomy Research*., 6(2): 499-509.

Kumar, D., Singh, S.N., Dwivedi, G.K. 2005. Seed yield and quality of Buffelgrass (*Cenchrus ciliaris)* as influenced by row spacing and fertilizer level. *Tropical Grasslands*., 39: 107-111.

Rajora, M.P., Jindal, S.K., Manjit S., Patidar, M. 2011. Seed production and germination in Buffelgrass (*Cenchrus ciliaris* Linn.) genotype CAZRI 75 under Arid conditions. *Annals of Arid Zone*., 50(1): 37-40.

Sala, O.E. 1988. The effect of herbivory on vegetation structure. In: Werger, M.J.A., Van der Aart, P.J.M., During, H.J., Verboeven, (eds.). *Plant form and vegetative structure*, Academic publishing, The Hague, The Netherlands, pp. 317-330.

Waldron, B.L., Robins, J.G., Jensen, K.B., Palazzo, A.J., Cary, T.J., Berdahl, J.D. 2006. Population and environmental effects on seed production, germination and seedling vigor in Western Wheatgrass (*Pascopyrum smithii* {Rydb.} A. love). *Crop science*., 46: 2503-2508.