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Research Application Summary

Evaluation for seed yield and related traits among ecotypes of *Cenchrus ciliaris* L.

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Abstract

Cenchrus ciliaris is widely promoted as a choice grass species for reseeding Arid and Semi-arid Lands (ASALs). Nine ecotypes of *C. ciliaris* collected from selected sites in Kenyan ASALs were evaluated for seed yield and related traits in three KALRO centres (Kiboko, Buchuma and Mtwapa) in a randomized complete block design with three replicates. The seeds were analyzed for seed yield, mean caryopsis number per spikelet, germination rate, germination capacity, mean germination time and length of germination. Buchuma site (234 kg/ha) had higher (P<0.05) mean seed yield than Kiboko and Mtwapa with 108 and 109.8 kg/ha, respectively. Seed yield varied between ecotypes at Kiboko and Mtwapa but not at Buchuma. All ecotypes had a mean of less than one caryopsis per spikelet except KLF1, KLF2 and MGD3. Seed yield was significantly positively correlated with caryopsis per spikelet (r = 0.78) but significantly 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 that was collected from a seasonally flooded preserved grazing area in agro-ecological zone six recorded the poorest germination characteristics across all sites. The low germination capacity of some of the ecotypes could be due to dormancy characteristics that adapted them to the environmental conditions of their sites of collection.

Key words: *Cenchrus ciliaris*, dormancy, grass ecotype, Kenya, reseeding, seed germination, seed yield

Résumé

Cenchrus ciliaris est largement promu comme espèce de choix pour le réensemencement des terres arides et semi-arides (ASALs). Neuf écotypes de C. ciliaris collectés sur des sites sélectionnés dans les ASAL kenyans ont été évalués pour le rendement en graines et les caractères apparentés dans trois centres KALRO (Kiboko, Buchuma et Mtwapa) dans un dispositif de blocs complets randomisés avec trois répétitions. Les graines ont été analysées pour le rendement en graines, le nombre moyen de caryopsis par épillet, le taux de germination, la capacité de germination, le temps moyen de germination et la durée de germination. Le site de Buchuma (234 kg / ha) avait un rendement moyen en graines plus élevé (P <0,05) que Kiboko et Mtwapa avec 108 et 109,8 kg / ha, respectivement. Le rendement en graines variait entre les écotypes à Kiboko et Mtwapa mais pas à Buchuma. Tous les écotypes avaient une moyenne de moins d'un caryopse par épillet sauf KLF1, KLF2 et MGD3. Le rendement en graines était significativement corrélé positivement avec les caryopsis par épillet (r =

0,78) mais significativement négativement corrélé avec le pourcentage d'épillets vides (r = -0,75). L'écotype KLF1, un semoir élevé, avait la capacité de germination moyenne la plus élevée à 71% et le MGD3 en avait le moins avec 22,5%. L'écotype MGD3 collecté dans une zone de pâturage préservée inondée de façon saisonnière dans la zone agro-écologique six a enregistré les caractéristiques de germination les plus faibles sur tous les sites. La faible capacité de germination de certains des écotypes pourrait être due à des caractéristiques de dormance qui les ont adaptées aux conditions environnementales de leurs sites de collecte.

Mots clés: *Cenchrus ciliari*s, dormance, écotype de l'herbe, Kenya, réensemencement, germination des graines, rendement en graines

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 to quality seeds through farmer trainings (Kimitei *et al.,* 2010). Seed bulking 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. 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. Soil moisture, management aspects such as row spacing and fertilizer levels are among the factors that can influence seed yield in grasses. Kumar *et al.* (2008) found that seed yield of Marvel grass was depressed by heavy rains while supplementation with irrigation enhanced seed yield among range grass species (Koech *et al.*, 2014). Narrow spacing depressed seed yield in *C. ciliaris* with 40 cm (75.9 kg/ha) and 60 cm (83.7 kg/ha) row spacing yielding less than 75 cm that yielded 97 kg/ha (Kumar *et al.,* 2005).

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 (Rajora *et al.,* 2011. Seed weight had positive correlation to seed yield in CAZRI 75 genotype of 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 but with more seedling recruitment during the subsequent year. Seed dormancy due to seed coverings allows for accumulation of a persistent soil seed bank. Variation in germination capacity and seed dormancy among ecotypes of *C. ciliaris* have previously been recorded. Thus the study aimed at evaluating variability among the nine ecotypes of *C. ciliaris* in terms of seed yield and related attributes and identify high seed yielding ecotypes.

Materials and methods

Study area. The study involved nine of the 12 ecotypes of *Cenchrus ciliaris*. The study was conducted in three sites, Kiboko, Buchuma and Mtwapa research stations of the Kenya Agricultural and Livestock Research Organization (KALRO). Figure 1 shows the monthly and total annual rainfall for 2013 and 2014. Mtwapa and Buchuma stations are in the coastal Kenya and located in agro-ecological zones III and V, respectively. Rainfall is bimodal in distribution at Mtwapa and Buchuma with the short rains occurring in October-December. The long rains occur in March-August in Mtwapa and in March-June in Buchuma.

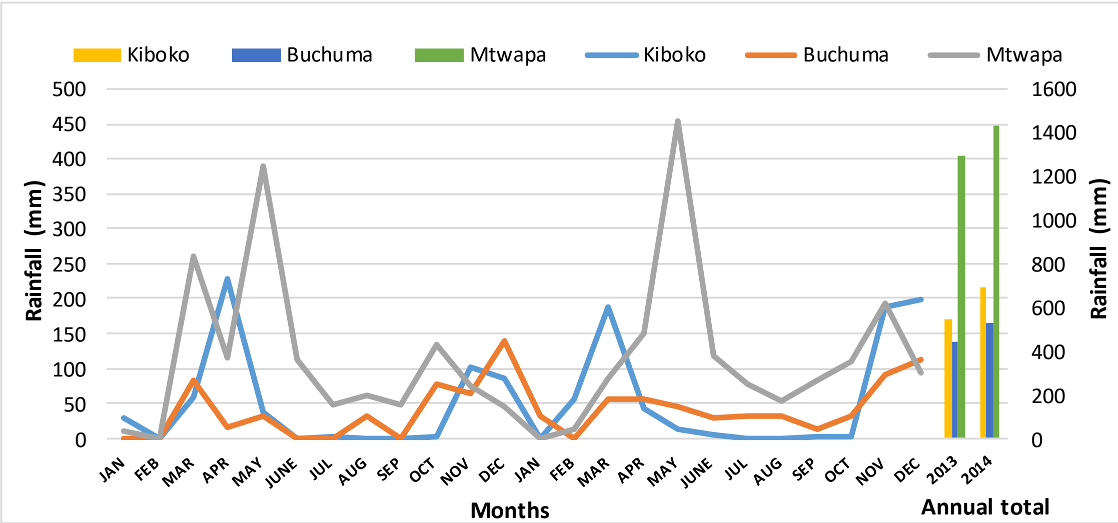

Figure 1. Monthly and total annual rainfall (mm) for Kiboko Buchuma and Mtwapa study sites for 2013 and 2014

Planting and plot management. The experimental design was randomized complete block design with three replicates. Seed bed preparation was done by ploughing and levelling the ground to a fine tilth using a rake. The plots consisted of five rows of four metres long with a distance of one metre between plots. The planting of Kiboko plots was done during 2012 short rains. Planting for Buchuma and Mtwapa sites was done during the long rains in May 2013. Seedlings established in plastic trays at Kiboko were transplanted to the plots. But tuft splits were used in cases where there was shortage of seeds. Standardization by cutting of herbage to 5 cm stubble in each plot per site was done at the beginning of short rains in early November 2013.

Data collection and analysis. All seed heads were harvested per plot at the end of the short rains season in January 2014 from the three study sites and taken to KALRO Kiboko station for processing. Seed harvesting was done by stripping all the seeds on a seed head. Due to the variation and subsequent spread in seed maturity between tillers, seed harvesting was done thrice for three consecutive weeks. After cleaning by removing all plant material and remaining with only spikelets, each seed sample was weighed using an electric balance (Scout Pro SPU601, Ohaus Corporation, USA). The initial seeds harvested from the three replicates of each ecotype were mixed and sub-sampled for germination analysis. Four replicates of 25 caryopsis each were placed on moistened filter papers in plastic petri dishes and germinated at room temperature. Germination, defined as the appearance of a root, was counted daily from day 1 to 14. 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.

Germination data were analysed for germination capacity (GC), length of germination (LG), germination time (MGT) and the germination rate. Germination capacity was expressed as the percentage of the total number of germinated seeds relative to the total number per replicate. Length of germination (LG) was the days from the start of germination to the end per replicate. Mean germination time (MGT), which is the average length of time required for maximum germination of the seeds was calculated as indicated by Ranal and Santana (2006). Germination rate was analysed using Kotowski's coefficient of velocity (CoV) which is an estimate of the germination rate and measures the distribution of germination regarding the number of seeds germinated in time. The analysis of variance (ANOVA) for the different seed traits was performed and means separated using Least Significant Difference (LSD) at $p<0.05$ in Genstat 15th edition. Genstat 15th edition was used in correlation analysis on the recorded data set.

Results and discussions

Buchuma site with 234 kg/ha had higher mean seed yield than Kiboko and Mtwapa each with 108 and 109.8 kg/ha, respectively (P =0.001, LSD0.05 43.4, CV=50.9%). Ecotype KLF1 with 201.7 kg/ha had the highest seed yield at Kiboko while KLF2 with 165.8 kg/ha had the highest yield at Mtwapa followed by KLF1 with 145.4 kg/ha. There were no statistical differences between ecotypes at Buchuma (P>0.05). Four ecotypes, MGD1, MGD3, TVT1 and TVT3, significantly produced higher seed yield at Buchuma than at Kiboko and Mtwapa. Seed yield for KLF2 and KBK3 did not differ between sites.

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 Kiboko (84.5 mm) and Mtwapa (45.5 mm). Flowering of the plots occurred in December thus implying that adequate amounts of rainfall could have allowed for better seed setting at Buchuma than at 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. Koech *et al.* (2014) recorded depressed seed yield in *C. ciliaris* under rainfed conditions (21.6 kg/ha) compared to irrigation at 80, 50 and 30 % field capacity soil moisture content that yielded 150.5, 136.6 and 156.6 kg/ha, respectively. The lack of differences in seed yield across sites for KLF2 and KBK3 could imply stability to environmental effect. The two ecotypes successfully established in the three study sites.

There were differences in caryopsis number within and between sites. Mtwapa site had the highest in mean caryopsis number with 0.99 while Kiboko site had the least with 0.66 (LSD0.05 = 0.0869). All ecotypes had overall mean of less than one caryopsis per spikelet except KLF1 (1.14), KLF2 (1.08) and MGD3 (1.39). Ecotype KBK1 with 0.33 had the lowest in mean number of caryopsis per spikelet against total mean of 0.79 and with the highest percent empty spikelets at 69.5 %. Caryopsis number per spikelet is an important seed trait. The trait determines how much pure seed is available per seed lot. This is probably the cause for ecotype KBK1 to rank among the lowest in seed yield despite being a high yielder in dry matter. The ecotype was found to be late flowering with the lowest percent fertile tillers (22%) compared to others like KLF1 with 78 % during morphological characterization studies. 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).

The number of caryopsis in a 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. Over 50 % of sampled spikelets were empty for four ecotypes, namely, KBK1 (70 %), MGD1 (60 %) and KLF3 (51%) and TVT3 (50 %). The high percentage of empty spikelets for KBK1 may have translated into lower seed yield, which was supported by correlation results indicating that seed yield was positively correlated with caryopsis number (r =0.8) and negatively to percent empty spikelets (r = -0.8).

For germination capacity, ecotype effect was significant (P<.001) while site effect was not significant at P<0.05. The interaction of ecotype x environment was significant at P<0.0.5. Figure 2 shows the mean percent germination capacity for *C. ciliaris* ecotypes from Kiboko, Buchuma and Mtwapa study sites. KLF1 had the highest 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 LSD0.05 of 10.2%). Seeds of MGD3 had the lowest germination capacity at Kiboko (18 %) and Buchuma (26 %). The ecotype also recorded the lowest germination (22.5 %) among the seeds harvested from the wild at the time of germplasm collection.

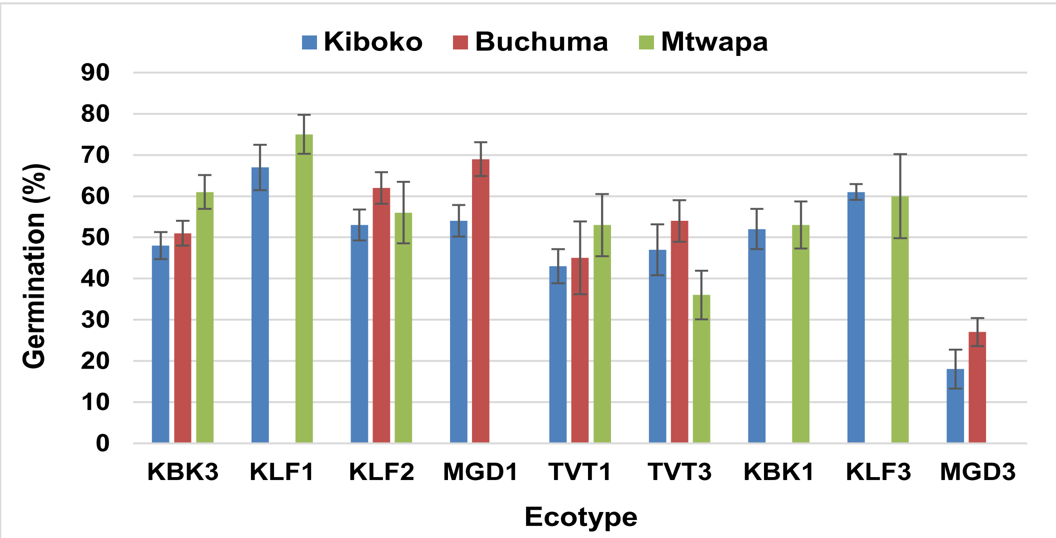

Figure 2. Mean percent germination capacity + SE (P<0.001) of seeds of *Cenchrus ciliaris* ecotypes harvested from Kiboko, Buchuma and Mtwapa study sites

Table 1 shows the mean germination rate, germination time and length of germination for *C. ciliaris* ecotypes at Kiboko, Buchuma and Mtwapa. The columns shows the mean germination rate, germination time and length of germination per site. For site x ecotype interaction, the data were compared along rows showing performance of each ecotype across the three sites.

Table 1. Mean Coefficient of velocity (CoV), mean germination time (MGT) and length of germination (LG) of seeds of *Cenchrus ciliaris* ecotypes harvested from Kiboko, Buchuma and Mtwapa

Site	KIBOKO			BUCHUMA			MTWAPA		
Ecotype	COV	MGT	LG	COV	MGT	LG	COV	MGT	LG
KBK 1	$\underline{68.4}^{a}$	1.5^{d}	2.5^{d}	-*	-	-	$\underline{44.7}^{a}$	2.3^{d}	3.3^{c}
KBK 2	43.4^{cd}	2.3^{cd}	5.5^{cd}	-	-	-	-	-	-
KBK 3	40.7^{d}	2.5^{cd}	5.6^{cd}	27.5^{b}	3.7^{bcd}	9.0^{ab}	35.9^{bc}	2.9^{cd}	5.3^{bc}
KLF 1	56.3^{b}	1.8^{d}	3.8^{d}	-	-	-	40.1^{ab}	2.5^{d}	4.5^{c}
KLF 2	27.6^{f}	3.7^{abc}	$\underline{10.8}^{a}$	$\underline{37.1}^{a}$	2.7^{de}	6.0^{bc}	26.8^{de}	3.9^{b}	11.5^{a}
KLF 3	52.7^{bc}	2.0^{d}	5.3^{cd}	-	-	-	29.3^{cd}	3.5^{bc}	8.7^{ab}
MGD 1	30.1^{ef}	3.5^{bc}	8.0^{abc}	24.7^{b}	4.1^{b}	8.5^{ab}	-	-	-
MGD 3	21.5^{f}	$\underline{5.0}^{a}$	7.3^{bc}	15.1^{c}	$\underline{6.8}^{a}$	$\underline{11.3}^{a}$	-	-	-
TVT 1	27.7^{f}	3.7^{abc}	$\underline{11.3}^{a}$	26.3^{b}	4.0^{bc}	7.5^{bc}	25.6^{de}	4.0^{b}	8.5^{ab}
TVT 2	27.2^{f}	4.5^{ab}	10.0^{ab}	-	-	-	-	-	-
TVT 3	39.0^{de}	2.6^{cd}	4.8^{cd}	43.7^{a}	2.4^{e}	6.0^{bc}	20.4^{e}	$\underline{4.9}^{a}$	$\underline{11.3}^{a}$
Mean	**39.5**	**3.0**	**6.8**	**30.1**	**3.8**	**7.6**	**31.2**	**3.5**	**7.7**
P_value	<.001	<.001	<.001	<.001	<.001	0.016	<.001	<.001	<.001
LSD$^{0.05}$	10.3	1.47	3.37	8.2	1.09	3.43	7.2	0.78	3.44
CV%	18.1	34	34.5	18.5	19.6	30.7	15.8	15.5	30.6

Column means with different letter superscript differ at $P<0.05$; *missing values for unestablished plots at the site

KBK1 recorded the highest germination rate (CoV) at Kiboko and Mtwapa with 68.4 and 44.7 %, respectively. In both sites, the ecotype had the least mean germination time of 1.5 and 2.3 days for Kiboko and Mtwapa, respectively. MGD3 ecotype with the longest mean germination time at Kiboko (5.0 days) and Buchuma (6.8 days). The low germination attributes of MGD3 could be due to the significantly 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 have been found to have more rapid germination.

The low germination capacity in some of the ecotypes could also be attributed to dormancy characteristics that adapted them to the climatic conditions of their origin (O'Connor and Everson, 1998). The low germination capacity and other germination characteristics of MGD3 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 (Cornaglia *et al.,* 2009). Cornaglia *et al.* (2009) found that successful establishment of seedlings is achieved when flooding and grazing conditions are followed by high moisture seasons. The high dormancy in MGD3 seeds could have been selected for by the normally succeeding long dry seasons. Use of alternating temperatures should be tested in breaking dormancy in MGD3 seeds. Long term germination studies are necessary to identify potential peak in germination of MGD3 seed lots. 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 where recruitment was necessary. Wissman (2006) observed higher number of smaller plants in grazed lands compared to few large ones in ungrazed areas. 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 (Kirwa, Personal observation).Seeds of KLF2 ecotype had higher germination rates at Buchuma (37.1 %) than Kiboko (27.6 %) and Mtwapa (26.8 %) (Table 5.29). This could infer efficient seed setting at Buchuma due to adequate soil moisture as was observed with seed yield. Ecotype TVT1 did not exhibit ecotype x environment effect in germination capacity, mean germination time and germination rate. Production of TVT1 seeds from varied environments with similar conditions as the study sites may not affect the quality of the seeds.

Seed yield per hectare was positively significantly correlated to number of caryopsis per spikelet (r = 0.8) but negative to percent empty spikelets (r = -0.8). Mean number of caryopsis per spikelet was negatively significantly correlated to dry matter yield (kg/ha) with r = -0.7 and wet herbage yield (r = -8). The mean caryopsis per spikelet negatively significantly correlated with number of empty spikelets (r = -0.9). 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. This indicates that the observed germination capacity was not influenced by the new establishment sites. In both trials (2012 and 2014), KLF1 ecotype was the highest in germination capacity and MGD3 lowest.

Conclusion

Mean seed yield was varied between study sites and also among ecotypes. Mean seed yield higher at Buchuma than Kiboko and Mtwapa which could be attributed to the higher rainfall amounts at Buchuma during the study. Ecotype KLF1 presented the best seed quality results based on the measured germination attributes and the higher seed yield while MGD3 ecotype had very low seed quality exhibited through poor germination characteristics across sites.

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