Performance of Napier grass (*Cenchrus purpureus* L.) genotypes grown under limited soil moisture.

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Keywords: Napier grass; soil moisture; water use efficiency; biomass yield

Abstract

Napier grass (*Cenchrus purpureus* Schumach L.) is an important perennial forage native to Africa and grown in many tropical and subtropical countries. It is considered as a short-term drought tolerant forage which is a useful trait in areas that are characterized by low precipitation during the dry season. To exploit the potential of this grass and identify water use efficient (WUE) genotypes, a field drought stress trial was conducted at Bishoftu, Ethiopia. Eighty-four Napier grass genotypes were planted in a p-rep design in four replications. The genotypes were evaluated for forage performance during the dry season of 2019 and 2020 based on agro-morphological traits under two soil moisture regimes- moderate water stress (MWS) and severe water stress (SWS). The results indicated the existence of significant diversity among the genotypes for agro-morphological traits and photosynthetic performance. Consistently high biomass producing genotypes with enhanced water use efficiency were observed across harvests in each soil moisture regime, which indicates the possibility of utilizing these genotypes for high biomass production under low soil moisture conditions after further validation in other environments.

Introduction

Tropical agricultural environments such as sub-Saharan Africa (SSA) have been affected by degradation of natural resources, triggered by climate change and over exploitation (Adeniyi 2016). This has led to frequent extreme temperature events, and changes in rainfall amount and distribution that have impacted agricultural productivity (Salem et al. 2011). Erratic and below optimum precipitation conditions during forage growth will significantly reduce biomass production and feed availability, which is already one of the main limiting factors for increased livestock productivity. Securing the availability of forage biomass yield throughout the season is one of the strategies that can be employed for sustainable livestock production in drought prone and degraded areas of SSA. Hence, the development of forage genotypes that are best adapted to produce in drought stress environments would contribute to intensify livestock production in marginal areas as well as to improve natural resource management. Napier grass (*Cenchrus purpureus*) is an important forage crop in tropical and subtropical environments (Esilaba et al. 2011). Napier grass grows from sea level to 2100 m above sea level in the tropics and produces best growth at temperatures ranging from 25 to 40 °C (Singh et al. 2013). It is also considered as a short-term drought tolerant forage, which is an important characteristic in areas that are affected by frequent drought stress conditions (Taylor et al. 2014). Napier grass is popular among smallholder dairy farmers, especially for the cut and carry feeding system, as it produces a high forage yield per unit area and can withstand repeated cuttings during a year (Kabirizi et al.2015). To exploit the potential of Napier grass for drought stress tolerance, a field drought stress trial was conducted using a panel of genotypes with the objective of identifying genotypes with higher biomass productivity and enhanced water use efficiency under field moisture stress conditions.

Methods and Study Site

Eighty-four Napier grass genotypes were used for the field drought stress study, performed in Bishoftu, Ethiopia. These genotypes were planted using a partially replicated (p-rep) design with four replications and evaluated for drought stress tolerance during dry seasons in 2019 and 2020, using agronomic and

physiological performance under two soil moisture regimes i.e., moderate (MWS) and severe (SWS) water stress conditions. The field drought stress was imposed using two soil moisture conditions where two blocks were exposed to MWS, that corresponds to 20 % volumetric soil moisture content (VWC), while the other two blocks were exposed to SWS, that corresponds to 10 % VWC. The VWC of the blocks was monitored using a soil moisture probe (HD, England). In the dry season, plants were harvested at every 8 weeks of regrowth, resulting in a total of 6 harvests. In each harvest, leaf length (LL), leaf width (LW), photosynthetic efficiency (Fv/Fm) and biomass yield data were collected. The water use efficiency (WUE) was calculated from the amount of water supplied and total dry weight (TDW) yield. The collected data were analyzed for statistical significance using analysis of variance (ANOVA) and subjected to additive main effects and multiplicative interaction (AMMI) analysis to identify high yielding and stable genotypes in terms of biomass yield under drought stress.

Results

The results from the dry season harvests revealed significant genotype, treatment, and harvest effects for the traits LW, LL, Fv/Fm, TDW and WUE (Table 1). Analysis of genotype by treatment interaction also revealed significant differences in LL, TDW and WUE, indicating the performance of individual genotypes differ between the two soil moisture level treatments i.e. MWS and SWS. The performance of genotypes was highly affected by harvest that signifies a differential response of genotypes to different harvests which is presumably linked to specific climatic variables during each regrowth period.

The genotype by harvest interaction was further analyzed using AMMI analysis to decompose the interaction effects. An AMMI biplot showed the existence of high variability for both genotype and harvest variables (Figure 1). The first two principal components in MWS, PC1 and PC2 contribute 50% and 26 % interaction effect respectively (Figure 1, A and B). In SWS, PC1 and PC2 contribute 57 % and 25 % of the interaction effect respectively (Figure 1, C and D). Genotypes that are near to the origin have least interaction effect while genotypes close to the axis have more general stability (Figure 1 A and B). Genotypes such as 16839, 16819 and BAGCE 30 and harvests 3, 4 and 6 produced above average TDW both in MWS and SWS conditions. While genotypes 18662, 16797 and 16790 and harvests 1, 2 and 5 produced below average TDW (Figure 1, C and D).

The yield stability index analysis further identifies top ranking Napier grass genotypes based on stable production of biomass across harvests (Table 2). Under MWS, the top stable productive genotypes were 16819, 16803 and 16839 and, under SWS, the top genotypes were 16819, CNPGL 93-42 and CNPGL 92-66-3.

Table 1. Summary ANOVA for agro-morphological and physiological traits from moderate and severe water stress condition in dry season harvests

Sources of variation	Traits (P-Level)				
	LW	LL	Fv/Fm	TDW	WUE
Genotypes	<.001	<.001	<.001	<.001	<.001
Treatments (MWS/SWS)	0.04	0.03	0.04	0.05	0.05
Harvest	<.001	<.001	<.001	<.001	<.001
Genotype X Treatment	NS	<.001	NS	<.001	<.001
Genotype X Harvest	<.001	<.001	<.001	<.001	<.001
Treatment X Harvest	<.001	<.001	<.001	<.001	NS
Genotype X Treatment X Harvest	NS	<.001	NS	<.001	<.001
CV %	9.4	6.1	2.6	17.8	13.4

Moderate moisture stress (MWS), Severe moisture stress (SWS), Leaf width (LW), Leaf length (LL), Photosynthesis efficiency (Fv/Fm), Total dry weight (TDW), Water use efficiency (WUE), coefficient of variation (CV), non-significant (NS), and Probability level (P-level)

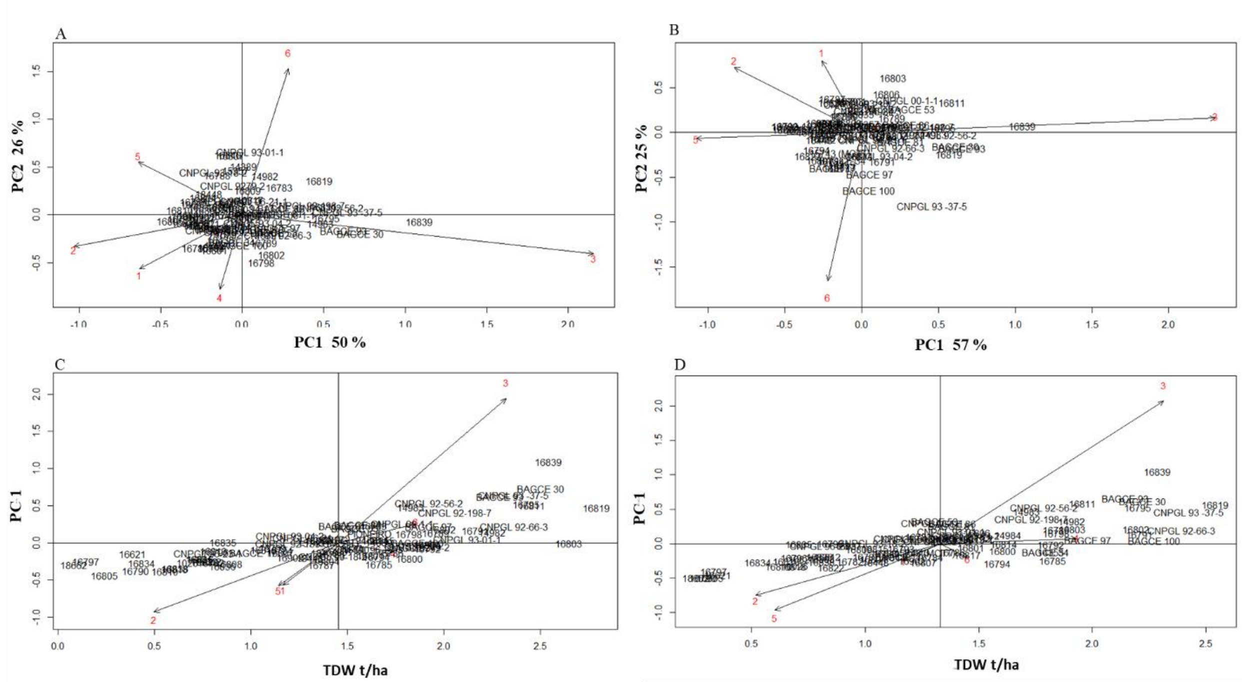

Figure 1. Biplots of an Additive Main effects and Multiplicative Interaction (AMM)I analysis of Principal component 1 (PC1) and Principal component 2 (PC2) upper lane A) Moderate water stress B) Severe water stress and biplot dry weight (TDW) vs PC1 lower lane C) moderate moisture stress and; D) severe moisture stress conditions with 84 Napier grass genotypes and 6 harvests (numbered in red) in the dry season.

Table 2. Top 10 Napier grass genotypes in terms of stability analysis across six harvests for moderate water stress (MWS) and severe water stress (SWS) conditions.

Genotype	MWS				Genotype	SWS			
	TDW mean (t/ha)	rY	rASV	YSI		TDW mean (t/ha)	rY	rASV	YSI
16819	2.79	1	78	79	16819	2.54	1	79	80
16803	2.65	2	3	5	CNPGL 93 -37-5	2.42	2	80	82
16839	2.55	3	84	87	CNPGL 92-66-3	2.39	3	33	36
BAGCE 30	2.5	4	83	87	16839	2.29	4	84	88
16811	2.46	5	77	82	BAGCE 100	2.27	5	58	63
16795	2.43	6	79	85	BAGCE 30	2.22	6	82	88
CNPGL 92-66-3	2.36	7	45	52	16791	2.21	7	32	39
CNPGL 93-42	2.36	8	82	90	16795	2.2	8	77	85
BAGCE 93	2.29	9	81	90	16802	2.19	9	39	48
14982	2.25	10	50	60	BAGCE 93	2.15	10	83	93

Rank based on dry biomass yield (rY), rank based on AMMI stability variance (rASV), Yield stability index (YSI), total dry weight (TDW), Moderate water stress (MWS) and Severe water stress (SWS).

Discussion

The results of analysis of variance for agro-morphological traits suggested the existence of significant genotypic variation of growth production under moisture stress and the influence of moisture stress treatments (MWS/SWS) on agronomic and physiological responses. These genotypic variations are important to exploit the potential of the genotypes to maximize forage production under different soil moisture regimes. The performance of genotypes was also greatly affected by harvest that can be characterized by specific climatic variables (Habte et al. 2020).

The evaluation of genotypes based on different years and location provide useful information to determine a genotypes adaptability and stability of production (Whaley et al. 2019). The dry matter yield of genotypes across harvests was analyzed using AMMI to reveal high yielding and stable genotypes. In general, the identified genotypes that are stable and highly productive were similar in both MWS and SWS conditions based on stability index ranking that suggests that these genotypes have enhanced water use efficiency under soil moisture stress conditions. Thus, the top biomass yielding genotypes identified based on total dry weight (TDW) would be potential candidates for future utilization and breeding programs for drought stress environments.

Acknowledgements

The authors would like to thank Tesfaye Tadesse, Yirsaw Wubete, Fetene Argaw and Yilikal Assefa for their contribution to field data collection. Authors would like also to thank the Rural Development Administration (RDA) of the Republic of Korea and the CGIAR Research Program on Livestock for financial support.

References

Adeniyi A. (2016). Climate change induced hunger and poverty in Africa. J. Glob. Biosci., 5, 3711–3724.

Esilaba O., Muturi M., Cheruiyot K., Okoti M., Nyariki M., Keya A., et al. (2011). The desert margins programme approaches in upscaling best-bet technologies in arid and semi-arid lands in Kenya, in Innovations as Key to the Green Revolution in Africa, ed. by Bationo A, Waswa B, Okeyo, Jeremiah M and Maina F. Springer, New York, pp. 1177–1191.

Habte E., Muktar MS., Abdena A., Hanson J., Sartie AM., Negawo AT., Machado JC., Ledo FJS., Jones CS. (2020). Forage Performance and Detection of Marker Trait Associations with Potential for Napier Grass (Cenchrus purpureus) Improvement. Agronomy. 10(4):542.

Kabirizi J., Muyekho F., Mulaa M., Msangi R., Pallangyo B., Kawube G., Zziwa E., Mugerwa S., Ajanga S., Lukwago G.,Wamalwa E., Kariuki I., Mwesigwa R., Nannyeenya-Ntege W., Atuhairwe A.,Awalla J., Namazzi C., Nampijja Z. (2015). Napier grass feed resource: production, constraints and implications for smallholder farmers in Eastern and Central Africa. Naivasha, Kenya, 159 p.

Singh P., Singh P., Obeng E. (2013). Elephant grass. In Biofuel Crops: Production, Physiology and Genetics; Singh, B.P., Ed.; CAB International: Fort Valley State University, Fort Valley, GA, USA, pp. 271–291.

Taylor, S. H., Ripley, B. S., Martin, T., De-Wet, L. A., Woodward, F. I., and Osborne, C. P. (2014). Physiological advantages of C4 grasses in the field: a comparative experiment demonstrating the importance of drought. Glob. Change Biol. 20, 1992–2003. doi: 10.1111/gcb.12498

Whaley R., Eskandari M. (2019). Genotypic main effect and genotype-by-environment interaction effect on seed protein concentration and yield in food-grade soybeans (Glycine max (L.) Merrill). Euphytica 215, 33.