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Evaluation of Elephant Grass (*Pennisetum perpureum*) Variety for Agronomic Parameters and Biomass Yields under Rain Fed Condition to Improve Feed Availability in South Omo, South-Western Ethiopia

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Abstract

The Elephant grass species is among the tropical-grass and have provided high amount biomass to the livestock. Therefore, this study was initiated to evaluate the agronomic parameters and biomass yields of four Elephant grass varieties under rain fed condition in South Omo Zone. The four Elephant grass varieties such as ILRI-16840, Werer-1333, Areka-local and Werer-local were evaluated in randomized complete block design with three replications per variety. The data on agronomic parameters, leaf to stem ratio, biomass yields were analyzed using the Generalized Linear Model (GLM) procedures of SAS, and Least Significant Difference (LSD) was used for mean separation. The higher($p<0.05$) fresh (38.16ton/ha) and dry biomass yield (18.27ton/ha) were obtained from the ILRI-16840 variety, while the lower fresh biomass yield (18.6ton/ha) and dry biomass yield (8.7ton/ha) were obtained from the Werer-local variety, respectively. Based result from this study, we concluded that the ILRI-16840 variety was best candidate to improve feed availability for enhanced livestock production.

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Introduction

South Omo Zone is among the zones in the Ethiopian Southern Nations, Nationalities and Peoples' Region (SNNPR). The south Omo has large livestock population in SNNRP by possessing about 2,733,147 cattle, 1,415, 361 sheep and 3, 110, 966 goats [1]. However, the outputs (meat, milk and growth rate) obtained from cattle; sheep and goat are generally very low due to the poor feed quality and insufficient year round feed supply [2,3]. Moreover, in the study area, cattle, sheep and goat husbandry practice is completely natural-pasture-based [2-4]. It is evidenced that the natural-pasture-based feeding practice is greatly affected by dynamics of pasture-forages, which is influenced by climate change impacts [2-4]. Thus, the evaluating and introducing the adaptable and nutrient-enrich forages species to complement the pasture-based-feeding practice is among the recommended options for South Omo to mitigate the feed shortage and climate change impacts [2-4]. Amongst the promising forage species promoted to mitigate feed and nutrient shortfalls and climate change impacts in Ethiopia is Elephant (*pennistum perperum*) grass species. This grass is a very versatile species, which can be grown under a wide range of conditions and providing valuable forage throughout the tropics [5]. Elephant grass is mainly used in cut-and-carry systems ("zero grazing") and fed in stalls, or made into silage or hay [6]. The dry matter yields of Elephant grass cultivars ranged from 20ton/ha to 80ton/ha under high fertilizer inputs, but yields are in the range of 2-10ton/ha without fertilizer [5,7].

The Elephant grass has low protein content about 4% DM at 70 days, but at 30 days, its crude protein reaches about 21% DM [8]. The neutral detergent fiber concentrations vary from 55 to 75% DM, while acid detergent fiber values ranged from 49.59 to 58.82 [9,10]. In Hawaii, the live-weight gains as high as 549kg/ha for Beef cattle grazing on mature Elephant grass with live-weight gains of 1kg/head/day during the growing season and 480 kg/ha/year are achievable [5,11]. In feedlot sheep, Elephant-grass supplemented with 30% concentrate allowed an average daily gain of 95g/day, which is comparable to that fed different grass (*Cenchrus ciliaris*, *Panicum-molle* and *Urochloa mosambicensis*) [12]. In Brazil, chopped Elephant- grass hay (60days re-growth) fed to goat resulted in Organic Matter (OM) digestibility (61%) comparable to those obtained with pearl millet (*Pennisetum glaucum*) and *Sudan grass* (*Sorghum × drummondii*) hays, and higher than those obtained with forage sorghum hay [13]. However, with this promising potential, different Elephant grass varieties have not been evaluated for agronomic parameters and biomass yields under rain fed condition in South Omo Zone. Thus, the present study was intended to screen different Elephant-grass varieties for agronomic-parameters.

Material and methods

Description of study area

The study was conducted from April to June, 2019 (autumn season) and August to September, 2019 (summer season) at on-station of Jinka Agricultural Research Centre of South Omo Zone. The Jinka Agricultural Research Center is located 729 km South-west of Addis Ababa at geographical coordination of 36^0 $33'$-37^0 $67'$E and 5^0 $46'$- $6^0 57'$N with an altitude of 1450meter above sea level. The rainfall distribution of the study area is bimodal with main rainy season started from March to June (autumn season) and the second cropping season, from July to November (summer season). The average annual rainfall of the area in the last ten years was 1326.7mm with the average annual temperatures of 22.4^{0}C. The soil of the experimental site is loam in texture and comprised organic matter content of 5.88%, total nitrogen content of 0.24%, cat ion exchange capacity of 32.40cmol kg^{-1}, available phosphorus content of 3.41mg kg $soil^{-1}$ and soil pH of 6.41 [14].

Experimental treatments and design

The Elephant grass varieties such as ILRI-16840, Werer-1333, Areka-local and Werer-local were investigated in this trial.

The ILRI-16840 and Areka-local varieties were introduced from Bako Agricultural Research Center and Areka area, respectively, while Werer-1333 and Werer-local were collected from Werer Agricultural Research Center. The 4X2 factorial combination was arranged in randomized complete block design with three replicates per variety. The tested varieties were planted in 4m x 3m plot area, each variety was assigned randomly to plots within block, and cuttings were planted in four rows per plot with 0.75cm between row and 0.5cm between plants with 1m between plots. Then the parent plants were cut into stems with three nodes per cutting and planted at 20cm deep at an angle of 40° by recommendation of [15]. The two testing seasons were evaluated in order to clearly identify the suitable season for successful Elephant grass variety production (Figure 1).

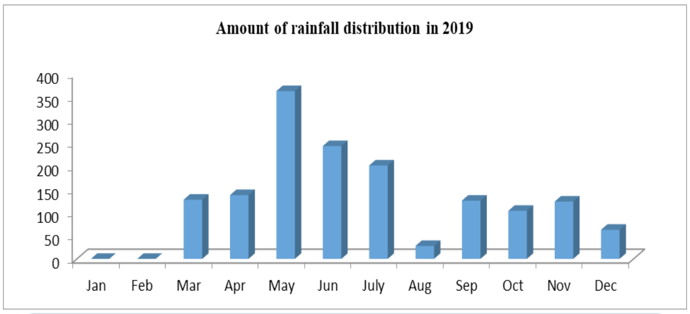

Figure 1: Amount of rain fall distribution over testing seasons in 2019.

Data collection

The agronomic data like Plant Height (PH), tillers per plant, number of Nodes Per Plant (NNPP) and Leaf to Stem Ratio (LTSR) were measured by harvesting middle of two rows using suckles. The tillers per plant were counted from the five culms after harvesting and average of plants was considered. The plant height was measured from five plants, which were randomly taken from each plot by using a steel tape from the ground level to the highest leaf. The numbers of nodes per plant were measured from the five plants, which were used for plant height measurement by counting all nodes per plant, and average was considered. To determine biomass yields, all plants per variety in the plot were clipped at 5cm from the ground level from two rows next to the guard rows. The weight of the total fresh sample was measured from each plot in the field and about 500g sample was taken from each plot and allotted in to oven dried set at 105oc for overnight (12hrs). The biomass yields were calculated by using formula stated by [16]. The biomass yield (ton/ha) = TFW x (DWss /HA x FWss) x10; where TFW = Total Fresh Weight kg/plot, DWss = Dry Weight of Sub-Sample in gram, FWss = Fresh Weight of Sub-Sample in gram, HA = Harvest Plot Area in square meters and 10 is a constant for conversion of yields in kg/m to ton/ha. In order to measure leaf to stem ratio, the morphological plant parts were separately weighed to know their sample fresh weight, then oven dried for 12 hours with a temperature set at $105^o{}_c$ and separately weighed to estimate the proportions of these morphological plant parts. The leaves were separated from stems and the fractions were estimated based on the dry weight of each component.

Data Analysis

The agronomic and yield data's were subjected to analysis of variances (ANOVA) using the Generalized Linear Model (GLM) procedure of Statistical Analysis System (SAS) software [17]. The significant differences among the means were declared at p< 0.05 and means were separated using Duncan's least significant difference (LSD) with model of *Yijk = μ + Vi + Sj + Vi* Sj + eijk*, where; yijk = all dependent variables; μ = overall mean; Vi = the effect of variety; Sj = the effect of season; Vi*Sj = the interaction effects of variety and season and eijk = random error.

Results and Discussion

Effects of variety on agronomic parameters

The effects of elephant grass varieties under rain fed condition at on-station of Jinka Agricultural Research Center on agronomic parameters are presented in Table 1. The longer (p<0.05) plant height was obtained from the Areka-local variety, while shorter plant height was observed for Werer-local variety, but the plant height of Areka-local variety was comparable to plant height of Werer-1333 variety.

The higher (p<0.05) tillers per plant were observed for Werer-local variety, while a few tillers per plant were obtained from the ILRI-16840 variety, but tillers per plant were similar (p>0.05) among the ILRI-16840, Areka-local and Werer-1333 varieties. Pertaining to the number of nodes per plant, result revealed that the higher (p<0.05) number of nodules per plant were observed for Werer-local variety than ILRI-16840, but nodules per plants were similar (p>0.05) among the ILRI-16840, Werer-local and Areka-local varieties. The plant height is among the important agronomic practices, which is used to determine appropriate harvesting stage and biomass yields for elephant grass varieties for on-time-utilization by animals. The higher plant cutting height for the Areka-local variety in this study than other elephant grass varieties is due to varietal-potential to well adapt in tested agro-ecology. Similarly, [18] and [10] from the Ethiopia observed differences in plant cutting height above the ground for the different Elephant grass cultivars was due to varietal differences. Moreover, the study reported by [19] was showed that understanding the plant cutting height of Elephant grass cultivars is imperative to estimates biomass yields of cultivars. The average plant cutting height obtained from this study (2.12m) which ranged from 2.19m to 2.56m for four Elephant grass varieties is within average value reported by [20] which ranged from 2m to 2.66m, and [10] which ranged from1.09m to 3.13m from Ethiopia. However, plant height from the present study is higher than reported value, which was ranged from 1m to 1.3m by [15] and [18], which ranged from 0.87m to 1.35m and values ranged from 1.07m to 1.26m by [21]. The determining of number of tillers and nodes per plant are so important agronomic parameters, which are considered during selection of appropriate forage species or variety for higher biomass production, adaptability and establishment potentials. The higher tillers and number of nodes per plant for Werer-local variety than other varieties in this study are might be varietal-difference as plant height. The studies reported by difference scholars [19,22,23] were demonstrated that the significant difference among the Elephant grass cultivars is due to varietal-difference.

The average tillers per plant (24.75) which ranged from16 to 34 from the present study was higher than values (16.62) reported by [20] for six Elephant grass-cultivars, (18.83) by[18] for five Elephant grass-cultivars and[10] for five Elephant grass-varieties. The result on number of nodes per plant from present study was higher that reported value of (10.08) by [20] for six Elephant grass-cultivars.

Table 1: The effects of Elephant grass varieties on agronomic parameters under rain-fed condition at on-station of Jinka Agricultural Research Center of South Omo in 2019 copping year.

Varieties	PH (m)	TPP	NNPP	SR (%)
ILRI-16840	2.27^{b}	16^{b}	8.8^{b}	89.93
Werer-1333	2.35^{ab}	23^{b}	13^{ab}	76.82
Areka-local	2.65^{a}	26^{ab}	12^{ab}	89.11
Werer-local	2.19^{b}	34^{a}	16^{a}	81.6
Average	2.12	24.75	12.45	84.37
SEM	17.89	5.12	3.02	6.95
LSD	37.93	10.85	6.41	14.74
CV	3.56	6.34	7.33	4.5

Keynotes: (Means with the different letters (a, b) in across the column for agronomic parameters at growing stage are significantly different at p<0.05; PH: Plant Height; TPP: Tillers per Plant; NNPP: Number of Nodes per Plant; SR: Survival Rate; SEM: Standard Error of Mean; LSD: Least Significance Difference; CV: Coefficient of Variation).

Effects of planting seasons on agronomic parameters

The effects of planting seasons on the agronomic parameters are presented in Table 2. The result revealed that the longer plant height (p<0.05) was obtained in autumn season (Beligi in Ethiopia) than summer season (Meher in Ethiopia), while tillers per plant were not affected (p>0.05) by tested seasons. Correspondingly, the higher (p<0.05) number of nodes per plant and survival rate were observed in the autumn season than summer season. The higher agronomic parameters (PH, TPP, NNPP and SR%) were obtained in autumn season than summer season from this study is due to fact that higher rainfall which make faster plant growth and triggering the more tillers and nodes per plats, survival rate, and plant height (Figure 1). Inline to findings from this study, the previous studies reported by different researchers were demonstrated that the growth parameters of forage species might be greatly affected by weather conditions such as rainfall and temperature [10, 21, 24, 25].

Table 2: The effects of seasons on agronomic-parameters under rain-fed condition at on-station of Jinka Agricultural Research Center of South Omo in 2019 copping year.

Seasons	Agronomic parameters			
	PH (cm)	TPP	NNPP	SR
Autumn	270.58^{a}	25	15.22^{a}	90.45^{a}
Summer	202.50^{b}	24	9.67^{b}	78.28^{b}
Average	236.54	24.5	12.41	84.36
SEM	12.65	3.62	2.13	4.92
LSD	26.82	7.67	4.54	10.43

Keynotes: (Means with the different letters (a, b) in across the column for agronomic parameters at growing stage are significantly different at p<0.05; PH: Plant Height; TPP: Tillers per Plant; NNPP: Number of Nodes per Plant; SR: Survival Rate; SEM: Standard error of mean; LSD: Least Significance Difference).

Variety by season interaction effect on agronomic parameters

The variety by season interaction effects on agronomic parameters are presented in Table 3. The result for season and variety interaction effect revealed that the higher (p<0.05) plant height was observed for Areka-local variety than the ILRI-16840, Werer-1333 and Werer-local varieties by keeping autumn season constant, and however, it was insignificant (p>0.05) among the ILRI-16840, Werer-1333 and Werer-local varieties. The higher (p<0.05) tillers per plant were observed for Werer-local variety than ILRI-16840, Areka-local and Werer-l333 varieties by keeping summer season constant, but it was insignificant (p>0.05) among the ILRI-16840, Areka-local and Werer-1333 varieties. . Pertaining to number of nodes per plant, the higher (p<0.05) number of nodules per plant was obtained from the Werer-local variety than the ILRI-16840, Areka-local and Werer-1333 varieties by keeping autumn season constant, but number of nodules per plant was insignificant (p>0.05) among the all varieties by the keeping summer season constant. The significant variety by season interaction effects for agronomic parameters showed that tested Elephant grass variety responded differently to different seasons.

This is confirming to us is that it is highly essential to evaluate the performance of the agronomic parameters of Elephant grass variety across season to categorize best candidate variety with higher agronomic parameters across seasons. The variety by season interaction result demonstrated that one variety was better one season for specific agronomic parameters, but it was not better in other season for specific or different agronomic parameters. Similar to the result from the present study [26], who evaluated different Oat varieties for agronomic and biomass yield parameters observed different Oat varieties responded differently to different planting seasons for different agronomic-parameters. Similarly, [27] and [28] who studied Napier grass genotypes and Trifolium species, respectively across environments found that Napier grass genotypes and Trifolium species responded differently for agronomic performance across the test environments.

Table 3: The variety by season interaction effects on agronomic-parameters under rain-fed condition at on-station of Jinka Agricultural Research Center of South Omo in 2019 copping year.

Variety	Season	Agronomic parameters			
		PH (cm)	TPP	NNPP	SR
ILRI-16840	Autumn	265[ab]	18[bc]	9.66[b]	93.20[a]
	Summer	188[c]	14[c]	8[b]	86.67[a]
Werer-1333	Autumn	258[b]	15[c]	14.77[ab]	92.73[a]
	Summer	213[bc]	30[ab]	11[b]	93.77[a]
Areka-local	Autumn	313[a]	25[bc]	14.22[ab]	84.44[a]
	Summer	217[bc]	27[abc]	9[b]	60.92[b]
Werer-local	Autumn	247[b]	41[a]	22.22[a]	82.10[a]
	Summer	191[c]	26[bc]	10[b]	81.11[ab]

Keynotes: (Means with the different letters (a, b, c) in across the column for agronomic parameters at growing stage are significantly different at p<0.05; PH: Plant Height; TPP: Tillers per Plant; NNPP: Number of Nodes per Plant; SR: Survival Rate).

Effects of *elephant* grass varieties on biomass yields and leaf to stem ratio

The effects of elephant grass varieties on fresh and dry biomass yields, and leaf to stem ratio are presented in Table4. The result revealed that the ILRI-16840 variety yielded higher (p<0.05) fresh and dry biomass yields than Werer-local variety, but fresh and dry biomass yields were similar (p>0.05) between Werer-1333 and Areka-local varieties. The fresh biomass yield is important parameters, which allow farmers and pastoralists for cut and carry system for using the herbage yield of forage [6,20]. The higher biomass yield for ILRI-16840 variety than the other varieties from this study is due to the varietal difference. Similarly, the different scholars from Ethiopia were reported that the variability in the biomass yields among the forage species was due to differences in genetic-potential of forage species [21,25,27]. The findings from the present study for fresh biomass yield, which was averaged about 28.87 ton/ha was lower than reported values of (49.81ton/ha) and (77.43ton/ha) for six and five Elephant grass cultivars under rain-fed and irrigated condition by [20] and [18], respectively. The result on dry biomass yield from this study was relatively similar to previously reported dry biomass yield value of (14.13ton/ha) by [18] for five Elephant grass cultivars, (12.77ton/ha) by [15] for Nine Elephant grass cultivars and (13.37 ton/ha) by [20] for six Elephant grass cultivars. However, the dry biomass yield from this study was higher than reported value of (6.84ton/ha) by [27] for six Elephant grass cultivars and (4.2ton/ha) by [29] for nine Elephant grass cultivars, but it was lower than reported value of (41.2 ton/ha) and (41.05 ton/ha) by [10] and [30], respectively under irrigated condition.

Variety by season interaction effect on biomass yields and leaf to stem ratio

The variety by season interaction effect on biomass yields and leaf to stem ratio are presented in Table 5. The result revealed that ILRI-16840 variety gave higher (p<0.05) fresh and dry biomass yields than Werer-1333, Areka-local and Werer-local varieties in autumn season. Similarly, in summer season, the ILRI-16840 variety yielded higher (p<0.05) fresh and dry biomass yields than rest varieties, but both biomass yields were similar (p>0.05) between Werer-1333 and Areka-local varieties. Regarding to variety by season interaction effect on leaf to stem ratio, the leaf to stem ratio was comparable (p>0.05) among the all varieties in autumn season, but in summer season, Werer-local variety had higher leaf to stem ratio, while leaf to stem ratio was similar for ILRI-16840, Werer-1333 and Areka-local varieties. The significant difference for the biomass yields between varieties by keeping planting season constant from this study was indicated that different variety responded differently for different planting seasons. The higher biomass matter yield was obtained for all Elephant grass varieties in autumn season than summer is due to higher amount and distribution of rainfall, and suitable temperature. The study reported by [31] showed that suitable temperature and better rainfall are the major explanations for getting better dry biomass yields of forage species. Moreover, the significant different for leaf to stem ratio is due to interaction effect of variety and biomass yields from the present study was indicated that one variety is better in one season, but its betterment is not continued in other season. As example, leaf to stem in autumn season was higher for the Werer-local variety, but leaf to stem ratio of ILRI-16840 variety was lower and however, ILRI-16840 variety had higher biomass yields.

Table 4: The effects of *Elephant* grass varieties on biomass yields under rain-fed condition at on-station of Jinka Agricultural Research Center of South Omo in 2019 copping year.

Varieties	FBY(ton/ha)	DMY(ton/ha)	Leaf to stem ratio
ILRI-16840	38.16[a]	18.27[a]	1.06
Werer-1333	29.15[b]	12.74[b]	1.03
Areka-local	29.57[b]	14.67[b]	1.07
Werer-local	18.60[c]	8.70[c]	1.35
Mean	28.87	13.59	1.12
SEM	2.5	1.3	0.16
LSD	5.39	2.8	0.35
CV	5.6	6.7	4.3

Keynotes: (Means with the different letters (a, b, c) in across the column for biomass yields and leaf to stem ratio at growing stage are significantly different at $p<0.05$; FBY: Fresh Biomass Yield; DMY: Dry Matter Yield; SEM: Standard Error of Mean; LSD: Least Significance Difference; CV: Coefficient of Variation).

Table 5: The variety and season interaction effects on biomass yields and leaf to stem ratio under rain-fed condition at on-station of Jinka Agricultural Research Center of South Omo in 2019 year.

Variety	Seasons	Biomass yield parameters		
		FBY (ton/ha)	DBY (ton/ha)	Leaf to stem ratio
ILRI-16840	Autumn	38.89[a]	18.71[a]	0.99[ab]
	Summer	37.43[ab]	17.83[ab]	1.13[ab]
Werer-1333	Autumn	29.72[c]	13.48[c]	1.12[ab]
	Summer	28.57[c]	12[cd]	0.94[b]
Areka-local	Autumn	30.87[bc]	14.77[bc]	1.31[ab]
	Summer	28.27[c]	14.57[bc]	0.83[b]
Werer-local	Autumn	19.20[d]	9[d]	1.45[a]
	Summer	18[d]	8[d]	1.25[ab]
SEM		3.6	2.83	0.24
LSD		7.6	3.89	0.5

Keynotes: (Means with different letters (a, b, c, d) in across column for biomass yields and leaf to stem ratio at growing stage are significantly different at $p<0.05$; FBY: Fresh Biomass Yield; DBY: Dry Biomass Yield).

Conclusion

The higher plant height was observed for the Areka-local variety, while shorter plant height was observed for Werer-local variety. The higher tillers per plant were observed for Werer-local variety and a few tillers per plant were obtained from the ILRI-16840 variety. The higher dry biomass yield was observed for ILRI-16840 variety and lower dry biomass yield was observed for Werer-local variety. The higher dry biomass yield obtained for all variety in autumn season than summer season. Based on result from this study, we concluded that ILRI-16840 variety was superior variety to adapt in tested agro-ecology for higher dry biomass yield. In addition, we suggested that future research will consider the quality parameters and feeding effects of varieties on animal performances (meat, milk and growth rate) which were not covered under this study due to budget limitation.

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