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Comparative evaluation of forage grasses for stability analysis using GGE biplot and AMMI and forage yield modelling

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ABSTRACT

The need for cultivation of forage grasses to feed animals, as a way of ameliorating the clashes between herders and crop farmers cannot be over emphasized. Therefore, this study was conducted during 2019 at three diverse agro-ecological zones in Kwara State, Nigeria to assess the yield potential, stability, and the possibilities of improving forage yield through secondary traits. Hence, three forage grasses (Elephant grass, *Pennisetum purpureum*; Gamba grass, *Andropogon gayanus*; and Ruzi grass, *Brachiaria ruziziensis*) were laid out in randomised complete block design (RCBD) wherein data was collected on vegetative, stress index traits and yield and were subjected to analysis of variance (ANOVA). Traits with significant G × E were subjected to stability analysis using genotype × genotype × environment interaction (GGE) biplot and additive main effects and multiplicative interaction (AMMI). Structural equation model was used to depict the association between yield and secondary traits. The results revealed significant ($p < 0.05$) difference among forage grasses for yield and other traits, hence, they are amendable to selection and improvement through breeding efforts. AMMI and GGE biplot effectively identified the best and most stable forage grass as *Pennisetum purpureum* (28.59 t/ha) for general adaptations, and Ruzi and Gamba for target environments. Plant height, number of tillers, leaf area, dry matter content and stay green are valuable secondary traits that are employable in improving forage yield. Pennisetum can meet the feed demand of herder's animals, which, if adopted for cultivation and use, can reduce the incessant crises between farmers and herders in Nigeria.

Key words : Forage, grass, herbage, stability analysis, sustainable, yield

INTRODUCTION

Forage grasses, belonging to poaceae family, are not usually cultivated in Nigeria, but rather grow as weeds. Forage grasses are the ultimate source of feed for ruminant such as cattle, sheep and goats, raised by herdsmen. Crop and feed production in Nigeria and most parts of Africa is largely rainfed (Binuyo *et al.*, 2016). Crop farmers and pastoralists are dependent on rain for the survival of their crops and animals respectively, within the available rainy season gap as constricted by climate change (Binuyo *et al.*, 2016; Yousef *et al.*, 2018; Mathew *et al.*, 2020). The need to simultaneously use land for crop production and grazing by crop farmers and pastoralists respectively results in conflicts (Yusuf *et al.*, 2017; Maryam *et al.*, 2019). Crop farmers' and pastoralists' conflicts are accompanied by huge negative consequences including loss of lives and properties (Chukwuma, 2020).

As a solution to this menace, there are efforts to reduce nomadic methods of raising animals by herder and make them settle, cultivate forage to feed their animals. In view of this development, there is a need to identity high yielding and stable grasses. Therefore, grasses such as elephant grass (*Pennisetum purpureum*), Gamba grass (*Andropogon*

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gayanus) and Ruzi (*Brachiaria ruziziensis*) with proven records of meeting nutritional demands of livestock (FAO, 2015) were evaluated through multi environment trials.

Forage yield of genotypes evaluated in multiple environments can change from one environment to another thus making identification and selection of high yielding genotypes difficult (Yayis, 2019). Stability analysis helps in identifying stable and high yielding genotypes. Different methods of analyzing genotype x environment interactions and stability analysis are abound (Ige *et al.*, 2020). AMMI (additive main effects and multiplicative interaction) and GGE (genotype × genotype × environment interaction) biplot are most commonly used. AMMI decomposes sources of variance into genotype, environment and GE interaction. Both genotype and environment are explained as additive effects, while G × E interaction are explained as the multiplicative non-additive component which is analyzed by principal components. AMMI tests interaction and stability (Brankovic-Radojcic *et al.*, 2018). The GGE biplot proposed by Yan and Tinker (2006), provides graphical representation of best genotype and environment in Which Won Where/ what, identify mega environments, specific and general adaptation (Yayis, 2019).

Structural equation model (SEM) builds the relationship between dependent and independent variable and the covariance between independent variables in order to provide cause and effect relationship while accounting for error (Nazmi, 2013). There is paucity of information on the use of AMMI and GGE bilot in assessing stability in forage grasses and modeling of forage yield in Nigeria. Therefore, the objectives of this study were: i) to examine the potential of forage grasses; ii) to identify stable and high yielding forage grass(es) for general and target environments using AMMI and GGE biplot iii) to model forage yield based on secondary traits in order to enhance future breeding efforts.

MATERIALS AND METHODS

The experiments were conducted in the rainy season of 2019 at three diverse and representative agro-ecological zones of Kwara State. The experimental sites were Malete in Moro Local Government Area (LGA) in Kwara North, Oke-Oyi in Ilorin East LGA (Kwara Central) and Erin-Ile in Oyun LGA (Kwara South) (Fig. 1). While Erin-Ile has climatic characteristics similar to rain forest, Malete and Oke-Oyi belong to Southern Guinea Savannah zone of Nigeria. Farmers' fields were obtained and used to evaluate three varieties of grasses namely: Elephant grass (*Pennisetum purpureum*), Gamba grass (*Andropogon gayanus*) and Ruzi grass (*Brachiaria*

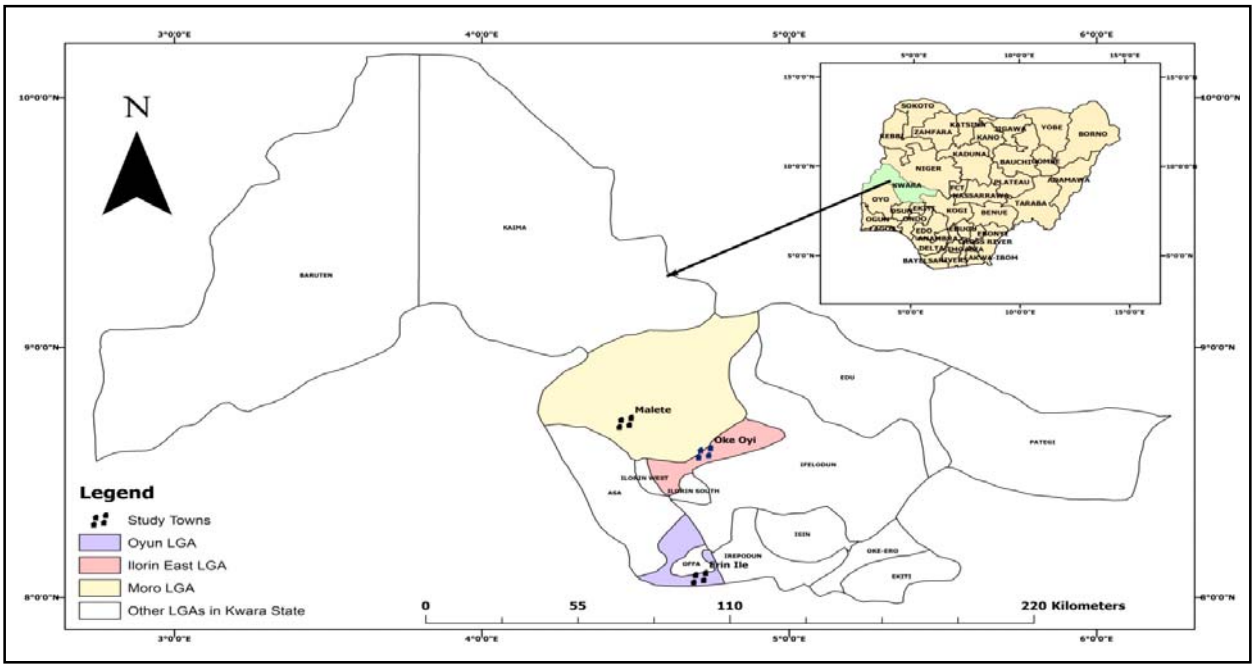


Fig. 1. Map of three experimental sites across Kwara State.

ruziziensis). The seeds of the three forage grasses were sown by drilling on a plot of 1 × 100 m. The experiment was laid out in randomized complete block design (RCBD) with three replicates in each location. Pre-emergent herbicide was applied at planting, followed by hand weeding and basal application of 30 kg/ha NPK fertilizer was supplied.

The growth parameters recorded were i) Plant height (cm) at 1, 2 and 3 months after sowing (MAS), ii) number of tillers at 1, 2 and 3 MAS, iii) leaf area at 3 MAS was measured as length x breath of leaf multiplied by correction factor of 0·905 (Kemp, 1960). iv) stay green was rated on a scale of 1 - 5 at 3 MAS, where 1 represented virtually dead foliage, and 5 indicated green foliage. v) pest severity was rated on a scale of 1-5 based on pest infestation at 3 MAS with being no symptoms of pest attack and 5 being high defoliation as a result of pest damage vi) disease severity was rated on a scale of 1-5 based on symptoms of disease infection at 3 MAS with 1 being no symptoms of disease attack and 5 being highly ravaged grass as a result of diseases. vii) total biomass weight in kg/plot. viii) forage yield was estimated and expressed in ton/ha. Data collected were subjected to both combined analysis of variance (ANOVA) and location based ANOVA with the aid of SAS 9.4 version. Means showing significant ($p < 0.05$) difference were separated using LSD. Means at each of the locations and their interactions were depicted graphically. G x E analyses were performed for stability analysis using GGE biplot and AMMI with the aid of GEA-R 4.1 version. The AMMI stability value (ASV) was determined as described by Purchase *et al.* (2000). The smaller the ASV score, the more stable genotypes are across the experimental locations (Farshadfar *et al.*, 2011). Yield stability index was obtained by summing the yield ranking and ASV ranking (Adjebeng-Danquah *et al.*, 2017). SEM was used to depict the cause and the effect relationship using STATA 16.0.

RESULTS AND DISCUSSION

The three forage grasses evaluated had significant ($p < 0.05$) mean squares for plant height (PH) (Fig. 2) and number of tillers (NoTillers) (Fig. 3) at 1, 2 and 3 months after sowing (MAS) at all the three experimental locations. The trend from 1 MAS to 3 MAS showed that Pennisetum (*Pennisetum purpureum*) was consistently and significantly ($p < 0.05$) taller and with more tillers than Gamba (*Andropogon gayanus*) and Ruzi (*Brachiaria ruziziensis*) in the order of Pennisetum > Gamba > Ruzi in each of the environment. Forage grasses had the highest plant height at Erin-Ile and the least at Oke-Oyi. The combined ANOVA showed that forage grasses and location had significant ($p < 0.05$) mean square for plant height and number of tillers at 1, 2 and 3 MAS (Table 1). As expected, plant height increased over time with Gamba and Ruzi being 73 and 60 % the height of Pennisetum at 3 MAS. Also, Pennisetum produced 1.5 and 2.5 times tillers as Gamba and Ruzi, respectively (Table 1).

LSD	PH1	PH2	PH3
Erin-Ile	5.57	32.56	25.66
Malete	6.54	12.21	15.49
Oke-Oyi	10.25	24.02	17.16

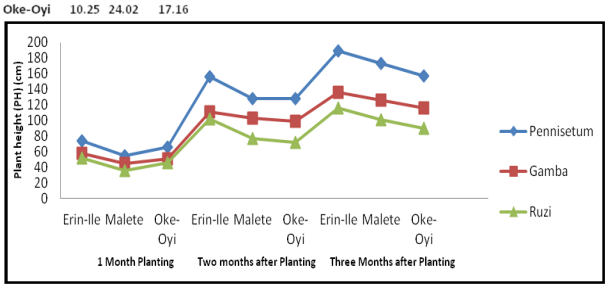


Fig. 2. Trends in plant height (cm) at three locations during the growth period of pasture.

LSD	NoT1	NoT2	NoT3
Erin-Ile	3.5	5.7	4.6
Malete	1.3	7.0	4.7
Oke-Oyi	3.7	7.3	5.9

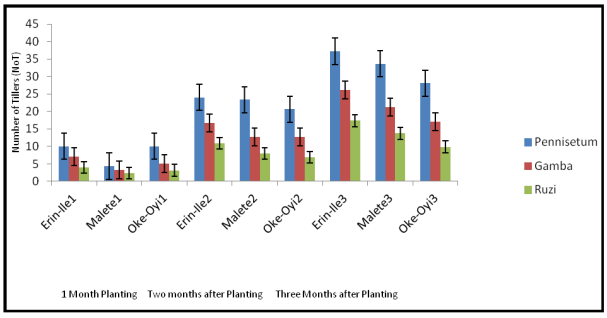


Fig. 3. Trends in number of leaves at three locations during the growth period of the forage grasses.

Pennisetum (*Pennisetum purpureum*), Gamba (*Andropogon gayanus*) and Ruzi (*Brachiaria ruziziensis*) varied in height and tillering ability throughout the growth period of the grasses. Similar variation has been reported in Pennisetum (Ansa and Garjila, 2019) and forage maiwa (Lawal, 2016) evaluated under different cutting regimes in

Table 1. Combined ANOVA across three locations for plant height and number of tillers (NoT) at 1, 2 and 3 months after sowing (MAS)

Source	d. f.	Plant height (1MAS)	Plant height (2 MAS)	Plant height (3 MAS)	NoT (1 MAS)	NoT (2 MAS)	NoT (3 MAS)
Replications	2	265.97**	49.01	124.23	5.87	8.85	16.71*
Location (L)	2	596.11**	1435.82**	1526.12**	32.56**	33.27*	165.73**
Forage grass (F)	2	977.02**	6655.63**	11605.58**	56.07**	454.51**	852.10**
F x L	4	12.23	102.59	27.18	5.87*	2.41	1.23
Error	16	29.50	118.03	60.35	1.85	7.31	4.50
R-Square		0.89	0.90	0.96	0.88	0.90	0.97
CV		10.15	10.01	5.82	24.90	17.93	9.34
Mean		53.49	108.50	133.58	5.46	15.08	22.70
Forage grasses							
Pennisetum		64.89	137.49	172.70	8.11	22.67	32.99
Gamba		51.11	104.44	125.94	5.11	14.00	21.47
Ruzi		44.47	83.56	102.11	3.16	8.58	13.65
LSD		5.43	10.86	7.76	1.36	2.70	2.12

*and ** = Significant at P = 0.05 and P = 0.01 levels, respectively; df = Degree of freedom; Rep = Replication; CV = Coefficient of variation; LSD = Least significant difference.

Nigeria and also Tanzania (Maleko *et al.*, 2019). Variation in plant height and number of tillers implied that there was room for selection and improvement of forage grasses as similar assertions have been reported in soybean (Lawal, 2020) and forage grasses (Maleko *et al.*, 2019). Pennisetum was most variable for plant height and number of tillers and hence offer the highest potential for improvement. Taller grasses have better chance of tapping more sunlight for photosynthesis and producing more photosynthates and hence biomass. Plant height and number of tillers are complimentary components of biomass weight and hence forage yield (Ansa and Garjila, 2019).

Stay green rating was significantly ($p < 0.05$) different among the forage grasses with Ruzi being the greenest (average of 4.5/5). *Pennisetum* and Gamba had comparable (2.9/5) greenness across the three locations. Forage grasses at Oke-Oyi had the least stay green score at two weeks before harvest (data not shown). Combined ANOVA (Table 2) showed that the forage grasses and locations had significant ($p < 0.05$) mean squares for stay green with a mean score of 3.57/5. Stay green, a measure of chlorophyll concentration in plants, an indication of resilience to stress varied among the forage grasses. Ruzi being the greenest at two weeks before harvest implied active production of photosynthates when senescence had set in among other forage grasses. Also, retention of greenness in herbage implied the presence of Mg, N which are important in animal nutrition (Pareek *et al.*, 2018). Forage grasses varied significantly ($p <$

Table 2. Mean squares for combined ANOVA across three locations for abiotic (stay green) and biotic (pest and diseases severity) stresses and yield parameters

Source	d. f.	Stay green	Pest severity	Diseases severity	Leaf Area	Dry Matter Content	Foliage yield (t/ha)
Replications	2	0.18	0.08	0.001	0.02**	7.33*	27.39
Location (L)	2	0.79**	1.13**	1.54**	0.03**	81.71**	295.06**
Forage grass (F)	2	7.96**	20.33**	24.72**	0.09**	131.02**	413.97**
F x L	4	0.15	0.16*	0.24**	0.001	18.83**	56.54**
Error	16	0.08	0.04	0.03	0.00	1.99	8.37
R-Square		0.93	0.98	0.99	10.29	15.21	13.70
CV		7.95	8.96	7.36	0.03	1.41	2.89
Mean		3.57	2.32	2.31	0.29	9.27	21.12
Forage grasses							
Pennisetum		3.03	1.41	1.33	0.39	13.57	28.59
Gamba		3.03	4.06	4.22	0.29	6.27	15.34
Ruzi		4.66	1.50	1.37	0.20	7.99	19.44
LSD		0.28	0.21	0.17	0.03	1.41	2.89

*and ** = Significant at P = 0.05 and P = 0.01 levels, respectively; Df = Degree of freedom; Rep = Replication; CV = Coefficient of variation; LSD = Least significant difference.

0.05) in response to pests and diseases.

Pest and diseases were most severe at Erin-Ile and least severe at Malete (data not shown). Combined ANOVA (Table 2) showed that forage grasses and locations had significant ($p < 0.05$) mean square for pest and disease severity. Gamba grass was the most susceptible to pests (4.06/5) and disease (4.22/5) across the three locations. Pennisetum and Ruzi were tolerant to pests (average of 1.45/5) and diseases (average of 1.35/5) respectively. The difference observed in response to pest and disease attack could be due to the difference in their morphology and tolerance mechanisms which could provide basis for the development of tolerant varieties. Pests and diseases attack reduce yield and quality of crops including herbage (Ivelina, 2018). Gamba grass being the most susceptible, had the least yield which could be attributable to its susceptibility to pests and diseases. Although Gamba grass was taller and produced more tillers than Ruzi, it was however lighter due to its susceptibility to pests and diseases attack as pest and diseases reduce the biomass weight of forage (Ivelina, 2018). Combined ANOVA (Table 2) showed forage grasses were significantly ($p < 0.05$) different for leaf area and dry matter content in the order of Pennisetum > Gamba > Ruzi across the locations. Leaf is a photosynthetic apparatus of plants, and wider surface area could also have implication in improved production of photosynthates.

Dry matter content is a reflection of mineral and nutrient left in forage after water extraction. Pennisetum had the highest dry matter content, and it varied considerably compared to that of Gamba and Ruzi. Fig. 4 showed that *Pennisetum* had significantly ($p < 0.05$) higher forage yield at each of the locations and across the environments (Table 2). Forage yield across the environments was in the order of *Pennisetum* (28.59 t/ha) > Ruzi (19.44 t/ha) > Gamba (15.34 t/ha). High variation in the yield of forage grasses implied that high genetic difference among the grasses and potential for improvement. *Pennisetum* was the most yielding at each location and across environments. *Pennisetum* and Ruzi were most variable for forage yield and hence most amenable to further breeding efforts (Ansa and Garjila, 2019, Maleko *et al.*, 2019).

There was no significant ($p < 0.05$) forage grass x location interaction for vegetative

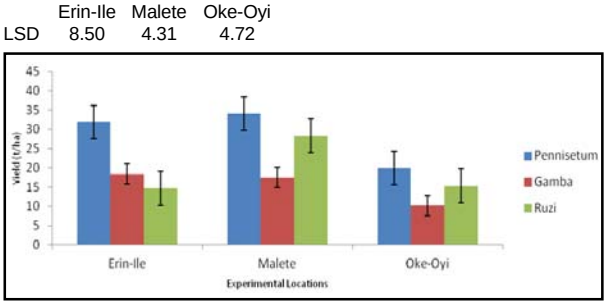


Fig. 4. Yield of forage grasses at three experimental locations.

traits and stay green, it was however significant ($p < 0.05$) for pests and diseases severity, dry matter content and forage yield (Table 2) which implies differential response of forage grasses to the environmental conditions as a result of distinctive soil and climatic characteristics. Erin-Ile has agro ecological features of the Rain forest of the Southern Nigeria as it shares boundary with the region while Malete and Oke-Oyi belong to the Southern Guinea Savannah zone. Pest and diseases were most severe at Erin-Ile. Heavy infestation of pest and disease are characteristics of rain forest zones. Malete and Oke-Oyi had low pest and disease attack. This agreed with the reports of Aderolu *et al.* (2018) that savannahs usually have low pests and diseases attack and are suitable for grasses. Malete, a savannah region out yielded Erin-Ile, a rain forest zone. Forage yield superiority in Malete could be as a result of less pest and disease infestation, adequate temperature and sunlight penetration due to less cloud cover that characterized the savannah (Shehu *et al.*, 2018).

Table 3 showed that AMMI analysis of variance was significant ($p < 0.05$) for the effects of forage grasses, location and their interactions for pest and disease severity, dry matter content and forage yield. Genotype x environment interaction which results in crossover effect implied changes in mean ranking of genotypes in different environments. G × E interaction obscures breeding effort (Yayis, 2019) hence, stability analysis methods are used to identify stable and high yielding genotypes that respond to enhanced environmental conditions (Farshadfar *et al.*, 2011).

Environment influenced the response of the forage grasses to pest and disease severity, dry matter content and forage yield, resulting in genotypes that are adapted to a particular environment. Also, forage grasses as

factor accounted for largest proportion of the treatment sum of squares for 93.39% (pest severity), 92.47% (disease severity), 52.33% (dry matter content), and 50.35% (forage yield). Location accounted for 5.17, 5.74, 32.64 and 35.89% for pest severity, disease severity, dry matter content and forage yield, respectively. Forage grass x location interaction accounted for 1.44 - 15.04%, PC1 accounted for 76.21 - 99.98% while PC2 accounted for 0.02 to 23.79% for pest and disease severity, dry matter content and forage yield. AMMI revealed that forage grasses (genotype) accounted for more than 90% of the observed variation in pest and disease severity and over 50% in dry matter content and forage yield. This suggests the preponderance of heritable variation for these traits and hence, ease of genetic improvement through breeding efforts (Tsegaye *et al.*, 2007).

AMMI incorporated with polygon illustrated target genotype(s) for specific environments with regards to different traits. For instance, Pennisetum and Ruzi had low pest and disease infestation at Erin-Ile while Gamba was highly infested at Oke-Oyi and Malete. Pennisetum was adapted to Erin-Ile, Ruzi was adapted to Oke-Oyi and Malete (data not shown). Table 3 showed that Pennisetum had the highest forage yield (28.59 t/ha) and the least AMMI stability value (ASV) (2.60) and yield stability index (YSI) (2) and was ranked first. Ruzi (19.44 t/ha), though had higher yield than Gamba (15.34 t/ha), had similar YSI (5) and were ranked third. AMMI stability value (ASV) is known to be valuable in identifying stable genotypes. Low ASV is premium while high ASV is undesirable, as the lower ASV of genotype(s), the more stable the genotype(s) and vice versa (Farshadfar *et al.,* 2011) Pennisetum had the least ASV and the highest yield. It is thus the most stable and highest yielding forage based on yield stability index (YSI) which combined yield and stability into an index (Adjebeng-Danquah *et al.*, 2017). Ruzi with a moderate yield can be recommended for specific environment; Oke-Oyi and Malete.

Principal component axis I (PC I) and PC II accounted 99.93% and 0.04% (pest severity), 99.98% and 0.02 (disease severity), 84.3% and 15.71% (dry matter content) (data

Table 3. G × E (% Exp.) from AMMI analysis for pest and disease severity and forage yield

Source		Disease severity			Pest severity		
	Df	SS	MS	% exp.	SS	MS	% exp.
Location (L)	2	3.07	1.54**	5.74	2.25	1.13**	5.17
Forage grass (F)	2	49.45	24.72**	92.47	40.67	20.33**	93.39
F x L	4	0.96	0.24**	1.79	0.63	0.16*	1.44
PC1	3	0.95	0.32**	99.41	0.63	0.21*	99.98
PC2	1	0.01	0.01ns	0.59	0.00ns	0.00ns	0.02
Residuals	18	0.46	0.03	0.001	0.85	0.05	0.001
		Dry matter content			**Forage yield**		
	df	SS	MS	% Exp.	SS	MS	% Exp.
Location (L)	2	163.43	81.71**	32.64	590.11	295.06**	35.89
Forage grass (F)	2	262.03	131.02**	52.33	827.94	413.97**	50.35
F x L	4	75.30	18.82**	15.04	226.16	56.54**	13.75
PC1	3	57.38	19.13**	76.21	192.09	64.03**	84.93
PC2	1	17.91	17.91*	23.79	34.07	34.07**	15.07
Residuals	18	46.50	2.58	0.001	188.69	10.48	0.001

		Ranking of forage grasses on the basis of yield and AMMI stability value (ASV)						
Forage Grass	Yield (t/ha)	Rank (A)	PC1 score	PC2 score	ASV	ASV rank (B)	YSI (A+B)	YSI Rank
Pennisetum	28.59	1	-0.45	0.58	2.60	1	2	1
Ruzi	19.44	2	1.00	-0.04	5.64	3	5	3
Gamba	15.34	3	-0.55	-0.54	3.15	2	5	3

*and** = Significant at P = 0.05 and P = 0.01 levels, respectively; df = Degree of freedom; PC= Principal component; SS = Sum of square; MS = Mean square; % Exp = Percentage explained; PC = Principal component.

not presented) as well as 82.25% and 17.75% (forage yield) respectively (Fig. 4). Which won where or what showed that pest and disease severity had the same inclination for the forage grasses. Ruzi was most adaptable to Malete and Oke-Oyi while Pennisetum and Gamba were best for Erin-Ile with reference to dry matter content and forage yield respectively (Fig. 5). Two mega environments observed for forage yield were Erin-Ile and Malete clustering with Oke-Oyi.

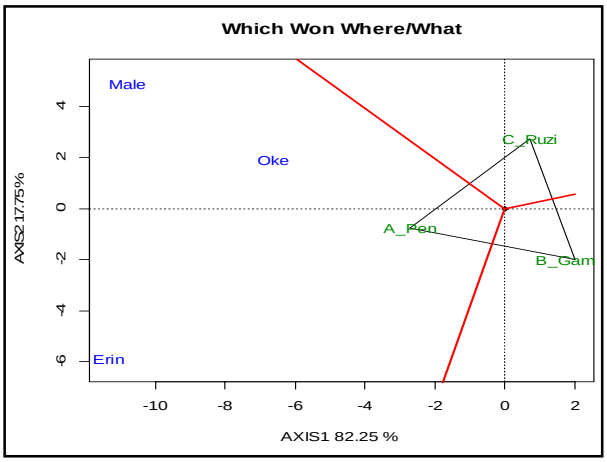


Fig. 5. Which won where/what for forage yield.

Pennisetum had the least PC II scores, Ruzi had the highest PC II scores for forage yield. GGE biplot, as a stability tool gives graphical illustration of the best variety, best location, mega locations, specific adaption, cross over effect etc (Peprah *et al.*, 2020). PCI and PCII of GGE biplot accounted for over 95% of the observed variations for forage yield among the forage grasses. GGE biplot identified Ruzi as the most adapted to Malete and Oke-Oyi while Pennisetum and Gamba were best for Erin-Ile with reference to forage yield. Similar results have been reported for cashew (Aliyu *et al.*, 2014) and cassava (Peprah *et al.*, 2020) where vertex genotype was considered as the best variety in such environment. Based on PC II scores, GGE biplot identified Pennisetum as the most stable forage grass and Ruzi as the least stable for forage yield based on PC II scores.

Fig. 6 showed that with regards to forage yield, Oke-Oyi had the least angle with Average Environmental Axis (AEA) and the shortest vector while Erin-Ile had the widest angle to AEA and the longest vector, followed closely by Malete. The Average Environment Axis (AEA) runs through the average environment at the centre of biplot origin. Imbedded in the average environment are mean coordinates of the three test locations. The smaller the angle between a test location and AEA, the more such a location represents other test environments (Yan and Tinker, 2006). With regards to forage yield, Oke-Oyi was most representative of the other environments while Erin-Ile and Malete were the least representative of other test environments. However, Erin-Ile and Malete were more discriminatory than Oke-Oyi. Generally adapted genotypes are usually chosen from test environment(s) that are both discriminatory and representative (Yan and Tinker, 2006). Thus, Oke-Oyi is a good test location where generally adapted forage grass can be selected, the generally adapted forage grass is Pennisentum. Furthermore, specifically adapted genotypes for a target location are selected from discriminatory but non-representative environment (Yan and Tinker, 2006). Hence, Gamba was the target grass for Erin-Ile while Ruzi was most adapted to Malete. The centre of the concentric circles represents the ideal environment, which is most discriminating and most representative (Peprah *et al.*, 2020). Thus, the ideal test environment is Oke-Oyi, it is a place to choose the best forage grass. Peprah *et al.* (2020), observed that good test environments should bear high PC1 scores, (most discriminating), and close to zero for PC2 scores (most representative of an average environment). With regards to forage yield Malete is correlated with Oke-Oyi. Fig. 7 show the LR fitted model for the relationship between forage yield, vegetative traits and stress index traits. The structural equation is: Forage yield=0.0074*Plant height @3MAS +

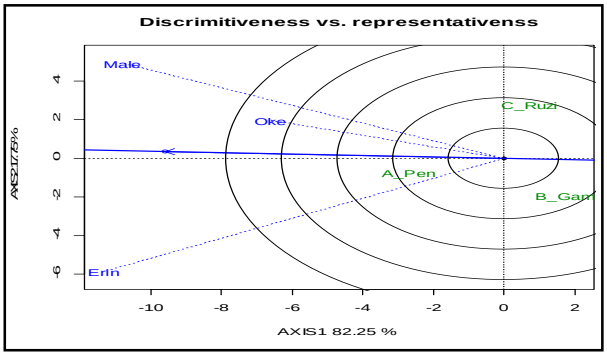


Fig. 6. Discriminatory ability vs. representativeness for forage grasses showing relationship between genotype and environment for forage yield.

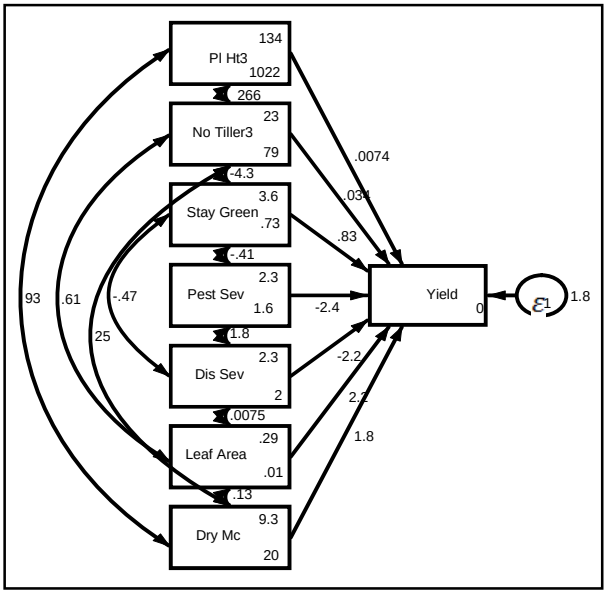


Fig. 7. Structural equation model fitted for forage yield based on vegetative and stress index (Pl Ht3= Plant height, No Tiller3= Number of tillers both at 3 MAS, Pest Sev= Pest severity, Dis Sev= Disease severity, Dry Mc= Dry matter content, LR test of model vs. saturated: chi2(1) = 6.60, Prob > chi2 = 0.0102 P>1.02%, hence model is fitted).

0.034*Number of tillers @3MAS +0.83*stay green - 2.4*pest severity -2.2*disease severity + 2.2*leaf area + 1.8*Dry matter content.

Forage yield was positively correlated to plant height, number of tillers, stay green, leaf area and dry matter content and negatively correlated to pest and disease severity. There was positive covariance between plant height and number of tillers, pest and disease severity, leaf area and dry matter content, plant height and dry matter content, number of tillers and dry matter content as well as number of tillers and leaf area. Negative covariance existed between number of tillers and stay green, stay green and pest severity as well as stay green and disease severity. Yield as a complex trait cannot be improved through direct selection in most crops. Secondary traits are usually targeted for improvement in order to improve yield. Structural equation model revealed that forage yield, which is dependent on herbage biomass can be improved by enhancing plant height, number of tillers, stay green, leaf area and dry matter content. This agreed with the reports of Nazmi (2013), who used SEM to establish the relationship between soil properties and yield of wheat in Iran. Also, forage yield can be improved by reducing the incidence of pests and disease (Aderolu *et al.*, 2018). It was also observed that as plant height increases, number of tillers increases. Also, pests attack aggravates disease severity as pests serves as vectors or window of attack for diseases. Similarly, leaf area, plant height and number of tillers improve dry matter content of forage grasses. However, pest and disease attack reduce the stay green and chlorophyll concentration of forage grasses as pest invaded or disease ridden grasses are pale or yellow.

CONCLUSION

Adequate room exists for the improvement of forage grasses through breeding efforts and optimisation of the plant environment. AMMI and GGE biplot were adequate in identifying Pennisetum as the most yielding and most stable forage grass for general adaptation and Gamba and Ruzi for target environments. In addition, GGE biplot provided graphical illustration of mega environment. Plant height, number of tillers, leaf area, dry matter content and stay green are valuable secondary traits in improving forage yield. The forage yield recorded in this study attests to the potential of forage grasses in meeting the feed need of cattle, and thus, reducing the faceoff between crop farmers and herders as a result of competition in resource utilization.

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