# APPLICATION OF PRINCIPAL COMPONENT AND STABILITY ANALYSES TO SOME TRAITS IN FORAGE LEGUMES †

# [APLICACIÓN DEL COMPONENTE PRINCIPAL Y ANÁLISIS DE ESTABILIDAD A ALGUNAS CARACTERÍSTICAS EN LEGUMINOSAS FORRAJERAS]

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## SUMMARY

**Background**. Availability of quality feed in adequate quantity for animals is a perennial problem. Its search results in conflicts between crop farmers and herders. **Objectives.** This research investigated three forage legumes in order to determine the most yielding, adaptable and important traits that could be used for forage improvement. **Methodology.** The forage legumes were laid out in randomised complete block design across three environments. Data collected on growth and yield parameters were subjected to ANOVA, principal component analysis (PCA) and stability analysis using additive main effect and multiplicative interaction (AMMI). **Results** The result showed that there was significant ($p < 0.05$) difference among the forage legumes for vegetative traits, stress traits and yield, hence, they could be through breeding. For biomass yield, PC1 and PC2 accounted for 75.16 and 24.84% of G x E respectively based on AMMI. *Lablab purpureus* is the most yielding, stable, adapted to rain forest and savannah zones, with yield of 28,948.69 kg/ha. PCA revealed that the first three PCs accounted for 87% of the total variation. There was positive and significant association between biomass yield and vegetative traits. **Implication.** Flourishing vegetative growth is a good indicator of biomass yield. **Conclusion.** It is recommended that extension agents should encourage the adoption of lablab for production of feeds for ruminants, as it can serve as sustainable land use measure considering the modern restriction on land availability for grazing and solution to incessant pastoral and crop farmers crises in the tropics.
**Keywords:** Forage production; lablab; pastoral and crop farmers crises; G x E analysis; sustainable land use; extension message

## RESUMEN

**Antecedentes.** La disponibilidad de alimentos de calidad en cantidad adecuada para los animales es un problema permanente. Su búsqueda da como resultado conflictos entre agricultores y pastores. **Objetivo.** Este trabajo investigó tres leguminosas forrajeras mediante un diseño de bloques completos al azar en tres ambientes, con el fin de determinar su productividad, adaptabilidad y otros caracteres de importancia para la mejora del forraje. **Metodología.** Los parámetros de crecimiento y rendimiento se analizaron mediante ANOVA, análisis de componentes principales (PCA) y análisis de estabilidad utilizando el efecto principal aditivo y la interacción multiplicativa (AMMI). **Resultado.** Se hallaron diferencias significativas entre las leguminosas forrajeras para los rasgos vegetativos, relacionados al estrés y el rendimiento, lo que sugiere su utilidad como material de Mejoramiento genético. Para el rendimiento de biomasa, el PC1 y PC2 representaron el 75,16 y el 24,84% de la interacción Gen × Amb (AMMI). Lablab (*Lablab purpureus*) fue la más productiva (28948.69 kg/ha), estable, y adaptada a zonas de selva tropical y sabana. Las tres primeras PC representaron el 87% de la variación total. Hubo asociación positiva entre el rendimiento de biomasa y los rasgos vegetativos. **Implicación.** El crecimiento vegetativo floreciente es un buen indicador del rendimiento de biomasa. **Conclusión.** Se recomienda que los extensionistas fomenten la adopción de lablab para la alimentación de rumiantes, ya que puede servir como una

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medida de uso sostenible de la tierra considerando la restricción moderna en la disponibilidad de tierra para pastoreo y las problemáticas para la producción de forrajes y cultivos en los trópicos.
**Palabras clave:** Producción de forraje; Lablab; problemáticas en la producción de forraje y cultivos; análisis G x A; uso sustantable del suelo; extensión rural.

## INTRODUCTION

Climate change and its consequences, population pressure and urbanization resulted in reduced land availability and accessibility for crop production and traditional nomadic grazing with ruminants most especially cattle, sheep and goats (Froese and Schilling, 2019). As a result, crop farmers have abandoned traditional shifting cultivation and have become sedentary and residential. Herders are also in transition phase of being sedentary, because of the incessant crises that usually ensue between them and crop farmers, whenever the former are in search of feed for their animals. Forage legumes are nutritious, high quality fodder crops that are capable of meeting the protein and energy need of ruminants. In Nigeria, *Lablab purpureus*, *Centrosema pubescens* and *Stylosanthes guianensis* are some of the available forage legumes for animal nutrition. In addition, forage legumes are multipurpose crop that are capable of improving soil fertility and protecting the soil (Ewansiha *et al*., 2016). Priority in the adoption of forage legumes for cultivation as feed for animals, are the need to evaluate the yield potential of such legumes, determine their adaptation and G x E interaction in different agro-ecology zones, and assessment of traits that can be used in improving biomass yield. Additive main effects and multiplicative interaction (AMMI) is a common stability tool used in understanding G x E interaction. G x E interaction occurs when environment (E) changes the ranking of genotypes (G) hence, making the selection of well adapted genotypes difficult (Branković-Radojĉić *et al*., 2018; Lawal *et al*., 2020a). AMMI stability value can be used to identity genotype for target environment and also general environment (Aliyu *et al*., 2014). Principal component analysis (PCA) enjoyed wide usage in determining the most important traits that are worthy of consideration most especially in new cultivars or breeds and also relationship among genotypes. It has been used in crops such as maize (Beiragi *et al*., 2012), Lathyrus (Granati *et al*., 2003). Grouping of traits among genotype usually aid future breeding efforts (Ariyo, 1993). There is scarcity of information on the use of PCA along with AMMI on forage legumes. Therefore, the objectives of this study were to: (i). investigate the yield potential of forage legumes across diverse agro-ecology (ii). determine target forage legume for a specific agro-ecology and generally adapted forage legume. (iii) ascertain traits important in improving yield of forage legumes.

## MATERIALS AND METHODS

The forage legumes, namely Lablab (*Lablab purpureus*), Centro (*Centrosema pubescens*) and Stylo (*Stylosanthes guianensis*), were sown in Malete, Oke-Oyi and Erin-Ile with each belonging to Kwara North, Kwara Central and Kwara South senatorial district respectively. Erin-Ile has rain forest characteristics while Malete and Oke-Oyi belong to the Southern Guinea Savannah zone. The three forage legumes were laid out in randomised complete block design (RCBD) in three replicates. Sowing was at 5 x 75 cm intra and inter row spacing respectively on a single row plot. The fields were well prepared and weeds were effectively controlled with herbicides and supplementary hand weeding. 60 kg/ha of $P_2O_5$ as single superphosphate was applied as a basal treatment.

### Data Collection

Data were collected on: i). Plant height (cm) at 2, 4, 6 and 10 weeks after sowing (WAS), ii). number of leaves were counted at 2, 4, 6 and 10 WAS iii). l number of branches were counted at 2, 4, 6 and 10 WAS. iv) stay green was scored from 1 - 5 at 10 WAS, where 1 = yellow and almost dead leaves, and 5 = green lush leaves. v) pest severity was scored from 1-5 based at 10 WAS, 1 = no symptoms of pest attack and 5 heavily devastated by pest. vi) disease severity was scored from 1-5 based at 10 WAS, 1 = clean plant with no sign of infection and 5 totally devastated by disease. vii) total biomass weight (Kg) of above ground parts from each plot. viii) biomass yield was estimated forage yield in Kg/ha. ix) seed weight (Kg) was the weight of seeds harvested per plot x) Seed yield was the estimated seed yield in Kg/ha.

xi) $\text{Harvest index} = \frac{\text{Seed yield}}{\text{Biomass yield}}$

### Data Analysis

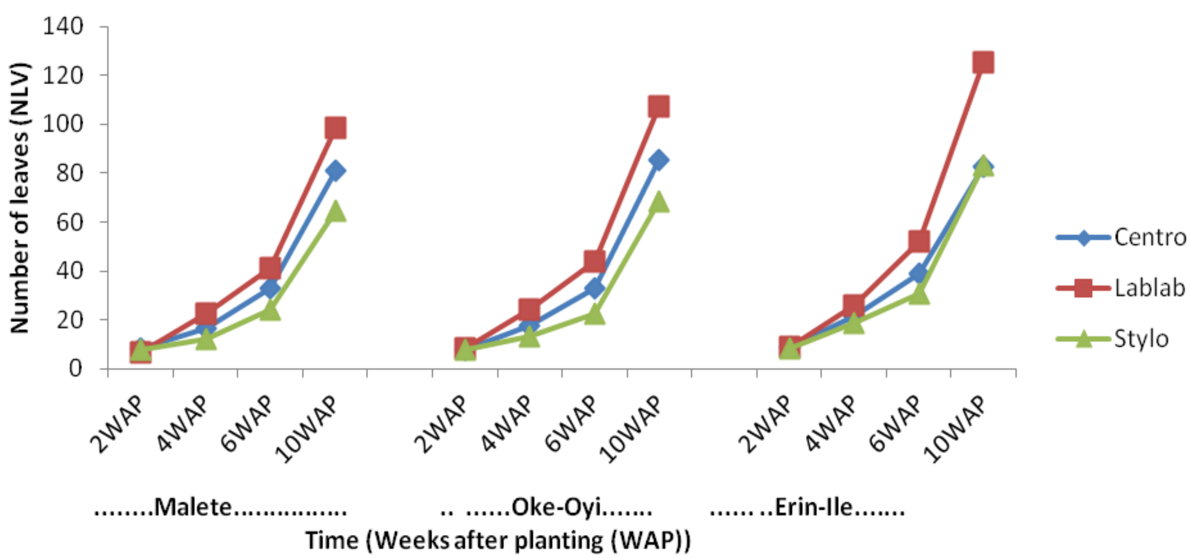
Analysis of variance (ANOVA) was performed for data collected with SAS 9.4 version and means showing significant ($p < 0.05$) differences were separated using LSD. Principal component analysis was done to determine the contribution of agronomic traits to grain yield. Correlation analysis was done to determine the association between traits. G x E analysis was performed with the aid of GEA-R 4.1 version using additive main effect and multiplicative interaction (AMMI). AMMI stability value (ASV) described by Purchase *et al*. (2001) was used to determine the most stable legume. Yield stability index was determined as described by Adjebeng-Danquah *et al*. (2017).

## RESULTS

The legumes do not differ significantly ($p < 0.05$) at 2 weeks after planting (WAP) for all vegetative traits namely number of leaves (Figure 1), plant height (Figure 2) and number of branches (Figure 3) at each of the locations. Also, combined ANOVA across the locations do not differ significantly for plant height, number of leaves and branches at 2 WAP (Table 1). However, forage legumes differed significantly for number of leaves (Figure 1), plant height (Figure 2) and number of branches (Figure 3) at 4, 6 and 10 WAP, and also for combined ANOVA (Table 1).

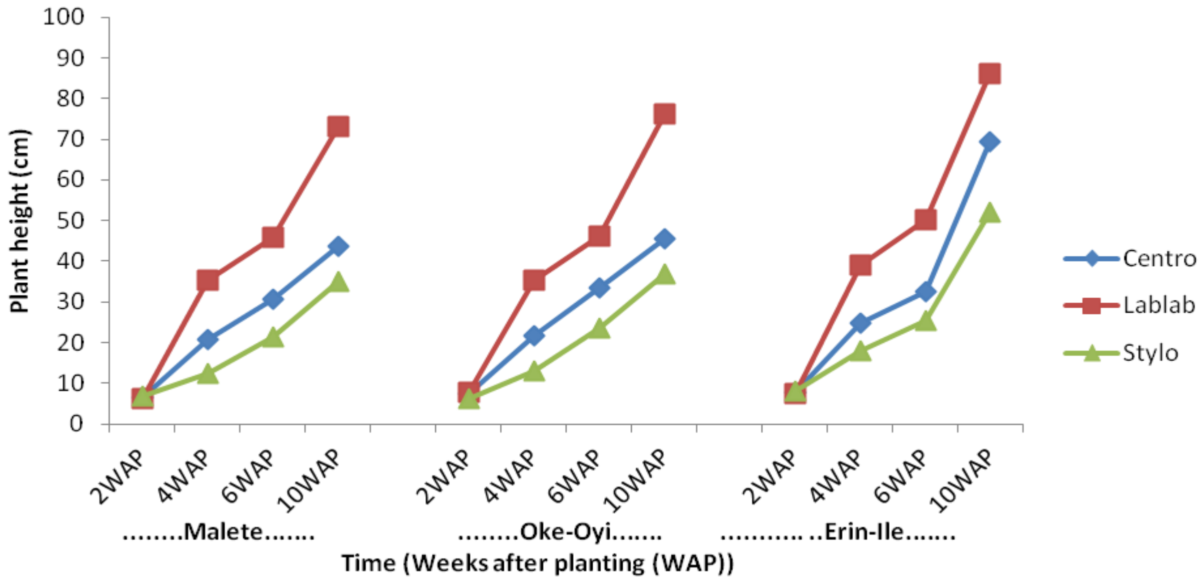
Figure 4 shows that there was significant ($p < 0.05$) variation among the forage legumes for stay green, pest severity and disease severity at each of the environments, and also from combined ANOVA across the environment (Table 2). Furthermore, Table 2 shows that the forage legumes differed significantly ($p < 0.05$) for days to flowering with Lablab having the highest days to flowering. More so, the forage legumes showed significant ($p < 0.05$) variation for biomass yield and seed yield (Table 2). Figure 5 shows that Lablab consistently had the highest biomass at each of the locations while Stylo remained low. Figure 6 shows that there was significant ($p < 0.05$) variation among forage legumes for seed yield with no genotype being consistently highest at all locations.

Table 3 shows that forage legumes (variety) accounted for 77.24% and 40.56% of the variation in biomass yield and seed yield respectively. Principal component (PC) 1 and 2 accounted for 100% of the observed variation. AMMI fitted with polygon shows that for biomass yield (Figure 7a), Lablab is adapted to Erin-Ile and Oke-Oyi, Centro and Stylo are suited to Malete and Oke-Oyi respectively. However, for seed yield (Figure 7b), Lablab, Centro and Stylo were adapted to Oke-Oyi, Malete and Erin-Ile respectively.



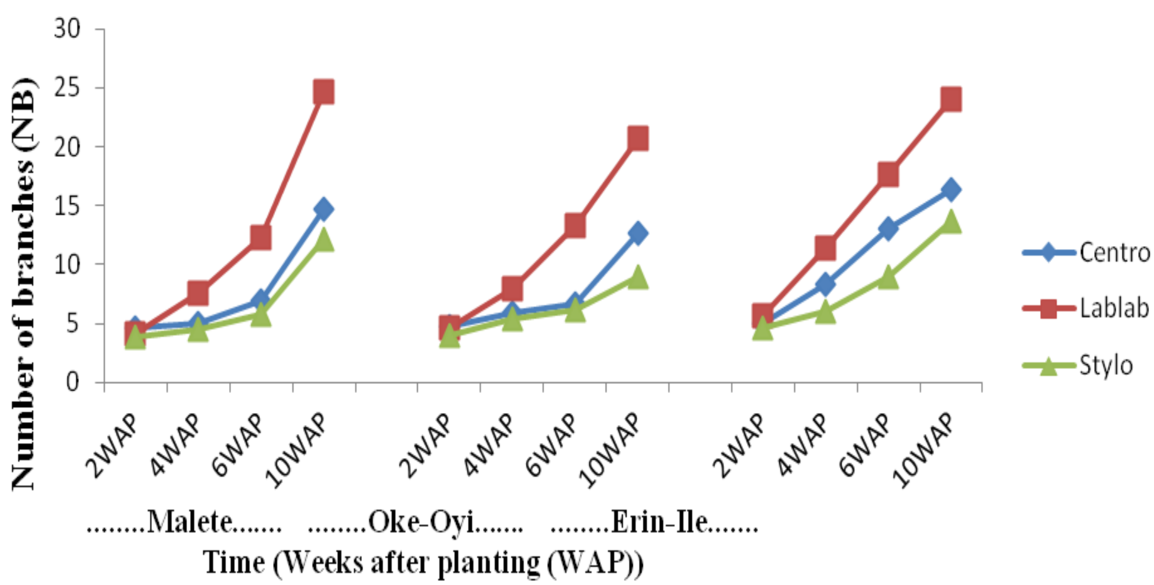

| | 2WAP | 4WAP | 6WAP | 10WAP |
|---|---|---|---|---|
| **LSD** | | | | |
| **Malete** | 1.19 | 8.26 | 5.85 | 10.48 |
| **Oke-Oyi** | 1.51 | 6.19 | 2.64 | 8.44 |
| **Erin-Ile** | 0.93 | 6.05 | 4.96 | 9.56 |

**Figure 1.** Trends in number of leaves at 2, 4, 6 and 10 WAP among legumes at each location.




| LSD | 2WAP | 4WAP | 6WAP | 10WAP |
|---|---|---|---|---|
| **Malete** | 0.84 | 1.42 | 3.02 | 3.40 |
| **Oke-Oyi** | 1.00 | 1.58 | 2.62 | 4.41 |
| **Erin-Ile** | 1.19 | 2.00 | 3.02 | 1.85 |

**Figure 2.** Trends in plant height (cm) at 2, 4, 6 and 10 WAP among forage legumes at each location.



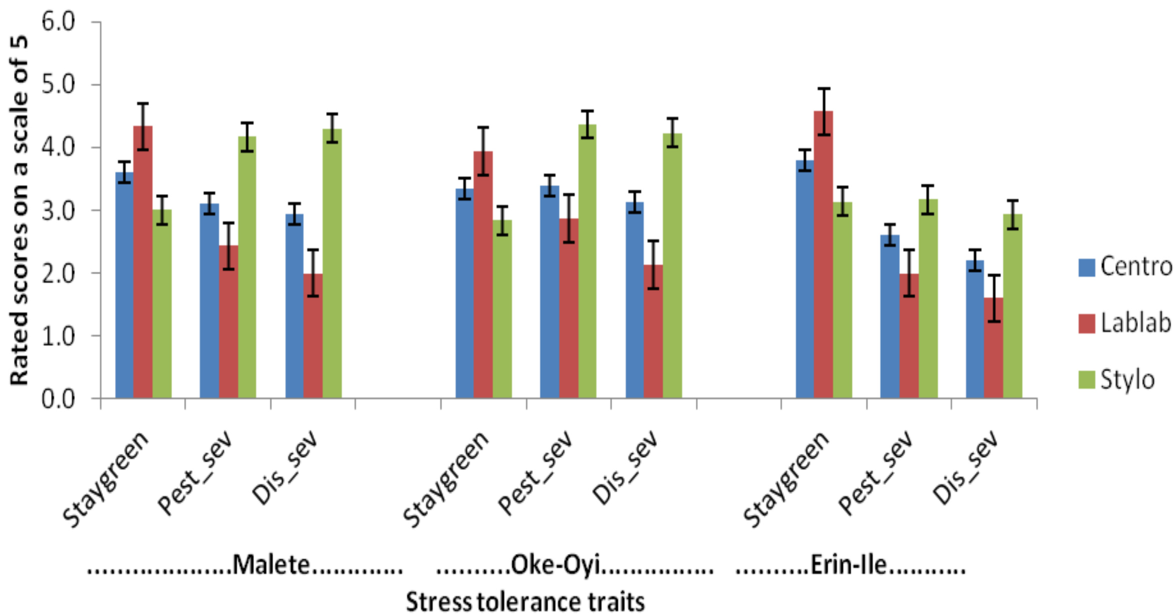

| LSD | 2WAP | 4WAP | 6WAP | 10WAP |
|---|---|---|---|---|
| **Malete** | 1.37 | 2.59 | 8.19 | 12.88 |
| **Oke-Oyi** | 2.23 | 3.29 | 8.23 | 23.63 |
| **Erin-Ile** | 2.00 | 2.39 | 9.00 | 18.57 |

**Figure 3.** Trends in number of branches at 2, 4, 6 and 10 WAP among forage legumes at each of the three locations.

**Table 1. Combined ANOVA for vegetative traits across three locations.**

| Source | Df | NLV2 | PH2 (cm) | NB2 | NLV4 | PH4 (cm) | NB4 | NLV10 | PH10 (cm) | NB10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Variety | 2 | 0.07 | 0.09 | 1.12 | 208.83** | 1128.97** | 31.72** | 3520.59** | 3249.27** | 320.7** |
| Replication | 2 | 0.37 | 0.38 | 0.06 | 9.12* | 2.61 | 0.40 | 86.62 | 2.49 | 8.01 |
| Env | 2 | 3.00* | 2.89** | 1.90** | 61.63** | 52.34** | 20.03** | 574.63** | 916.36** | 37.81** |
| Env*variety | 4 | 1.17 | 0.93* | 0.27 | 2.96 | 1.05 | 1.72* | 146.42 | 46.46 | 1.58 |
| Error | 16 | 0.61 | 0.24 | 0.17 | 1.53 | 7.38 | 0.48 | 58.75 | 16.15 | 2.39 |
| R-Square | | 0.54 | 0.73 | 0.73 | 0.96 | 0.95 | 0.94 | 0.90 | 0.97 | 0.95 |
| CV | | 9.74 | 6.87 | 8.89 | 6.46 | 11.10 | 10.04 | 8.66 | 6.98 | 9.41 |
| Root MSE | | 0.78 | 0.49 | 0.41 | 1.24 | 2.72 | 0.69 | 7.66 | 4.02 | 1.55 |
| Mean | | 8.05 | 7.10 | 4.61 | 19.16 | 24.46 | 6.88 | 88.49 | 57.54 | 16.43 |

*, ** =Significant at P<0.05 and 0.01 respectively PH, Plant height, NLV, NB number of leaves and branches respectively.




| LSD | Stay green | Pest severity | Disease severity |
|---|---|---|---|
| **Malete** | 0.96 | 0.79 | 0.30 |
| **Oke-Oyi** | 0.75 | 0.15 | 0.57 |
| **Erin-Ile** | 0.59 | 0.51 | 0.40 |

Pest_sev= pest severity, Dis_sev = disease severity, LSD= least significant difference

**Figure 4.** Variation in stress tolerance traits among legumes at each of the three locations.

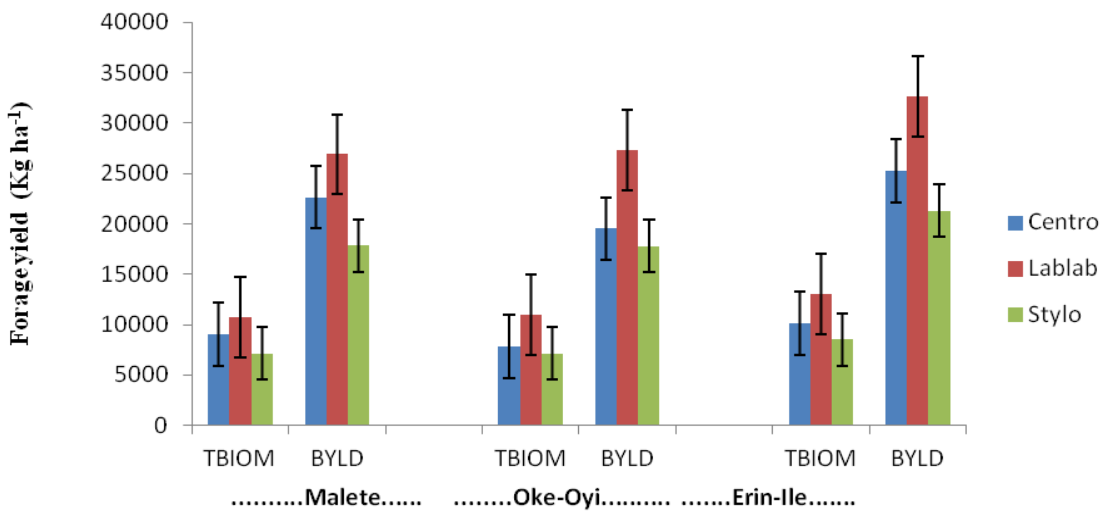
Table 4 shows that based on biomass yield, Stylo has the least AMMI stability value (ASV) and ranks best, followed by Lablab. However, yield stability index (YSI), which combined ASV and yield showed that Lablab ranks best with best biomass yield and good adaptation.

Table 5 shows that three principal components (PC) with Eigen values >1 accounted for 87% of the total variation. 67, 12 and 9% were percentages of the total variance attributable to the first three PCs. Biomass yield, number of leaves at 4 WAP, plant height at 4 and 10 WAP had the highest loading in PC1. Harvest index, seed yield and plant height at 2 WAP had the highest loading in PC2, while in PC3, number of leaves, branches and plant height at 2 WAP were most important.

**Table 2. Combined ANOVA for tolerance and yield traits across three locations.**

| Source | df | Stay green | Pest Severity | Disease severity | Days to flowering (days) | TBIOM x $10^4$(kg) | BYLD x $10^4$ (kg/ha) | Seed wt x$10^4$(kg) | EYLD x $10^4$ (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|
| Variety | 2 | 3.75** | 4.89** | 8.26** | 450.70** | 369769** | 23110** | 31.53** | 197.08** |
| Replication | 2 | 0.15 | 0.02 | 0.05 | 42.82** | 10513 | 657 | 0.23 | 1.41 |
| Env | 2 | 0.50* | 2.14** | 2.33** | 14.37 | 96591** | 6036** | 18.19** | 113.70** |
| Env*variety | 4 | 0.02 | 0.08 | 0.20** | 16.48* | 6186 | 386 | 14.01** | 87.57** |
| Error | 16 | 0.10 | 0.05 | 0.03 | 4.73 | 6948 | 434 | 0.48 | 3.02 |
| R-Square | | 0.85 | 0.95 | 0.98 | 0.93 | 0.00009 | 23110 | 0.0001 | 0.00095 |
| CV | | 8.69 | 7.30 | 6.21 | 4.17 | 0.0009 | 6036 | 0.0008 | 0.0008 |
| Root MSE | | 0.31 | 0.23 | 0.18 | 2.18 | 0.83 | 3.87 | 0.07 | 0.02 |
| Mean | | 3.61 | 3.12 | 2.83 | 52.15 | 0.93 | 6.57 | 0.83 | 2.10 |

*, ** =Significant at P<0.05 and 0.01 respectively, TBIOM= total biomass, BYLD= biomass yield, wt= weight, EYLD= Seed yield



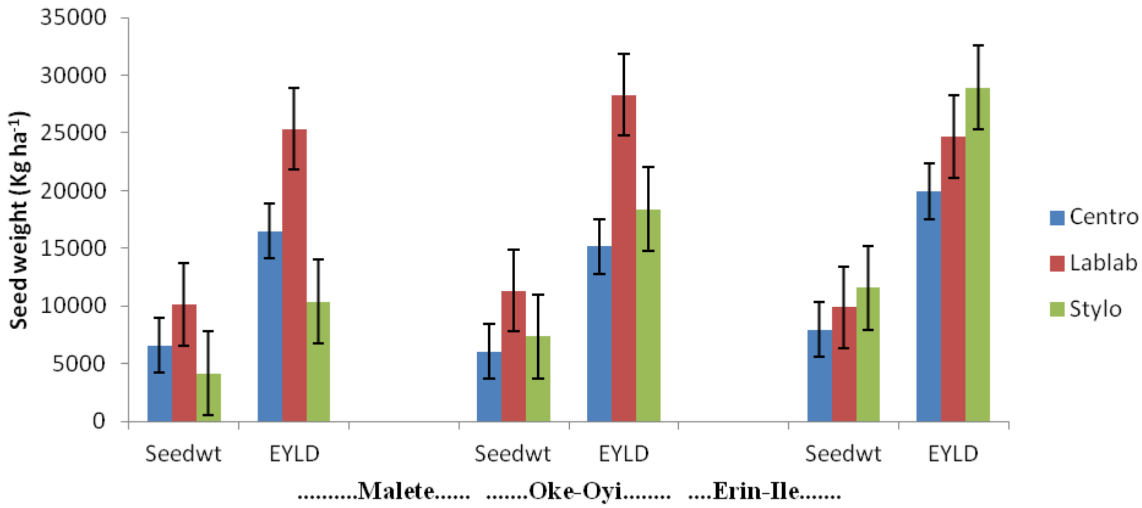

| **LSD** | **Total biomass (TBIOM)** | **Biomass Yield (BYLD)** |
|---|---|---|
| **Malete** | 957.39 | 2393.50 |
| **Oke-Oyi** | 2154.90 | 5387.20 |
| **Erin-Ile** | 2229.70 | 5574.30 |

**Figure 5.** Variation in forage biomass among legumes at each of the three locations.

**Table 3. AMMI Analysis for Biomass and seed yield among forage legumes.**

| **Source** | **df** | **SS x $10^5$** | **MS x $10^5$** | **% explained** | **SS x $10^5$** | **MS x $10^5$** | **% explained** |
|---|---|---|---|---|---|---|---|
| | | Biomass yield | | | Seed yield | | |
| **ENV** | 2 | 120.74 | 60.37** | 20.18 | 227.41 | 113.71** | 23.40 |
| **Variety** | 2 | 462.21 | 231.10** | 77.24 | 394.16 | 197.08** | 40.56 |
| **ENV*Variety** | 4 | 15.47 | 3.87 | 2.58 | 350.30 | 87.58** | 36.04 |
| **PC1** | 3 | 11.62 | 3.87 | 75.16 | 316.42 | 105.47** | 90.33 |
| **PC2** | 1 | 38.41 | 3.841 | 24.84 | 33.88 | 33.88** | 9.67 |
| **Residuals** | 18 | 82.62 | 4.59 | - | 51.26 | 2.85 | - |

** =Significant at P<0.01, PC= Principal component, SS= sum of square, MS= mean square, %- percentage




| LSD | Malete | Oke-Oyi | Erin-Ile |
|---|---|---|---|
| Seed weight (wt) | 1330.4 | 1864.4 | 1156.5 |
| Seed yield (EYLD) | 3326 | 466.09 | 2891.2 |

**Figure 6.** Variation in seed yield among legumes at each of the three locations.

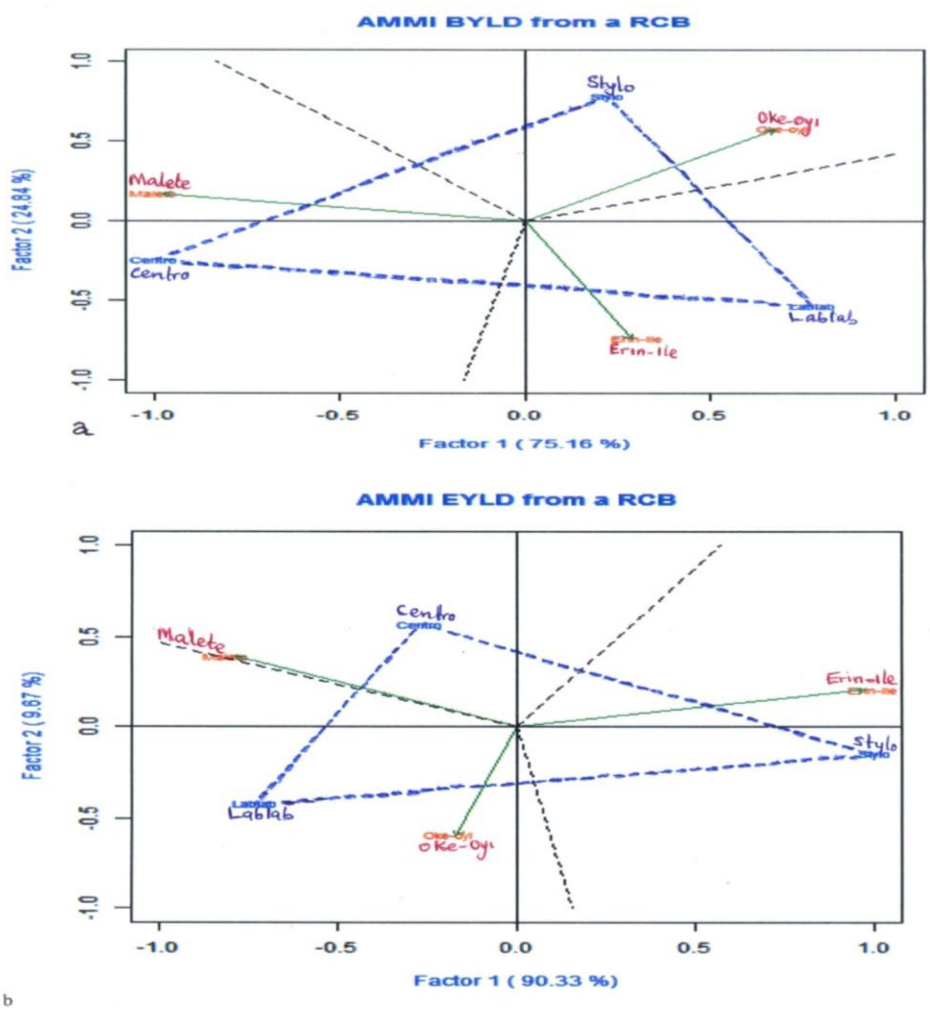



**Figure 7 (a-b).** AMMI incorporated with polygon for: (a) biomass yield and (b) seed yield.

**Table 4. Forage legumes ranking of biomass yield and seed yield using AMMI stability value (ASV), and yield stability index (YSI).**

| Forage Legumes | Yield (Kg/ha) | Rank (A) | PC1 score | PC2 Score | ASV | ASV rank (B) | YSI (A+B) | YSI rank |
|---|---|---|---|---|---|---|---|---|
| | | | | biomass yield | | | | |
| **Lablab** | 28948.69 | 1 | 0.78 | -0.54 | 2.41 | 2 | 3 | 1 |
| **Centro** | 22466.94 | 2 | -1.00 | -0.24 | 3.04 | 3 | 5 | 3 |
| **Stylo** | 18960.56 | 3 | 0.22 | 0.78 | 1.03 | 1 | 4 | 2 |
| | | | | seed yield | | | | |
| **Lablab** | 26111.9 | 1 | -0.27 | 0.57 | 6.85 | 3 | 4 | 1 |
| **Stylo** | 19224.53 | 2 | -0.73 | -0.42 | 3.06 | 2 | 4 | 1 |
| **Centro** | 17180.32 | 3 | 1.00 | -0.15 | 2.57 | 1 | 4 | 1 |

PC= principal component

**Table 5. Principal component analysis and Eigen vectors (loadings) of the first three principal components (PC) for investigated traits.**

| Factor | Eigen Value | Variance % | CumV % |
|---|---|---|---|
| 1 | 14.04 | 0.67 | 0.67 |
| 2 | 2.42 | 0.12 | 0.78 |
| 3 | 1.80 | 0.09 | 0.87 |
| Traits | PC1 | PC2 | PC3 |
| Days to 50% flowering (FWR) (days) | 0.1975 | -0.2021 | -0.1966 |
| Number of leaves at 2 WAP (NLV2) | 0.0717 | 0.1598 | 0.6099 |
| Plant height at 2 WAP (PH2) (cm) | 0.0756 | 0.3686 | 0.3124 |
| Number of branches at 2 WAP (NB2) | 0.1685 | -0.0066 | 0.4907 |
| Number of leaves at 4 WAP (NLV4) | 0.2543 | 0.0676 | 0.0172 |
| Plant height at 4 WAS (PH4) (cm) | 0.2518 | -0.0826 | -0.0941 |
| Number of branches at 4 WAP (NB4) | 0.2382 | -0.0149 | 0.1544 |
| Number of leaves at 10 WAP (NLV10) | 0.2442 | -0.0459 | -0.0055 |
| Plant height at 10 WAS (PH10) (cm) | 0.2584 | 0.0144 | -0.0012 |
| Number of branches at 10 WAP (NB10) | 0.2359 | -0.0924 | -0.2011 |
| Stay green (scored 1-5) | 0.2256 | -0.1682 | -0.1221 |
| Pest severity (scored 1-5) | -0.2454 | 0.0188 | -0.0464 |
| Disease severity (scored 1-5) | -0.2549 | 0.007 | 0.0245 |
| Total biomass (Kg) | 0.2502 | -0.0785 | 0.0712 |
| Biomass yield (Kg $ha^{-1}$) | 0.2502 | -0.0785 | 0.0712 |
| Seed weight (Kg) | 0.1836 | 0.423 | -0.1792 |
| Seed Yield (Kg $ha^{-1}$) | 0.1836 | 0.423 | -0.1792 |
| Harvest index | 0.0192 | 0.5966 | -0.2463 |

CumV= cumulative variance

Table 6 shows that biomass yield and seed yield are positively and significantly ($p < 0.05$) correlated with plant height, number of leaves and branches at 4 and 10 WAP, as well as stay green. Biomass yield was also positively and significantly ($p < 0.05$) associated with days to 50% flowering, However, both biomass yield and seed yield are negatively and significantly ($p < 0.05$) associated with pest and disease severity.

## DISCUSSION

The dynamics of climate change, population pressure and urbanisation have restricted the land available for crop farming, animal grazing and some other agricultural activities. As a result, agricultural intensification has been on the increase in addressing food insecurity. An impetus for agricultural intensification is quality seed. Likewise, feed insecurity for ruminants can be addressed by

**Table 6. Correlation analysis between investigated traits (including PCA identified traits).**

| Traits | FWR | NLV4 | PH4 | NB4 | NLV10 | PH10 | NB10 | Staygrn | Disev | BYLD | EYLD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FWR | 1 | 0.64** | 0.78** | 0.52** | 0.70** | 0.70** | 0.74** | 0.69** | -0.76** | 0.67** | 0.37 |
| NLV4 | | 1 | 0.91** | 0.84** | 0.84** | 0.92** | 0.84** | 0.79** | -0.91 | 0.85 | 0.69 |
| PH4 | | | 1 | 0.79** | 0.88** | 0.90** | 0.92** | 0.85** | -0.89** | 0.85** | 0.58** |
| NB4 | | | | 1 | 0.83** | 0.90** | 0.70** | 0.73** | -0.82** | 0.86** | 0.55** |
| NLV10 | | | | | 1 | 0.84** | 0.77** | 0.72** | -0.84** | 0.88** | 0.60** |
| PH10 | | | | | | 1 | 0.86** | 0.79** | -0.92** | 0.91** | 0.68** |
| NB10 | | | | | | | 1 | 0.83** | -0.84** | 0.79** | 0.55** |
| Staygrn | | | | | | | | 1 | -0.83** | 0.79** | 0.42* |
| Disev | | | | | | | | | 1 | -0.86** | -0.64** |
| BYLD | | | | | | | | | | 1 | 0.59** |
| EYLD | | | | | | | | | | | 1 |

**,* =Significant at P<0.05 and 0.01 respectively, FWR- days to 50% flowering, 4 and 10 are weeks after planting, PH, Plant height, NLV, NB number of leaves and branches respectively. BYLD= biomass yield, EYLD= Seed yield and staygren = stayreen

intensification of forage production through the cultivation of high yielding, adaptable and nutritious forage legumes. From the present study, *Lablab purpureus*, *Centrosema pubescens* and *Stylosanthes guianensis* had similar vegetative growth response in terms of plant height, number of leaves and number of branches at the inception of growth, to depict that there was latency in the genetic potential of each of the legumes. As growth progresses, the genetic potential of the different forage legumes became manifested (Caligari, 2001) to reveal the identity of the forage legumes, implying that there is opportunity for selection and improvement of these forage legumes through breeding (Lawal *et al*., 2020c). Similarly, *Lablab purpureus*, *Centrosema pubescens* and *Stylosanthes guianensis* have differential stay green potentials, hence, differential tendencies for their improvement with respect to stay green. Lablab, being the greenest at harvest, has higher concentration of chlorophyll (Monneveux *et al*., 2006) and Mg that is essential in animal nutrition. Also, higher stay green implied higher tolerance to the prevailing abiotic stress such as drought, heat/high temperature, low soil nitrogen (Bänziger *et al*., 2006), delayed senescence and greater potential of accumulating assimilate. Furthermore, *Lablab purpureus* was most luxuriant which could be as a result less incident of pest and diseases it showed, as pest and diseases are known to inhibit growth and development in plants (Aderolu *et al*., 2018) and hence herbage yield. More days to flowering recorded in *Lablab purpureus* implies that it is late maturing and hence, has more time to transfer photosynthate to the sink before senescence, as late maturing genotypes are usually more yielding than their early maturing counterparts (White *et al*., 1992, Lawal, 2020b). This is an important information for extension organizations, as it could guide pastoralist in the selection of appropriate forage varieties for herbage production. Variation in biomass and seed yield of forage legumes implied that the legumes have diverse genetic potential which can be exploited through selection and improved through breeding (Lawal, 2020b). Lablab was most yielding, thus, it is capable of providing feeding stuff for the ruminants. Cross over effect in seed yield was due to the significant interaction between genotype and environment (Patel *et al*., 2019) which implies that there was higher influence of environmental factors such as weather conditions, edaphic factors etc on seed yield. Significant genotype x environment complicates the effort of breeders and make selection of the best adaptable genotype difficult (Yayis, 2019; Lawal *et al*., 2020a). The large percentage of variation accounted for by principal components (PC) 1 and 2 implied that larger proportion of the variation is heritable, and hence can be improved. *Lablab purpureus*, *Centrosema pubescens* and *Stylosanthes guianensis* showed differing adaptation to different environments, thus, the presence of G x E, which results in specific adaptation for target environment. Significant G X E makes blanket recommendation of a variety to all test environments impossible. Breeding for target environments can limit feed and food security as it is tasking to achieve, but can remain about the only option in conventional breeding, when there is no generally adapted variety. More so, farmers cannot sow the same variety across different agro-ecologies. AMMI stability value (ASV) guides in selecting stable genotype, the lower its value the more adaptable and stable the genotype is (Farshadfar *et al*., 2011). *Stylosanthes guianensis* had the least ASV, hence, the most stable, followed by *Lablab purpureus.* Yield stability index (YSI) is a more robust measure of stability and yield (Adjebeng-Danquah *et al*., 2017) as it combines

ASV and yield. *Lablab purpureus* combined good adaptation with high yield, thus could be recommended for general adaptation across the rain forest and the savannahs. Loading in PC 1, 2 and 3 based on Eigen values showed the relative contributions of the traits to the total variation (Beiragi *et al*., 2012). Traits of concern in forage improvement are plant height at 10 WAP, number of leaves at 4 WAP and biomass yield. In addition, harvest index, seed yield and plant height, number of leaves and branches 2 WAP were also important. Similarly, Beiragi *et al*. (2012) used PCA analysis to identify important traits in some maize lines. Incidence of diseases was the most limiting constraint in production of forage legumes as it reduced or impaired growth by limiting number of leaves, number of branches, plant height, stay green and consequently seed yield and forage yield. This is similar to the report of Aderolu *et al*. (2018) on maize. Maturity had positive influence on vegetative growth and yield. The higher the days to maturity, the more luxurious and vigorous the legumes were and the higher the yield. In addition, taller plants had more leaves and branches, matured late and higher yielding. Biomass yield in forage legumes could be enhanced through luxuriant growth of vegetative characters (Maleko *et al*., 2019), and delayed maturity (as it gives more room for the accumulation of assimilate in the sink) (White *et al*., 1992, Lawal, 2020), delayed senescence and reduced incidence of diseases.

## CONCLUSION

*Lablab purpureus* is a valuable forage legume that can be adopted and cultivated for feeding large animals as nomads transform from crises-ridden nomadic grazing to the proposed ranching or sedentary animal husbandry. It is recommended that Extension agents should encourage pastoral farmers to adopt Lablab for forage production.

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