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Characterization of morphometric, physiological and biomass production in local maize (*Zea mays* L.) landraces of Sri Lanka

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***Abstract*—**A field trial was conducted with the aim of identifying maize germplasms which confer increased productivity along with resistance against fall armyworm *Spodoptera frugiperda* (Smith) infestation. Seventeen local maize landraces were collected from Ampara, Moneragala and Badulla districts and denoted as South Eastern University of Sri Lanka (*SEU*) collections. These were subsequently planted at Agrotech Park, Malwatta (DL2b) in yala 2020, and the responses were compared with Pacific-999. The results revealed that several landraces naturally possessed improved morphological, physiological, and yield traits. Early flowering was found in *SEU1* compared to variety *Pacific-999*. Similarly, *SEU14* showed improved cob dry weight (112.34 ± 22.13g) and the highest number of kernels per row (33.60 ± 2.63) while, *SEU9* recorded significantly higher LAI (1.79 ± 0.30) at the tasseling stage. The natural resistivity against fall armyworm was found to be higher in *SEU14*, *SEU15*, and *SEU16*. Cluster analysis revealed that three distinct groups of landraces were found while *Pacific-999* stands on its own. The novel traits found in this germplasm could be further confirmed through detailed photosynthetic and biomass trials with molecular marker-assisted selection. Once the traits are reaffirmed, they could be introgressed through maize plant breeding programs.

***Keywords*—**Fall armyworm, Landraces, Maize, Morphology, Physiology

I. Introduction

Maize (*Zea mays* L.) is a widely cultivated crop in many parts of the world because of its versatility, extensive adaptability, and resource use efficiency. It is one of the world's most important crops for food security, domesticated for human utilization as well as animal farming (Lana *et al.*, 2017). Maize is grown in varied environmental conditions both in the tropical and temperate regions which naturally follows an outcross pathway thereby causing wider variations in both phenotypically and hereditary traits within plant genomes (Rather *et al.*, 2003). As a result, a wide genetic diversity in growth, development, and grain filling has been reported such changes are some of the driving force for developing new genotypes with favorable maize traits (Betrán *et al.*, 2003). Typically, a landrace is described as an old populace of a well-developed crop that has been adjusted to the local conditions and the agronomic practices of farmers (Palumbo *et al.*, 2017). Recent evidences suggest that there are about 697 maize germplasm accessions in Sri Lanka and among them, 35 germplasms are landraces (PGRFA, 2008). However, the trait for morphology, physiology, and biomass variations of these accessions have been poorly understood.

Leaf photosynthesis exerts greater control on biomass production and grain yield when variation in factors such as dry matter partitioning, nutrient responsiveness and leaf area index (LAI) are minimized (Long *et al.*, 2006, Shanbao *et al.*, 2009). The cereal varieties released after 1980 is more closely correlated with an increase in biomass than with an increase in harvest index (Peng *et al.*, 2000). In terms of photosynthesis, maize plants follow the C_4 pathway which exhibits superior photosynthetic and biomass production than the C_3 counterpart plants such as rice, wheat, and barley. The primary reason for these characteristics is due to the suppression of photorespiration supported by unique leaf anatomy (Kranz-anatomy). However, recent findings have suggested that large variations exist in carbon concentrating mechanisms within the C_4 species (Edwards *et al.*, 2007). As such, the efficient photosynthetic rates and ability to fix CO_2 may vary among the landraces in such a way the production of biomass and yield derived from a unit land area is impacted. Moreover, photosynthetic efficiency of a plant depends on light interception which has been determined by the architecture of the canopy (Monsi *et al.*, 2005) whereby the leaf orientations, leaf angle, plant height, position and number of ears and tassel *etc*, which are important characters that determine the amount of light interception by a crop canopy. Therefore, maintaining an optimal canopy is essential in obtaining ideal rates of photosynthesis and subsequent carbohydrate mechanisms within the plants. The phenology such as days to 50% anthesis, days to 50% silk emergence, days to maturity are instrumental whereas the total biomass accumulation in crops depends on the length of the growing season and the crop growth rates. Thereby the maize germplasms can be characterization based on the above morphology and phenological variations (Radhouane, 2004). Moreover, yield variations among the maize germplasms for traits such as above-ground biomass, cob weigh and 1000-kernel weight have been reported (Muchie Fentie, 2016; Odeleye Odeleye, 2001). Maize grain yield is highly correlated with the total number of kernels per unit of the ground area filled at harvest time. The final number of filled kernels depends on the plant growth rate, mainly at the critical sensitive period around flowering time (Andrade *et al*. 2000). Kernel number has been closely related to the amount of assimilation at the time of the seed set (Zinselmeier *et al*. 1999), availability of assimilating and higher photosynthetic activity at the ear leaf-level could be important in the determination of final kernel numbers (Hammer *et al*. 1997). The interception of photosynthetically active radiation (PAR) during the first 30 days of flowering is a crucial factor while the development of kernel occurred at the topmost ear of the plant (Andrade *et al*., 2000). The biomass accumulation further accelerates when the relative proportion of biomass accumulation increases during and after anthesis and mobilizes assimilates to the grain after anthesis (Ludlow Muchow, 1990; Oaks, 1994). Apart from the plant morphological and physiological characteristics, plant breeders need to focus on the avenues on biotic and abiotic stresses exerted in the environment. More importantly, maize cultivation has been severely affected by the Fall Armyworm (FAW) *Spodoptera frugiperda* (Smith) particularly in 2018, the pest itself invaded across the major maize growing areas, which threatened the cereal production in Sri Lanka. Therefore, this study aims to investigate the characteristics of selected local maize germplasms for their morphological and physiological characteristics and their relationship with the biomass production about the resistance against fall armyworm infestation.

II. Methodology

A. Study area

The field experiment was conducted in the research farm, Agro Tech Park, Malwatta (7°20'N and 81°44'E; altitude 16.0 m above sea level), the South Eastern University of Sri Lanka, located in Ampara district (DL_{2b}) during January to June 2020. A total of 17 maize landraces and commercial elite hybrid maize variety *Pacific- 999* were evaluated to compare the morphological, physiological, and yield variabilities. The landraces were previously collected from three prominent maize growing districts viz Ampara, Moneragala and Badulla with them, the experiment was laid out as a randomized complete block design (RCB) with three replicates. Seeds were planted with a spacing of 30cm x 60cm in which Fifty plants in each plot (10m x 0.9m) were managed supplying recommended cultivation practices for maize by the Department of Agriculture (DOA), Sri Lanka. Harvesting was carried out at the stage of physiological maturity of maize which is indicated by the formation of the black layer at the base of the kernel (Joe Lauer, 1994).

1) Plant morphological measurements:

   The morphological characteristics data such as the leaf development rates (LDR) were recorded from 1 week after planting (WAP) to tasseling stage. The number of days taken for 50% flowering (tasseling) was recorded for each landrace. Then the plant height (HPL) was measured from the ground level to the base of the tassel. Consequently, the height at the base of the superior ear leaf (HEA), stalk diameter (DIA) at the height of 5 cm above the ground level using a Vernier calliper (LC = 0.02) were also measured. After the emergence of superior ear shoots, the length and the maximum width of the ear leaf (ELL, ELW) and in flag leaves (FLL, FLW) examined. Consequently, the ratio of HEA/HPL was calculated for each landrace. Then the indices of dry matter (DMI) were estimated using $DMI = HPL \times DIA^2$ as previously described by Louette Smale, (2000).

2) Plant physiological parameters:

   Chlorophyll content was estimated using chlorophyll meter (SPAD 502, Konica Minolta, USA) which was recorded in Soil-Plant-Analysis-Development (SPAD) units. Three readings near the leaf base, middle of the leaf, and at the leaf tip (excluding the midrib) were taken from the superior ear leaf and the flag leaf of randomly selected 10 plants of each germplasms. Furthermore, photosynthetically active radiation (PAR) and leaf area index (LAI) were measured with a ceptometer (AccuPAR, LP- 80, Meter Group Inc, USA) at the tasseling stage. The external PAR sensor was used to measure the above canopy light level, while the below canopy light levels were taken at 5 cm above the ground level. At least 8-10 measurements per plot were made on the cloudless clear sky between 10.30 am and 1.30 pm to minimize the proportion of diffuse radiation into the plant canopy. Then the Leaf Area Index (LAI) was estimated based on the ratio of the two PAR levels. Moreover, chlorophyll fluorescence parameters such that quantum yield (Qy) in 10 randomly selected light adopted flag leaves was measured by employing a Fluorpen (FP 100, Photon Systems Instruments, Czech

Republic). In addition, the natural resistivity against the fall armyworm was compared by visually counting the damages caused by FAW on the leaf foliage among the tested germplasms before spraying the insecticides.

3) Yield parameters:

Five randomly selected cobs were harvested from each plot to measure detailed parameters. The ear length (EAL), ear weight (Ewt), and cob weight (Cwt) at 18% moisture content were measured. Subsequently, the number of kernel rows per cob (RN) and the number of individual kernels per row (KR) were counted. Furthermore, the total numbers of kernels were estimated by KR × RN (Louette and Smale, 2000). Finally, grains were separated from the cobs and eventually weight of the 100 kernels (Kwt) was measured.

4) Data Analysis:

Data analysis was performed using SPSS (version 25.00) software. The Analysis of Variance (ANOVA) was carried out to test the significant ($p<0.05$) variation among tested landraces. Dunnet test was performed ($p<0.05$) to explore the mean differences between the treatments.

III. Results and Discussion

A. Morphological characteristics

The plant morpho-physiological and yield component of selected landraces were analyzed along with the commercial elite hybrid maize variety *Pacific- 999*. The results revealed hat the mean values of most of the traits were significantly (p¡0.05) different compared with the controlled variety (Table 01). The rate of leaf development per week was compared among all landraces. The highest rate was reported in *SEU7* while the landrace *SEU 17* had the lowest rates. Despite these observations, the *SEU14* and *SEU9* had moderate leaf development rates (Fig 1a).

The trait of 50 percent tasseling indicated that the variety *Pacific-999*, required 66 days, whereas other tested landraces required a lower number of days (Fig 1b). *SEU1* had the significantly ($p<0.05$) earliest flowering character whereby required 57 days. This variation could be viewed as the persistence of diverse the genetic makeup among tested landraces even though other field conditions is maintained at optimum for tested germplasms (Idikut Kara, 2011).

The mean plant height (HPL) of the germplasm showed that *SEU17* (185.5 ± 5.35 cm) was the tallest among the tested landraces whereas *Pacific- 999* (119.4 ± 4.15 cm) was the shortest (Fig. 2a). Furthermore, the mean plant height of all other landraces was 157.48 ± 5.27 cm. According to Abdel-Ghani et al. (2016), plant height is a heritable character which is closely associated with plant density. Moreover, the plant height correlates with grain yield of the plant as the high yield was observed in medium height maize plants (Fernandez *et al*., 2009). Further, HEA/HPL was compared where superior ear height is the crucial factor for breeding purpose. The present study found that the HEA/HPL ratio of maize landraces beside *SEU15* was significantly ($p<0.05$) higher compared to *Pacific-999*. Furthermore, the mean HEA/HPL ratio of landraces was 0.51 ± 0.02, and the highest and lowest ratios were shown by *SEU17* (0.57 ± 0.01) followed by *SEU15* (0.42 ± 0.02) (Fig. 2c). It is probable that the lower ear length affects the final yield of maize (Bicer, 2018).

The stem diameter is significantly affected by the genotypic variation. The present study revealed that the stalk thickness of *SEU13*, *SEU16* and *SEU17* were significantly higher ($p<0.05$) than *Pacific-999*. The thickest stalk was observed in *SEU3* (2.16 ± 0.08 cm), whereas the thinnest was exerted in *SEU16* (1.63 ± 0.07 cm) (Fig. 2b). This result is contrary to the findings of Yilmaz *et al*. (2007) observed that the stem diameter of hybrid maize varieties was significantly higher in comparison to traditional landraces.

In addition, dry Matter Indices (DMI) is a crucial factor when evaluating drought resistance of varieties. Previous studies revealed that the dry matter partitioning was higher for kernels as such, 40- 49 % of dry matter retains in the kernel which is initiated as a small portion of dry matter translocated before the silking period (Khan *et al*., 2017). In other terms, dry matter accumulation initiates at silking and the rest occurs during grain filling in hybrids in short-duration varieties (Bodnár *et al*., 2018).

The present study further confirmed that the tested landraces had possessed significantly higher DMI compared with the variety Pacific-999 hybrid which had the lowest DMI (257.21 ± 28.33 cm3) and it was not significantly different from *SEU1*, *SEU15*, and *SEU16* landraces ($p<0.05$) (Fig. 2d).

The flag leave characteristics were revealed. The landraces *SEU8*, *SEU14* and *SEU17* had displayed significantly different ($p<0.05$) compared with control. Similarly, most of the landraces produced significantly ($p<0.05$) wider ear leaves (Table 01), while commercial hybrid *Pacific-999* reported the narrowest flag leaf (6.36 ± 0.19 cm) and ear leaf (3.36 ± 0.18 cm). Furthermore, *SEU8* and *SEU9* reported significantly ($p<0.05$) higher ELL and FLL compared with *Pacific-999*. Among them, *SEU9* possessed the widest ear leaf (8.37 ± 0.18 cm) and the largest flag leaves with 41.96 ± 3.16 cm length and 5.03 ± 0.44 cm width respectively.

It can be argued that in maize, larger uppermost leaves including flag leaves has exert greater control in photosynthe-

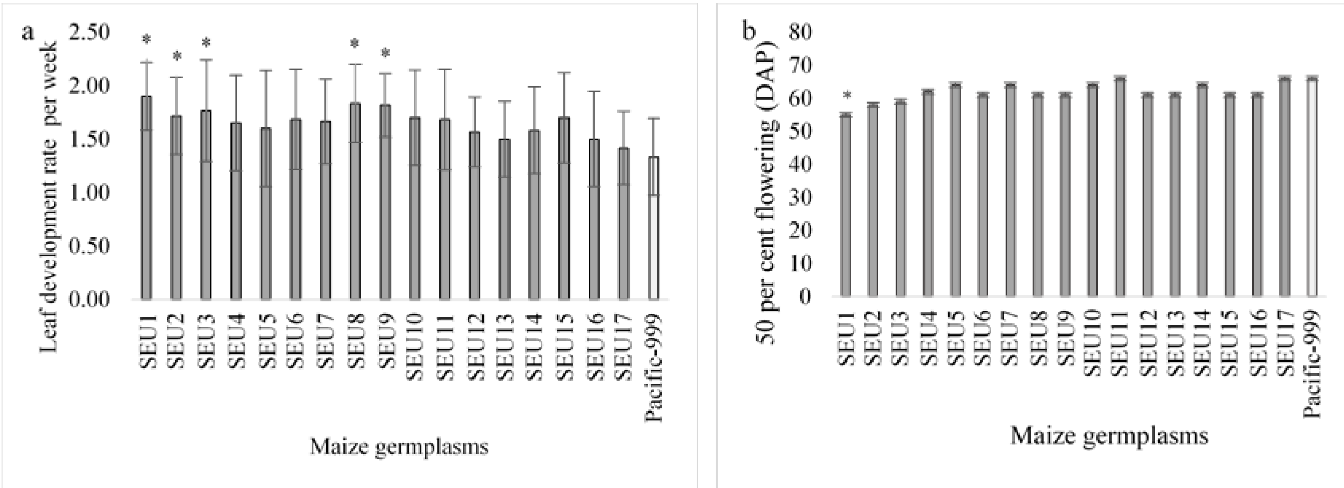

Fig. 1. **Leaf development rates and number of days taken for 50% flowering in maize landraces** (a) mean number of leaves emerged per week from randomly selected plants (n = 10) (b) days needed for 50% of tasseling of each germplasm (n = 15). Lines on the bars indicate the standard error. The symbol (*) indicates significant differences between the corresponding landrace and *Pacific-999* (p-value$<$0.05).

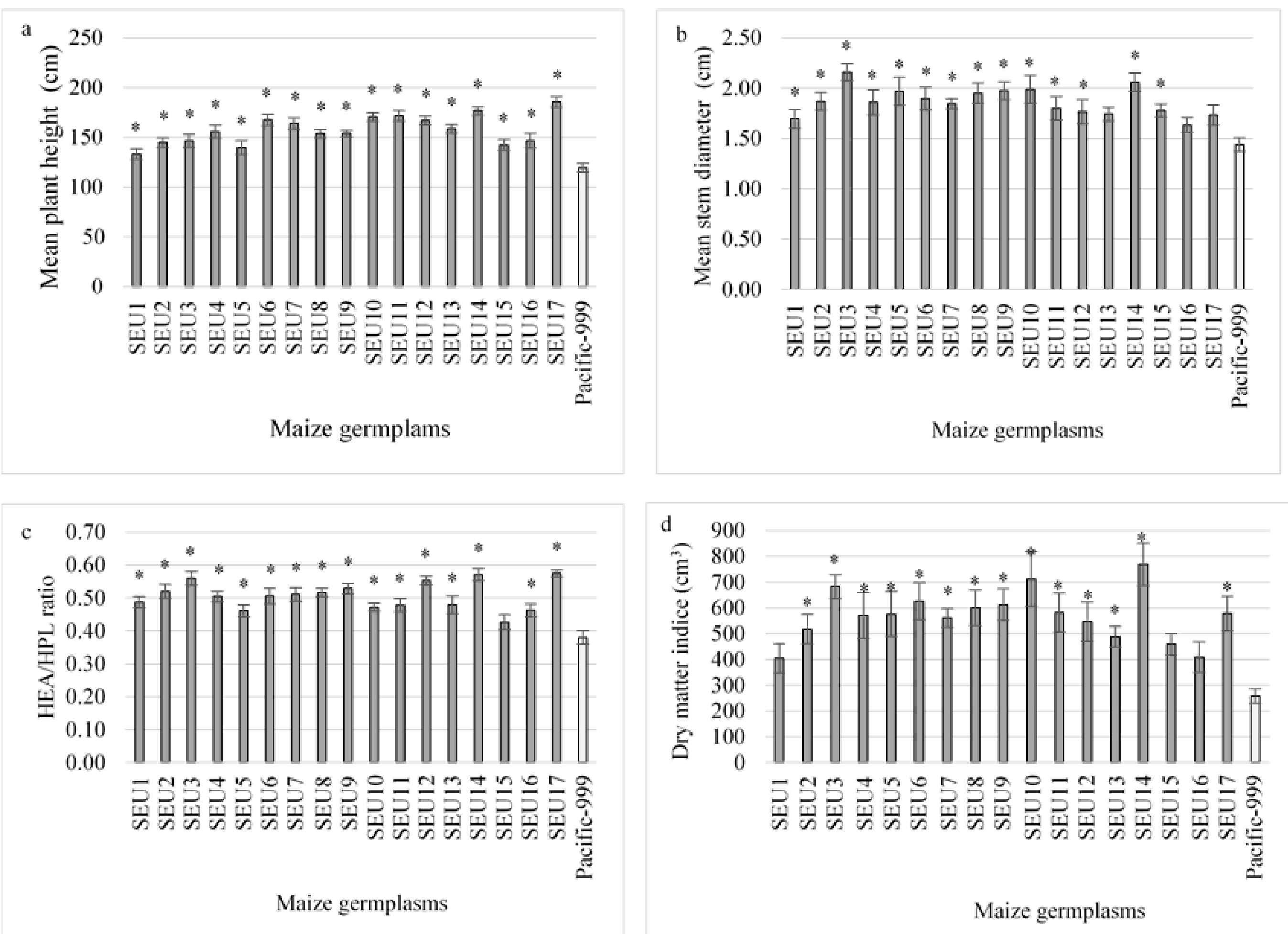

Fig. 2. **Plant height, average stem diameter, HEA/HPL ratio and dry matter indices of maize landraces** (a) Total plant height from ground level to base of flag leaf blade (n = 10). (b) Mean of the two perpendicular stem diameters at the 5 cm above the ground level (n = 10). (c) The proportion of the height of the plant at superior ear cob to total plant height (n = 10). (d) Indices calculated using stem diameter and the total height of the plant. Lines on the bars indicate the standard error. The symbol (*) indicates significant differences between the corresponding landrace and *Pacific-999* (p-value$<$0.05). .

sis rate and grain filling (Liu *et al*., 2015). It is probable that longest and widest leaf plays a major role in the absorption of sunlight which indicate the tested landraces possessed better leaf characteristics are comparable with the elite hybrid maize varieties, this aligns with the findings of Bänziger *et al*., (2000).

B. Physiological characteristics

The present study revealed that the LAI had showed significant ($p<0.05$) variations among landraces and the mean LAI of *SEU9* (1.79 ± 0.3) was significantly higher than *Pacific-999* at tassling stage (Table 02). In contrary, *SEU11* (0.45 ± 0.15), *SEU12* (0.5 ± 0.132) and *SEU13* (0.64 ± 0.19) possessed lower LAI than the *Pacific-999*.

It is widely agreed that LAI is a factor that plays an important role in both quantitative and qualitative features in plant yield (Breda, 2003). In general, the LAI tends to increases from seed germination up to the silking or tasseling stage then subsequently declines at post-anthesis stages (Tajul *et al*., 2013). Here, the LAI was measured at the tasseling stage aiming to obtain the maximum levels that a maize plant can attain. This observation can be correlate with the light interception required to induce photosynthesis in leaves. According to Hossain *et al*. (2014) claims that the higher amount of PAR interception occurs from vegetative to pre-flowering stages then after flowering PAR interception becomes reduced. The interplay between light and the photosynthesis depends on the light harvesting complexes of the chlorophyll pigment molecules present within chloroplast organelles of plant cells. This can be reflected b measuring the chlorophyll content in the leaves.

The chlorophyll content (in SPAD values) of flag leaves were significantly ($p<0.05$) vary among the landraces. SUE5 had the highest content in the flag and superior ear leaf while *SEU17* (31.26 ± 1.54) reported the lowest SPAD value (Table 02). Our results are in agreement with the findings of Kizilgeci (2018) who reported that SPAD values varied from 37.8 to 70 SPAD units in maize landraces collected from the Black Sea Region of Turkey. The chlorophyll content in leaves and green plant tissues is accountable for the primary determinant of yield through inducing photosynthesis thus it is proposed as a property that enhances productivity in plants (Ghimire Timsina, 2015). Furthermore, the ultracellular level reaction can be further elaborated by measuring the quantum yield of photosystem II (PSII) embedded in the thylakoid membranes within the chloroplasts. The light energy absorbed by chlorophylls associated with PSII can be used to drive photochemistry (Batra *et al*., 2014).

The present study further revealed that the chlorophyll fluorescence was significantly different ($p<0.05$) among the landraces whereas the highest and the lowest readings were observed in *SEU6* (0.71 ± 0.01) and *SEU5* (0.59 ± 0.02) respectively. Commercially grown *Pacific- 999* hybrids showed 0.69 ± 0.01 which was lower than the *SEU6*. This reveals that PSII system of *SEU6* had the greater quantum yield efficiency than the other tested landraces. However, in contrary, *SEU3* (0.61 ± 0.02) and *SEU5* (0.59 ± 0.02) showed significantly lower chlorophyll fluorescence value than the *Pacific-999*.

C. Yield Components

The present trial was focused on yield component traits such as EAL, Ewt, RN, KR and Kwt were measured. The results indicate that there were significant ($p<0.05$) variations among landraces. Cobs of *SEU14* (112.34 ± 22.13 g) were the weightiest followed by *SEU16*, *SEU2*, *SEU8* and *SEU1*. Meanwhile 100-kernel weight was highest in *SEU16* (33.12 ± 0.26 g). In contrary, kernel weight (Kwt) was higher in *SEU14*, (423.60 ± 56.26 g) followed by *SEU2*, *SEU7*, *SEU12*, *SEU13* and *SEU16* respectively (Table 3).

The evidence suggests that the yield component of maize and in other cereals are determined by several factors primarily, the inherent genetic factors contributes the most that possessed within plants. Once the yield traits are greater next the environmental conditions which maintained for cropping area particularly the water supply, is paramount in determining grain yield under the ideal fertilizer rates (Băşa *et al*., 2016).

During our field trial, all maize landraces were provided with the optimal agronomic conditions from seedling establishment up to the harvesting stage. Therefore, the variations found among data exerted by the genetic diversity among landraces. According to Carvalho *et al*. (2017) reported that phenotypic, genetic, and environmental factors positively correlate with the grain yield and grain weight per ear, and the grain yield and number of kernels per row in a cob was mostly influence in the heritability. Therefore, the influence of genotype is significant in determining the cob weight when the other field conditions are optimal.

TABLE I

LEAF AND COB CHARACTERISTICS OF MAIZE LANDRACES

Maize germplasms	WLE (cm)	ELL (cm)	NLE (Nos)	NE (Nos)	FLL (cm)	FLW (cm)
SEU1	6.92 ± 0.29	68.80 ± 3.63	6.30 ± 0.26	1.20 ± 0.13	27.18 ± 2.83	3.71 ± 0.26
SEU2	7.16 ± 0.22	77.41 ± 2.58	6.80 ± 0.24	1.50 ± 0.22	31.05 ± 2.80	3.47 ± 0.32
SEU3	8.17 ± 0.30*	79.54 ± 2.55	6.00 ± 0.15	1.90 ± 0.23	39.30 ± 2.87	4.34 ± 0.31
SEU4	7.12 ± 0.37	78.50 ± 4.87	6.10 ± 0.18	1.60 ± 0.22	36.66 ± 3.91	3.81 ± 0.33
SEU5	7.31 ± 0.44	77.52 ± 4.67	5.90 ± 0.23	1.80 ± 0.33	36.93 ± 2.52	3.79 ± 0.28
SEU6	7.46 ± 0.26	82.35 ± 4.14*	6.80 ± 0.20	2.40 ± 0.34*	38.78 ± 6.00	3.81 ± 0.37
SEU7	7.16 ± 0.12	80.40 ± 4.52*	6.50 ± 0.25	2.20 ± 025	38.35 ± 2.93	4.24 ± 0.23
SEU8	8.31 ± 0.28*	81.70 ± 2.94*	6.40 ± 0.25	2.20 ± 0.25	41.70 ± 2.41*	4.77 ± 0.24
SEU9	8.37 ± 0.18*	79.90 ± 2.58*	6.20 ± 0.20	2.50 ± 0.27*	41.96 ± 3.16*	5.03 ± 0.44*
SEU10	7.65 ± 0.36	87.00 ± 2.99*	7.30 ± 0.36*	2.40 ± 0.27*	36.50 ± 2.73	3.94 ± 0.33
SEU11	6.92 ± 0.28	80.90 ± 3.19*	7.10 ± 0.27	2.10 ± 0.18	36.30 ± 4.02	3.92 ± 0.52
SEU12	7.44 ± 0.45*	71.00 ± 2.54	6.00±0.21	1.78 ± 0.15	37.25 ± 2.69	4.54 ± 0.48
SEU13	7.29 ± 0.39	75.40 ± 2.84	7.00 ± 0.45	1.70 ± 0.21	30.80 ± 1.88	3.82 ± 0.34
SEU14	8.08 ± 0.41*	70.00 ± 2.24	6.40 ± 0.16	2.50 ± 0.17*	35.25 ± 2.45	4.58 ± 0.46
SEU15	7.16 ±0.46	65.40 ± 2.55	6.20 ± 0.13	1.80 ± 0.20	30.95 ± 2.41	3.68 ± 0.30
SEU16	7.73 ± 0.31*	76.70 ± 3.74	6.30 ± 0.21	1.67 ± 0.17	31.30 ± 2.17	3.72 ± 0.39
SEU17	8.11 ± 0.24*	81.50 ± 1.80*	6.10 ± 0.18	1.90 ± 0.28	40.15 ± 1.89	4.63 ± 0.19
Pacific-999	6.36 ± 0.19	66.80 ± 3.43	6.20 ± 0.13	1.40 ± 0.27	29.30 ± 1.03	3.36 ± 0.18

WLE: Width of year leaf, ELL: Ear leaf length, NLE: Number of leaves above the superior ear, NE: Number of ears, FLL: Flag leaf length and FLW: Flag leaf width. The symbol (*) indicates significant differences between corresponding maize landrace and *Pacific-999* (p value < 0.05). The values correspond to the average of each parameter ± SE (n=10).

TABLE II
VARIATIONS IN PHYSIOLOGICAL TRAITS AMONG MAIZE LANDRACES

Maize germplasms	LAI	Chlorophyll content at EL (SPAD units)	Chlorophyll content at FL (SPAD units)	Qy at FL
SEU1	1.17 ± 0.20	48.78 ± 1.85	44.22 ± 3.32	0.65 ± 0.02
SEU2	1.29 ± 0.18	51.36 ± 1.75	42.55 ± 1.47	0.64 ± 0.03
SEU3	1.53 ± 0.16	52.67 ± 2.27	42.59 ± 2.43	0.61 ± 0.02*
SEU4	1.37 ± 0.15	53.19 ± 1.76	41.22 ± 3.16	0.63 ± 0.025
SEU5	1.18 ± 0.10	54.44 ± 2.03	46.18 ± 1.94	0.59 ± 0.02*
SEU6	1.45 ± 0.27	50.33 ± 1.62	38.41 ± 1.71	0.71 ± 0.01
SEU7	1.49 ± 0.28	47.72 ± 1.12	41.02 ± 1.87	0.70 ± 0.01
SEU8	1.64 ± 0.19	46.87 ± 2.30	37.33 ± 2.80	0.63 ± 0.03
SEU9	1.79 ± 0.30*	50.04 ± 2.10	41.37 ± 3.16	0.68 ± 0.02
SEU10	1.61 ± 0.18	46.58 ± 1.42	38.62 ± 2.01	0.65 ± 0.01
SEU11	0.45 ± 0.15	47.32 ± 2.08	40.80 ± 1.32	0.67 ± 0.01
SEU12	0.5 ± 0.14	48.72 ± 2.12	34.08 ± 1.67	0.65 ± 0.02
SEU13	0.64 ± 0.19	45.83 ± 2.08	43.55 ± 2.43	0.63 ± 0.01
SEU14	1.31 ± 0.30	52.97 ± 1.94	37.23 ± 2.36	0.65 ± 0.01
SEU15	1.11 ± 0.19	43.11 ± 2.41	38.82 ± 2.74	0.66 ± 0.01
SEU16	1.46 ± 0.23	50.14 ± 1.47	36.68 ± 2.57	0.67 ± 0.01
SEU17	1.12 ± 0.10	50.34 ± 1.75	31.26 ± 1.54	0.67 ± 0.02
Pacific-999	0.80 ± 0.17	47.92 ± 1.72	37.31 ± 2.92	0.69 ± 0.01

LAI: Leaf area index, EL: Ear leaf, FL: Flag leaf and QY: Quantum yield. The symbol (*) indicates significant differences between corresponding maize landrace and *Pacific-999* (p-value < 0.05). The values correspond to the average of each parameter ± SE (n=10).

Next, the hierarchical cluster analysis was performed by incorporating the data of morphological, physiological, and yield traits. The resulting dendrogram from the origin of the height of the class showed that three groups of landraces were identified based on the minimum similarity level of 49.07% (Fig. 3). Although maize landraces collected from the same regions, they were resulted into different clusters owing to their genotype variations.

TABLE III
YIELD CHARACTERISTICS OF MAIZE LANDRACES

Maize germplasms	EAL (cm)	EWt (g)	RN (Nos)	KR (Nos)	Kwt (g)
SEU1	23.38 ± 2.01	96.78 ± 7.63	10.80 ± 1.01	25.60 ± 2.69	28.10 ± 0.92*
SEU2	24.70 ± 1.98	120.05 ± 10.76*	13.60 ± 0.50	30.80 ± 3.39	31.08 ± 0.99*
SEU3	28.94 ± 1.69*	92.09 ± 4.07	10.80 ± 0.66	26.60 ± 1.91	29.38 ± 1.13*
SEU4	26.12 ± 1.14	83.00 ± 8.20	10.20 ± 0.20*	27.40 ± 1.40	26.08 ± 0.99*
SEU5	38.12 ± 177*	98.21 ± 2.62	10.00 ± 0.31*	23.00 ± 1.67	29.38 ± 1.52*
SEU6	26.78 ± 1.29	83.71 ± 6.17	11.60 ± 0.50	27.20 ± 1.39	32.84 ± 0.25*
SEU7	24.92 ± 1.78	95.73 ± 12.79	12.60 ± 0.67	28.00 ± 3.88	29.00 ± 2.61*
SEU8	25.40 ± 1.37	84.56 ± 13.09	11.80 ± 0.80	26.80 ± 1.46	27.06 ± 1.55*
SEU9	28.38 ± 2.81*	66.25 ± 6.11	10.40 ± 0.24	27.20 ± 1.65	32.90 ± 5.5*
SEU10	25.28 ± 1.25	95.05 ± 11.85	11.40 ± 0.50	28.80 ± 1.24	29.32 ± 3.90
SEU11	30.50 ± 2.67*	78.39 ± 5.69	11.40 ± 0.24	27.00 ± 1.67	19.64 ± 4.74
SEU12	26.56 ± 1.25	57.42 ± 3.34	13.20 ± 0.58	30.40 ± 0.92	20.26 ± 2.14
SEU13	25.88 ± 0.47	64.77 ± 1.73	12.60 ± 0.50	32.40 ± 1.20*	25.50 ± 0.58*
SEU14	27.20 ± 1.44	142.59 ± 13.54*	13.80 ± 0.80	33.60 ± 2.63*	23.43 ± 1.37
SEU15	23.28 ± 1.44	86.54 ± 6.69	11.40 ± 0.67	27.60 ± 3.69	25.38 ± 1.70*
SEU16	24.32 ± 0.80	119.70 ± 12.02*	12.20 ± 0.37	29.20 ± 0.73	33.12 ± 0.26*
SEU17	30.36 ± 3.53*	99.15±12.57	11.60 ± 0.50	28.40 ± 0.50	27.19 ± 0.97
Pacific-999	21.40 ± 0.65	71.52±4.85	12.8 ± 0.58	22.60 ± 1.50	15.00 ± 0.70

EAL: Length of the ear, Ewt: Weight of an ear, Cwt: Weight of a cob RN: Number of kernel's row, KR: Number of kernels per row and Kwt: Weight of 100 kernels. The symbol (*) indicates significant differences between corresponding maize landrace and *Pacific-999* (p-value < 0.05). The values correspond to the average of each parameter ± SE (n=10)

Nine landraces (*SEU4*, *SEU5*, *SEU6*, *SEU7*, *SEU8*, *SEU9*, *SEU11*, *SEU12* and *SEU17*) were identified as a first group (Similarity level = 97.23%), then the second group (Similarity level = 97.22%) consisted of 3 landraces (*SEU3*, *SEU10* and *SEU14*) and the third group (Similarity level = 49.07%) included 5 landraces (*SEU1*, *SEU2*, *SEU13*, *SEU15* and *SEU16*). Furthermore, *SEU4* and *SEU7* showed the most similarity within the group followed by *SEU8* and *SEU9*, while the *Pacific-999* the elite commercial hybrid stands on its own.

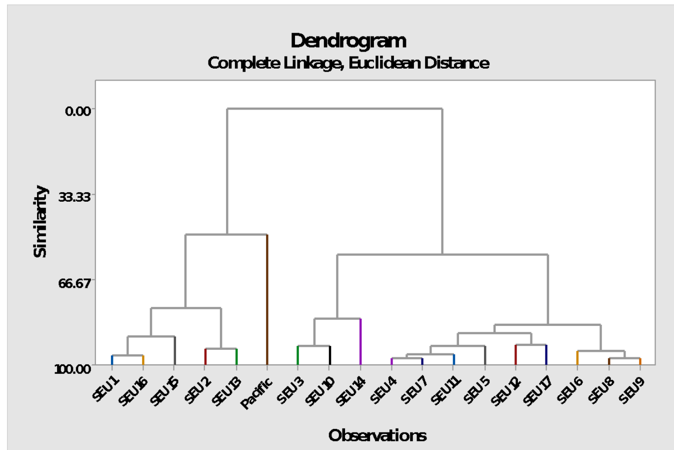

Fig. 3. Hierarchical cluster analysis of maize landraces for all morphological, physiological and yield traits.

D. Fall armyworm resistivity

The percentage of natural fall armyworm infestation was recorded before applying the insecticide to control the pest and the results indicated that infestation varies between 5% to 30% among the maize germplasm. The higher resistance against fall armyworm was observed in *SEU14*, *SEU15*, *SEU16* and *SEU17* (Fig. 4), whereas *SEU14* and *SEU16* were significantly ($p<0.05$) lower compared to the *Pacific-999* (11%). Thus, *SEU14* and *SEU16* landraces confers higher resistivity against fall armyworm infestation. Thus, it can be argued that the available local maize landraces exhibit wider plasticity against the fall armyworm resistivity.

IV. CONCLUSION AND RECOMMENDATION

The present study reveals that local maize landraces naturally possessed larger plasticity to morphological, physiological and biomass production when compared with the elite hybrid variety *Pacific-999*. Particularly, the landrace *SEU9* displayed increased photosynthetic efficiencies along with the broader flag and ear leaf areas and exhibited higher LAI and dry matter production while conferred with lower natural resistivity against FAW. On other hand, when considering cob characteristics, *SEU14* possessed the highest dry weight as they confer an increased number of kernels per cob and kernel weight, in addition, this landrace displayed

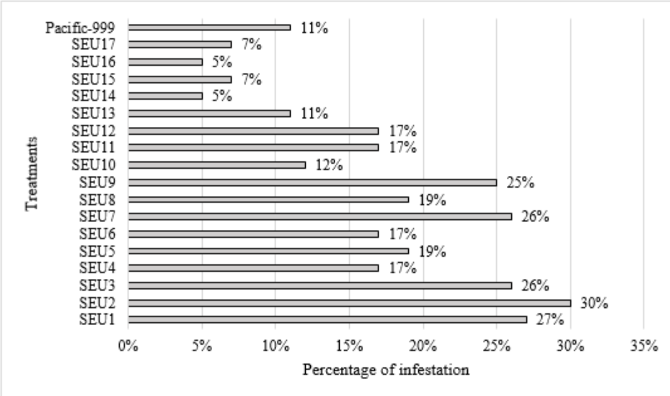

Fig. 4. **The Fall Armyworm infestation in maize landraces under natural field conditions before spraying insecticides:** Number of infested plants were counted out of 30 plants per each plot.

enhanced natural resistivity against FAW infestation. These elite germplasms will be further elucidated to confirm these displayed characteristics by employing state of the art technologies compose of chlorophyll fluorescence, ceptometers, and infrared gas analyzer encompassing with plant phenology and growth parameters. Furthermore, the FAW resistivity will be confirmed with multi-faceted laboratory and field trials. Once these traits are confirmed, these promisig germplasms could be introgressed with elite maize varieties through plant breeding programmes thereby to combine biomass and increased pest resistivity within a single plant genome. Moreover, the present research utilizes state-of the art instrumentation to identify elite plants from a larger population of maize germplasms. Such screening approach is vital for the future development of other cereal crop varieties to achieve sustainable development goals.

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