Towards Striga-resistant Gene pool in Nigerian Pearl millet landraces

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Abstract: Parasitism of crop plants by *Striga* species is a major constraint in the savannah zones of West Africa. A germplasm collection comprised of 240 accessions of pearl millet was screened under natural *Striga hermonthica* infestation to identify sources of *Striga* resistance. Data were collected at different time points, specifically at 70, 90 and 140 days after planting for *Striga* count, *Striga* vigour and *Striga* severity. Number of panicles, panicle weight and Grain yield were also measured. The results revealed significant variation in the resistance of pearl millet genotypes to *Striga*. Fifteen genotypes identified as the most resistant were free of emerged *Striga* shoots, 10 genotypes supported 1- 4 *Striga* shoots but with appreciable yield and 15 genotypes with 1-4 *Striga* shoots and low grain yield. Principal Component and cluster analyses grouped these genotypes into 3 main clusters medium yielding tolerant to *Striga*, low yielding susceptible to *Striga* and medium to high yielding resistant to *Striga*. The high level of resistance observed in some breeding lines enabled the selection of suitable parents for population development.

Keywords: Pearl millet, Landrace, Resistance, *Striga hermonthica*

1. Introduction

Striga also known as *Striga hermonthica* (Del.) Benth, poses a significant challenge to pearl millet production in various tropical and subtropical regions of Africa (Rouamba, Shimelis, Drabo, et al., 2023). This parasitic weed can cause substantial yield losses, ranging from 20 to 80% in Africa and up to 100% in severe cases, thereby negatively impacting food security [1]. Previous studies by [2], [3], [4], [5], [7], [8], [9] and [10] have highlighted the detrimental effects of Striga on pearl millet production. To address this issue, the present study aims to identify the sources of resistance and explore the key morphological and agronomic traits associated with pearl millet's ability to resist Striga infestation. By understanding the resistance mechanisms and trait that contribute to host-resistance, this research seeks to provide valuable insights for developing effective strategies to combat Striga and enhance pearl millet production.

2. Materials and Methods

The experiment was conducted in the Striga sick field in Birninkudu, Jigawa state, Nigeria, during the rainy season of 2022. To increase the Striga infestation, the method described by [2] was followed.
A total of 240 S_2 pearl millet lines were used in this study. These included 156 lines from the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), 82 landraces from Lake Chad Research Institute (LCRI) and two local pearl millet accessions obtained from the same location where the evaluation was carried out. These accessions served as checks.
The experimental design used was a 20 × 12 Alpha lattice design with two replications. Prior to the emergence of Striga, one hoe-weeding was performed. Subsequently, handpicking of weeds other than Striga was done whenever they emerge. Data were collected on the number of panicles, panicle weight, grain yield, Striga counts at 70, 90, and 140 days after sowing, as well as Striga vigour at the same time points.
To classify the pearl millet lines as resistant or susceptible, a scale described by [12] was used. The classification criteria were as follows:

- Resistant: No Striga emergence observed on the plot and no Striga symptoms observed on the plant.
- Moderately resistant: Few Striga emergences (2-3) per plot, but no Striga symptoms observed.
- Tolerant: *Striga* emergences observed on the host plant but no significant reduction yield
- Susceptible = >5 *Striga* plant emerged per plot and plants show severe *Striga* symptoms associated with stunted growth and yield reduction

3. Statistical analyses

The data was analysed using R Statistical software, specifically utilizing analysis of variance (ANOVA) to examine the differences between the measured traits. To explore the relationships between the traits, Pearson's correlation coefficient was employed. Additionally, principal component analysis (PCA) and cluster analysis were conducted using the same software to further analyze the data.

4. Results and Discussion

Performance of pearl millet genotypes under *Striga* infestation

The analysis of variance for *Striga* resistant traits and yield components of pear millet accessions showed a highly significant difference ($p<0.05$), as indicated in Table 1.

Table 1. Mean square from the analysis of variance *Striga* parameters, yield and yield components of pearl millet

Source	Sc70	Sc 90	Sc 140	Av_Se	Sv 90	Sv140	SS90	SS1 40	Np	Pw	Gy
Block (Rep)	0.01	0.49*	0.67	0.25*	0.83	1.09	4.78*	14.89	84.97	1108593	13683.03
REP	0.01	1.01	1.01	0.49	0.21	0.1	4.22	18.49	0.93	294884.7	19452.5
Entry	0.1**	1.30**	2.72**	0.90**	1.85**	4.74**	12.49**	42.91**	1055.65**	1861186**	389625.06**
CV	436.3	105.4	92.0	91.6	109.2	86.1	118.4	116.0	13.2	65.5	14.7
Mean	0.0	0.5	0.7	0.4	0.7	1.2	1.4	2.8	59.3	1579.3	858.9

Sc70, Sc90, Sc140 denote Striga count at 70, 90 and 140 days after planting respectively; Av_se=average Striga emergence; Sv90, Sv140 denote Striga vigour at 90 and 140 days after planting; Ss90, Ss140 denote Striga severity at 90 and 140 days after planting; Np, Pw,Gy denote number of panicles, panicle weight, and grain yield respectively, CV=Coefficient of variation

This study revealed a wide range of variation in Striga resistance traits among the pearl millet genotypes, which could be attributed to either climatic conditions or the genetic background of the genotypes. Out of the 15 genotypes analysed, including the two local varieties (Farmers' local1 and Farmers' local2), none showed any signs of Striga emergence and exhibited good agronomic performance (Table 2). This suggests that these genotypes possess resistance to Striga infestation and can serve as potential sources for developing for developing a breeding program aimed at enhancing Striga resistance and improving yield in pearl millet. Similar findings were reported by [14] and [10], where either an absence or a low number of emerged Striga indicated resistance.

Table 2. *Striga* parameters, yield and yield components (number of panicles and panicle weight) of pearl millet

Genotypes	Sc70	Sc90	Sc140	Av_Se	Sv90	Sv140	Ss90	Ss140	Np	Pw	Gy
Local checks											
Farmers'local1	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	53	2267	1754.67
Farmers'local2	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	56	2130	1076.00
Fifteen most resistant											
MPMG11074	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	84	2898	2549.33
IP 20990	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0 (0.7)	0(0.7)	59	2916	2528.34
MPMG11089	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0 (0.7)	0(0.7)	109	2755	2066.60
IP20717	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0 (0.7)	0(0.7)	56	2844	2009.33
MPMG11079	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0 (0.7)	0(0.7)	56	2389	1946.29
MPMG11051	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0 (0.7)	2(0.7)	51	3612	1856.00
MPMG11104	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	84	2619	1700.00
MPMG11015	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	72	2498	1652.67
IP 20511	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	71	2550	1646.65
MPMG11080	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	91	2432	1631.24

IP 20414	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	37	2234	1641.33
IP 12136	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	99	2515	1581.00
IP 20940	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	77	2159	1580.00
MPMG11108	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	111	1937	1548.00
MPMG11112	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	131	1780	1530.47
Mean	0	0	0	0	0	0	0	0	79.2	2542.53	1831.15
Range	0	0	0	0	0	0	0	0	94	1832	1018.86
LSD	**0.18**	**1.08**	**1.35**	**0.77**	**1.50**	**2.12**	**3.17**	**6.46**	**15.43**	**765.2**	**249.57**

LSD: Least Significant Difference at p = 0.05; Values in bracket are transformed; Values outside the bracket are untransformed; Sc70, Sc90, Sc140 denote Striga count at 70, 90 and 140 days after planting respectively; Av_se=average Striga emergence; Sv90, Sv140 denote Striga vigour at 90 and 140 days after planting; Ss90, Ss140 denote Striga severity at 90 and 140 days after planting; Np, Pw,Gy denote the number of panicles, panicle weight, and grain yield respectively

Relative importance of *Striga* and yield parameters

The findings from this study highlighted that Sc90, Sc140, Av._Se, Sv9, Sv140, Ss90. Ss140D Np, Pw and Gy contributed to the observed variability among the different pearl millet genotypes. These parameters can be effectively used to identify and select superior genotypes for inclusion in a breeding program focus on enhancing Striga resistance and improving yield. The analysis also revealed that the first two principal components (PCs) accounted for a significant portion of the diversity observed among the genotypes, which is consistent with previous research conducted by [6] and [13]. These studies emphasized the importance of considering parameters such as Striga emergence, Striga vigour, Striga severity, number of tillers, number of panicles and grain yield when selecting parents for hybridization programs aimed at enhancing yield improvement in pearl millet. Taking these yield-related parameters into account will be crucial in identifying and breeding genotypes with improved performance and resistance to Striga infestation.

Table 3. Eigenvectors and values from the two principal component axes used

Traits	Prin1	Prin2
Sc70	0.181	0.211
Sc90	**0.373**	0.050
Sc140	**0.372**	0.044
A_Se	**0.379**	0.062
Sv90	**0.357**	0.015
Sv140	**0.341**	0.004
Ss90	**0.369**	0.095
Ss140	**0.368**	0.063
Np	-.117	**0.435**
Pw	-.104	**0.613**
Gy	-.077	**0.607**
Eigenvalue	6.784	2.016
Proportion	0.617	0.183
Cumulative	0.617	0.800

Sc70, Sc90, Sc140, and A_Se denotes *Striga* count at 70 days, 90 days, 140 days and average *Striga* emergence respectively. Sv90= *Striga* vigor at 90 days, Sv140= *Striga* vigor at 140 days, Ss90= *Striga* severity at 90 days, Ss= *Striga* severity at 140 days, Np= number of tillers, Pw= panicle weight, Gy= grain yield

Relatedness of genotypes based on principal *Striga* and yield parameters

The genotypes obtained from the cluster analysis were divided into three main clusters: Cluster A (pink), Cluster B (blue), and Cluster C (yellow). Cluster A consisted of 78 accessions, which were characterized as low to medium yielding but tolerant to Striga. Around 70% of the genotypes in this cluster had a grain yield exceeding 800 kg/ha. Cluster B comprised 108 accessions, which exhibit low yields and susceptibility to Striga. Approximately 90% of the genotypes in this cluster had a grain yield of less than 500 kg/ha. The grouping of genotypes in this cluster indicated that yield played a significant role in distinguishing them, as it contributed greatly to the first two principal components. Cluster C consisted of 54 accessions, which displayed medium to high yields and resistance to Striga. Eighty three point three percent of the genotypes in this cluster had a grain yield greater than 1000 kg/ha. The clustering of the genotypes indicated the presence of genotypic variability among the accessions. Therefore, this germplasm shows promise for achieving both yield improvement and Striga resistance.

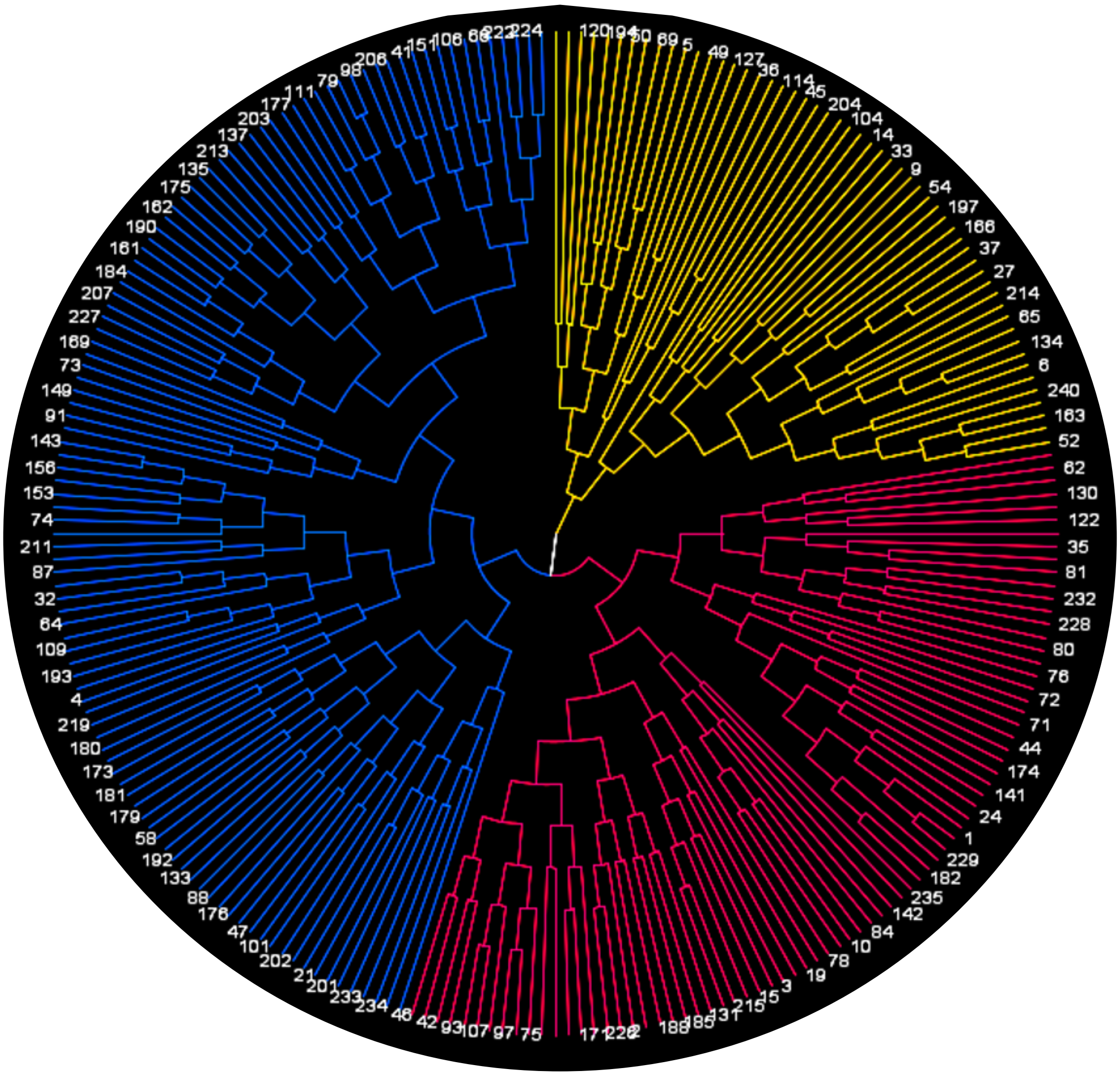

Figure 1. Agglomerative Hierarchical Clustering Dendogram constructed based on yield and *Striga* resistance parameters of pearl millet. The colours Pink, Blue, and Yellow are referred to as A, B, and C respectively. The numbers 1,2,3…240 refer to the first, second, third…last entry used in Appendix.

5. Conclusion

Based on the phenotypic data obtained from the screening, several potential sources of resistance to Striga were identified. Notable genotypes include MPMG11074, IP20990, MPMG11089, IP20717, MPMG11079, MPMG11051, MPMG11104, MPMG11015, IP20511, MPMG11080, IP20414, IP12136, IP20940, MPMG11108, and MPMG11112. These genotypes were grouped based on their response to Striga infestation and grain yield. The categorized groups included genotypes with low to medium yield and tolerance, genotypes with low yield and susceptibility, and genotypes with medium to high yield and resistance. These findings provide valuable insights for selecting and breeding genotypes that exhibit both resistance to Striga and higher yield potential.

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