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GENETIC DIVERSITY AND STABILITY OF GROUNDNUT MINI-CORE COLLECTIONS FOR EARLY AND LATE LEAF SPOT RESISTANCE IN NIGERIA

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ABSTRACT

Disease epidemics of early and late leaf spots (ELS and LLS, respectively) are affected by weather patterns such as hot and wet conditions, making them prevalent in the Guinea and Sudan Savanna zones of Nigeria. The objective of this research was to determine the genetic diversity and stability of groundnut (*Arachis hypogaea* L.) mini-core collections for ELS and LLS in Nigeria. The collections were evaluated at Bayero University Kano (2015, 2016 and 2017) and Minjibir (2017) during the rainy seasons. The data collected were analysed by a mixed model and Cluster analysis was carried out to summarise relationships among the mini-core collections. Significant differences were observed between the lines for kernel yield, ELS and LLS resistance. The highest kernel yield was recorded by ICG 12988 (1225 kg ha^{-1}). The highest yielding check variety was Samnut 24, with a kernel yield of 805 kg ha^{-1}. Lines with low ratings for ELS and LLS were in cluster one but had the lowest mean kernel yield; followed by Cluster 2 with a similar trend. Two lines, ICG 12988 and ICG 12989, were grouped in Cluster 10, which had the highest mean yield (1107 kg ha^{-1}), with ELS and LLS rating of 3 and 4, respectively. Check varieties such as Samnut 22, 24 and 25 were grouped in Cluster 9 and are moderately tolerant to leaf spots; while Samnut 26, which is a more recent improved variety was in Cluster 7 with moderate resistance to leaf spots. There was a significant line × environment interaction for kernel yield. ICG 12988 and ICG 12989 were highly unstable; while ICG 2019 was the most stable line followed by ICG 12697, ICG 3312 and ICG 8567. In general, results of the current study show a linkage between kernel yield and leaf spots diseases. Therefore, special breeding techniques such as backcrossing or marker-assisted backcrossing are required to improve lines identified with low yield but high resistance or high yield with low resistance.

Key Words: *Arachis hypogaea,* cluster analysis, spots diseases

RÉSUMÉ

Les épidémies de maladies des taches foliaires précoces et tardives (ELS et LLS, respectivement) sont affectées par des conditions météorologiques telles que des conditions chaudes et humides, ce qui les rend répandues dans les zones de savane de la Guinée et du Soudan au Nigeria. L'objectif de cette recherche était de déterminer la diversité génétique et la stabilité des collections de mini-noyaux d'arachide (*Arachis hypogaea* L.) pour ELS et LLS au Nigeria. Les collections ont été évaluées à Bayero University Kano (2015, 2016 et 2017) et Minjibir (2017) pendant les saisons des pluies. Les données recueillies ont été analysées par un modèle mixte et une analyse par grappes a été effectuée pour résumer les relations entre les collections mini-core. Des différences significatives ont été observées entre les lignées pour le rendement en grains, la résistance ELS et LLS. Le rendement en grains le plus élevé a été enregistré par ICG 12988 (1225 kg ha^{-1}). La variété témoin la plus performante était Samnut 24, avec un rendement en grains de 805 kg ha-1. Les lignées avec de faibles notes pour ELS et LLS étaient dans la grappe un mais avaient le rendement moyen du noyau; suivi du Cluster 2 avec une tendance similaire. Deux lignées, ICG 12988 et ICG 12989, ont été regroupées dans le groupe 10, qui avait le rendement moyen le plus élevé (1107 kg ha-1), avec une cote ELS et LLS de 3 et 4, respectivement. Les variétés de contrôle telles que Samnut 22, 24 et 25 ont été regroupées dans le groupe 9 et sont modérément tolérantes aux taches foliaires; tandis que Samnut 26, qui est une variété améliorée plus récente, appartenait au groupe 7 avec une résistance modérée aux taches foliaires. Il y avait une interaction ligne × environnement significative pour le rendement du noyau. ICG 12988 et ICG 12989 étaient très instables; tandis que ICG 2019 était la lignée la plus stable, suivie par ICG 12697, ICG 3312 et ICG 8567. En général, les résultats de la présente étude montrent un lien entre le rendement des grains et les maladies des taches foliaires. Par conséquent, des techniques de sélection spéciales telles que le rétrocroisement ou le rétrocroisement assisté par marqueur sont nécessaires pour améliorer les lignées identifiées avec un faible rendement mais une résistance élevée ou un rendement élevé avec une faible résistance.

Mots Clés: *Arachis hypogaea*, analyse par grappes, maladies des taches foliaires

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important food legume grown worldwide and considered to be a rich source of protein for both humans and animals. It is part of the mainstay to the livelihood of millions of small-holder farmers residing in semi-arid tropics (SAT) of the world (Janila *et al.,* 2013). The productivity of Africa (929 kg ha^{-1}) remains poor, compared to the United State of America (3,673 kg ha^{-1}) (FAOSTAT, 2018).

In the semi-arid region of West Africa, where groundnut is an important component of the farming systems, the stress imposed by the incidence of early and late leaf spots (caused by *Cercospora arachidicola* S. Hori and *Cercosporidium personatum* (Berk. & Curt.) Deighton, respectively), impacts adversely on the crop's performance (Padi, 2008). The diseases can cause total defoliation and reduce pod and fodder yields, to an extent of over 50% thereby resulting in low yields (Waliyar, 1991).

As the leaf spot disease epidemics are affected by weather patterns, such as hot and wet conditions (Shew *et al.*, 1988), they are prevalent in the Northern Guinea and Sudan Savanna zones of Nigeria during the rainy seasons. In recent times, groundnut varieties with high yield potentials have been developed and released for cultivation in Nigeria (NACGRAB, 2017). However, these varieties are moderately susceptible to early and late leaf spot diseases (Motagi, 2015).

Substantial genetic variation exists in cultivated groundnut for both early and late leaf spots (Holbrook and Dong, 2005).

Considering the number of groundnut germplasm accessions available in gene banks (around 15, 000), it is difficult to screen such a huge collection under field conditions. Hence, researchers have developed core (Holbrook *et al.*, 1993) and mini-core collections (Upadhyaya *et al.*, 2002) of groundnut that represent the genetic variability of the entire collection. Selection of resistant sources through systematic screening of mini-core collection accessions is in practice for infusing genetic diversity (Upadhyaya *et al.*, 2010).

Information on ELS and LLS resistance has been previously reported (Ashish *et al.*, 2014; Gaikpa *et al.*, 2015; Sudini *et al.*, 2015; Zongo *et al.*, 2017), however, the genetics of a particular trait may vary with variation in plant material and environment in which the materials are evaluated. Knowledge about the nature of genetic diversity and stability prevailing in the breeding material in the Nigerian semi-arid region is necessary to decide on a breeding procedure to be chosen for the improvement of groundnut for leaf spots resistance. The objective of this research was to determine the genetic diversity and stability of groundnut mini-core collections for ELS and LLS in Nigeria.

MATERIALS AND METHODS

The mini-core collections (231) and 13 varieties (local and improved) were evaluated at Bayero University Kano (2015, 2016 and 2017; Latitude 11º 58' N and Longitude 8º 25' E) and Minjibir (2017; Latitude 12 º 19' N and Longitude 8 º 63') during the rainy seasons of all experimental years. The materials were provided by ICRISAT, Nigeria. The collections were sowed using a randomised complete block design, with two replications. The plots were single rows, measuring 4 m long with intra- and inter-row spacing of 0.1 m × 0.75 m, respectively. Before sowing, the seeds were treated with Apron Plus 50 DS (Metalaxyl), at the rate of 1 gramme a.i. kg^{-1} of seed to prevent fungal seedling disease, and ensure good plant establishment. Fertiliser was applied at the rate of 20 kg ha^{-1} each of N and K_2O, and 40 kg ha^{-1} of P_2O_5 at planting.

The materials were planted under natural disease conditions in all the environments. The area used for the experiment was previously cultivated, with groundnut, for several years, resulting in a build-up of disease inocula. Data were recorded for early and late leaf spot as described by Subrahmanyam *et al.* (1995), at 50 and 70 days after sowing, respectively; as well as kernel yield.

The data collected were analysed by a mixed model, using JMP 10.1.2. The mini-core, environment, replications and the interaction between the mini-core and environment were all considered random effects. Cluster analysis was carried out to summarise the relationships among the mini-core collections into a dendrogram. Stability analysis was done using the R GGE Biplot Graphical User Interface package.

RESULTS

The result of the percent contribution of lines, environment, and line × environment interaction to the total variability observed for all measured traits are presented in Table 1. Lines accounted for about 18.42% of the variability observed for kernel yield, and the effect was significant ($P<0.05$). The interaction between lines and the environment for kernel yield was also significant ($P<0.05$) and contributed about 33.12% of the observed variability. The contribution of the environment to the total variability was negligible (0.10%). For ELS and LLS, the variance contribution from the environment (28.53 and 30.49%, respectively) doubled the contribution from lines (12.43 and 14.66%, respectively). The interaction between lines and environment variance component were 5.02% for ELS and 0.00% for LLS.

The highest kernel yield was recorded for ICG 12988 (1225 kg ha^{-1}), followed by ICG 12989 (990 kg ha^{-1}). The highest yielding check variety was Samnut 24, with a yield of 805 kg ha^{-1} (Fig. 1a). ICG 12697 had a disease

TABLE 1. Variance components and percent contribution of factors to yield and leaf spot diseases in groundnut mini-core

Random effect	Kernel yield (kg ha^{-1})	Early leaf spot	Late leaf spot
Lines	12323.004* (18.42)	0.120* (12.43)	0.348* (14.66)
Rep (Environment)	1268.51 (1.90)	0.001 (0.13)	0.030 (1.23)
Environment	64.84 (0.10)	0.28 (28.53)	0.724 (30.49)
Environment × Lines	22164.65* (33.12)	0.048 (5.02)	-0.042 (0.00)
Residual	31095.28 (46.47)	0.520 (53.89)	1.274 (53.62)
Total	66916.28	0.964	2.376
R^2	0.660	0.525	0.43
Root Mean Square Error	176.340	0.721	1.129

Number in parenthesis "( )" are percentage contributions, * = <.0001 (Wald P-value)

rating of 5 for both ELS and LLS (Fig. 1b), with a yield of 766 kg ha^{-1}; while ICG 12988 had ratings of 3 and 4 for ELS and LLS, respectively. The ratings for Samnut 24 for ELS and LLS were 4 and 3, respectively.

The mini-core collections were grouped into different clusters based on yield performances and disease rating in order to determine the magnitude of diversity present among the collections, for their resistance to ELS and LLS. Thirteen clusters were identified (Fig. 2) and had a r^2 of 0.77 (Table 2). Lines with low ratings for ELS and LLS (2 and 1, respectively) were in Cluster 1, but had the lowest mean kernel yield (206 kg ha^{-1}). This was followed by Cluster 2, with a similar trend. Two lines, ICG 12988 and ICG 12989, were grouped in Cluster 10; they had the highest mean yield (1107 kg ha^{-1}) with ELS and LLS ratings of 3 and 4, respectively (Table 2). Other clusters with moderate resistance and mean yield in increasing order were Clusters 7, 9 and 11.

Check varieties, such as Ex-dakar red, Samnuts 22, 24 and 25 were grouped in Cluster 9; while Samnut 26 which was a more recent improved variety was in Cluster 7. Ex-dakar and Samnut 21 were in Cluster 3. Generally, yield performance increased with a decrease in resistance, as shown by the scatter plot matrix (Fig. 3).

Table 3 shows the description of the codes used for the GGEBiplot analysis in order to identify stable lines. The highest yielding lines, ICG 12988 and ICG 12989, were highly unstable; while ICG 2019 with a mean yield of 783.86 kg ha^{-1} was the most stable line. This was followed by ICG 12697, ICG 3312 and ICG 8567 (Fig. 4). However, the stabilities of these lines were similar to those of Samnut 24 and Kwankwaso checks that were used. Samnuts 23 and 22 were also stable, but recorded yield below average; while Kampala was fairly stable with a below-average yield.

DISCUSSION

The significant variability observed among the mini-core collections for kernel yield (Table 1) shows that ample genetic variability exists among collections. However, there was evidence of line × environment interaction for the kernel yield. Ajeigbe *et al.* (2016) previously reported variability among groundnut cultivars, but influenced by different environments in the Savannahs of Nigeria. The effects of lines for ELS and LLS were also significant, but the percent variance contributions were low when compared to kernel yield. The genetic variability between the lines for ELS and LLS was low when compared to kernel yield. Also, percent variance contribution of the

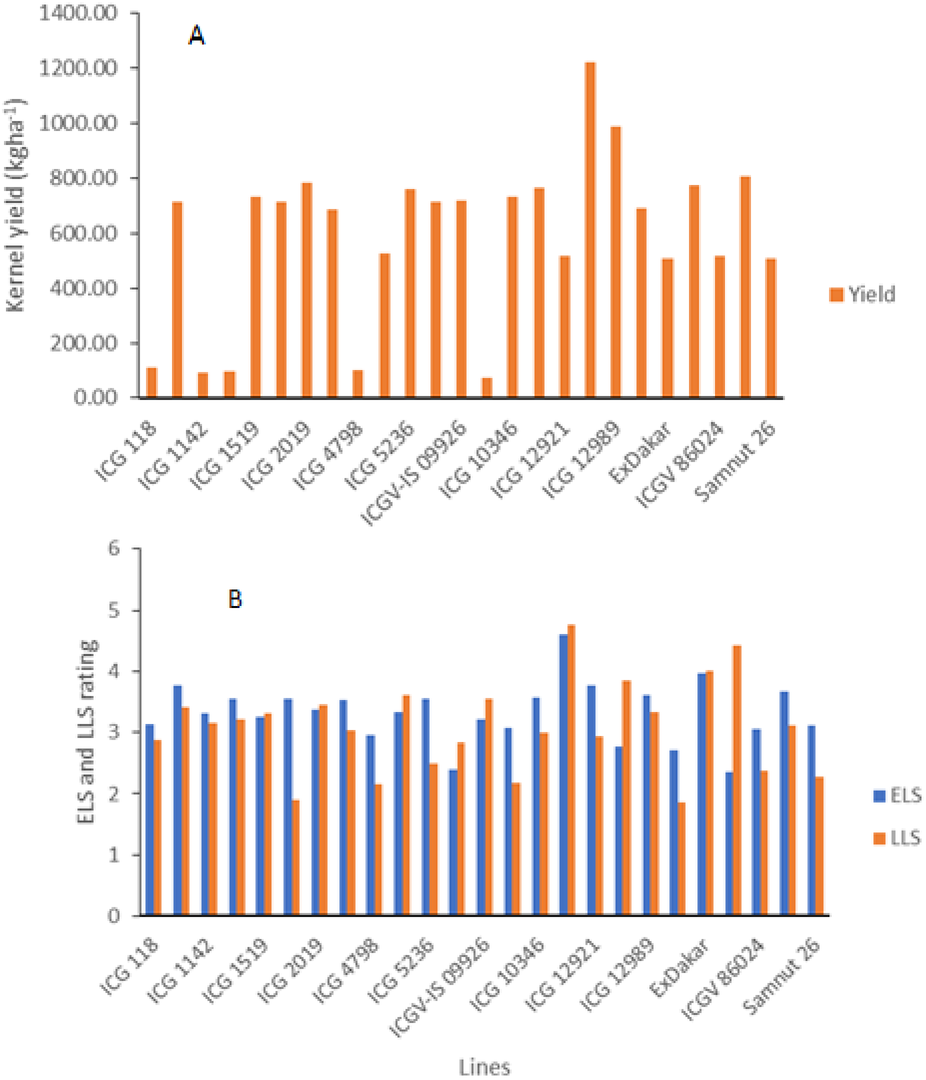

Figure 1. Mean performance of groundnut mini-core for kernel yield (A) and ELS and LLS (B) across the experimental sites in Kano, Nigeria.

environment to ELS and LLS was negligible and this corroborates the findings of several authors (Padmaja *et al*., 2013; Ashish *et al*., 2014; Zongo *et al*., 2017), who reported low response of ELS and LLS to environments. Such low response to the environment indicates that the incidences of leaf spots diseases were similar in all the environments, which may be due to the evaluation under natural infestation. ICG 12988 and ICG 12989 were the highest yielding lines and performed better than all the check varieties used, and they also had moderate tolerance for ELS and LLS. The lines that had high resistance were low in yield performance. Samnut 26 showed a moderate tolerance to ELS and LLS, and was the best performing check for disease resistance (Fig. 1b). This may be because it is a recently developed variety.

Cluster analysis identified 13 distinct groups; the most resistant lines were in Cluster 1. The two high yielding lines, ICGs 12988

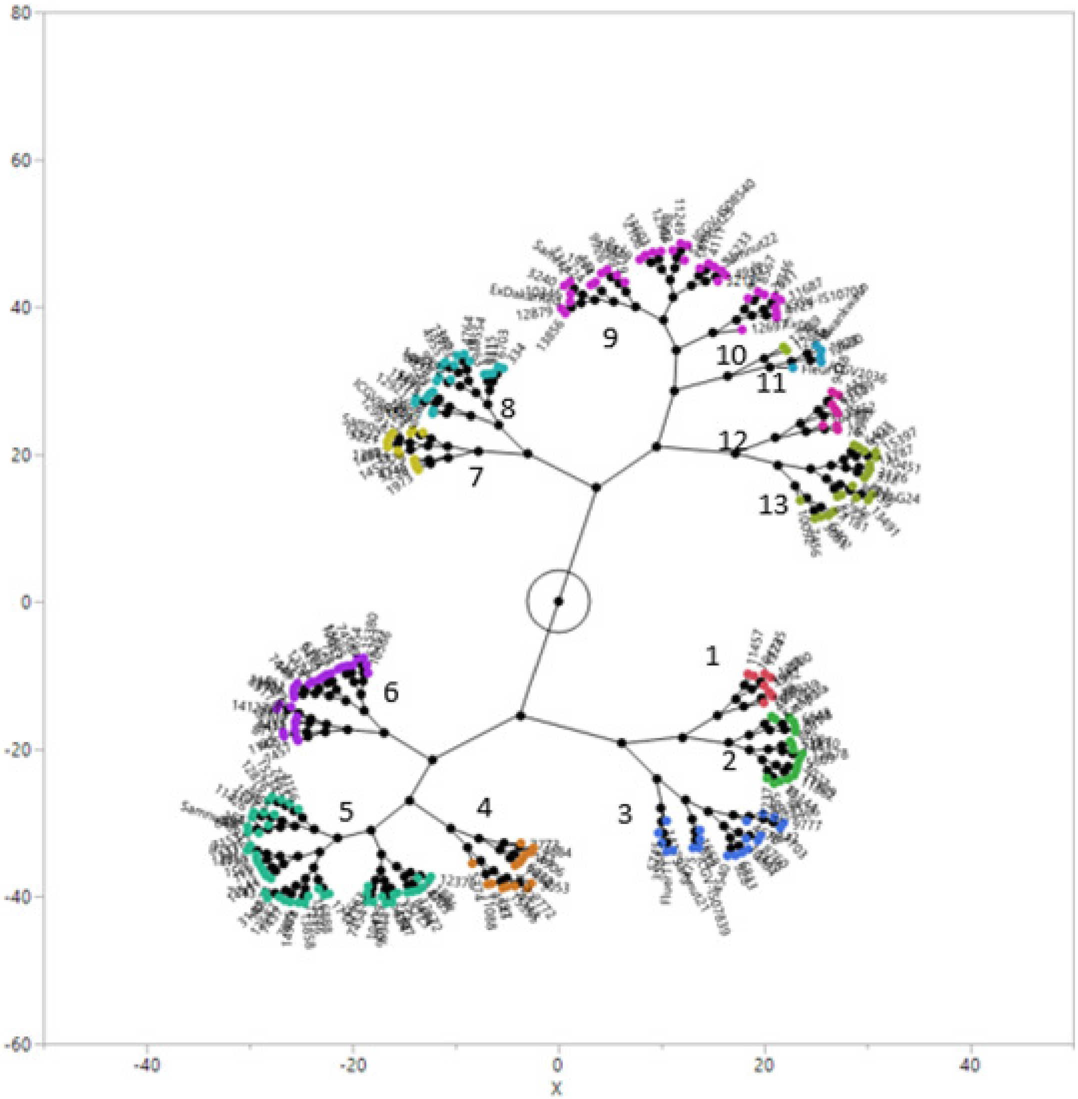

Figure 2. Cluster plot of groundnut mini-core collections across the experimental sites in Kano, Nigeria.

and 12989, were in Cluster 10 and they were the only lines in this Cluster. They were also moderately tolerant of ELS and LLS. Sudini *et al*. (2015) in India, reported ICGs 12988 and 12989 to be susceptible to LLS. Such differences in reactions to ELS and LLS may be attributed to the wide geographic differences and possible disease intensity between our location (Nigeria) and the location of the reported study (India). Cluster 9 contained some lines that have been previously reported to have resistance to ELS in Cameroon (Hamasselbe *et al*., 2007), and moderate resistance to ELS and LLS in Nigeria (Muhammad and Bdliya, 2011). In the present study, these lines were moderately tolerant of ELS and LLS. Check varieties, namely Samnut 24, Samnut 25, Samnut 22, Ex-Dakar and Ex-Dakar red also fell in this group. Samnut 22 has previously been reported to be resistant to ELS in Cameroon (Hamasselbe *et al*., 2007).

TABLE 2. Summary of the cluster analysis for groundnut mini-core collections

Cluster	Count	Yield	ELS	LLS
1	8	205.90	2.00	1.00
2	18	218.75	3.00	2.00
3	21	463.92	3.00	2.00
4	15	317.76	2.00	3.00
5	49	377.44	3.00	3.00
6	29	220.31	3.00	3.00
7	13	566.98	3.00	2.00
8	21	379.77	4.00	3.00
9	35	610.65	4.00	4.00
10	2	1107.22	3.00	4.00
11	5	651.52	3.00	4.00
12	8	247.87	4.00	4.00
13	20	431.26	4.00	4.00
R^2		0.77	0.76	0.81

TABLE 3. Code for the lines used in GGE Biplot analysis for the groundnut mini-core

Code	Lines	Code	Lines
1	ICG 118	19	ICG 9809
2	ICG 434	20	ICGV-IS 09926
3	ICG 875	21	ICG 10010
4	ICG 1142	22	ICG 10346
5	ICG 1418	23	ICG 12697
6	ICG 1519	24	ICG 12988
7	ICG 1973	25	ICG 12989
8	ICG 2019	26	ICG 14179
9	ICG 2773	27	Fleur11
10	ICG 3240	28	Kwankwaso
11	ICG 3312	29	Samnut24
12	ICG 4798	30	Kampala
13	ICG 5236	31	Samnut21
14	ICG 5745	32	Samnut22
15	ICG 6375	33	Samnut23
16	ICG 7302	34	Samnut25
17	ICG 7452	35	Samnut26
18	ICG 8567		

Cluster 7 had lines that showed moderate resistance to both ELS and LLS, and this included Samnut 26 which is a recently improved variety in Nigeria. Other clusters, namely 8, 12 and 13 comprised of susceptible lines. One of the susceptible checks, TAG 14, was in Cluster 13. Other lines in these clusters (8, 12, and 13) that have been reported by Sudini *et al.* (2015) to be susceptible are ICGs 115, 297, 332, 334, 7181 and 8083.

It was observed from the cluster groupings that there is a linkage between leaf spot diseases and kernel yield of groundnut (Table 2). This was also evident from the scatter plot matrix (Fig. 3), which shows that as the resistance level increased, there was a corresponding decrease in kernel yield. This further explains why the highest resistant varieties had low yields; while those with high yield were tolerant of the diseases. Hamasselbe *et al.* (2011) and Zongo *et al.* (2017) reported a positive correlation between ELS and kernel yield; revealing a high linkage between these traits. The correlation reported in this study was also positive (Fig. 3, the values in y and x axis). From the explanation given, "This was also evident from the scatter plot matrix (Fig. 3), which shows that as the resistance level increased, there was a corresponding decrease in kernel yield. This linkage between ELS and kernel yield can also be suggested for LLS because both ELS and LLS resistance is controlled by a similar polygenic system (Kormsa-art *et al.*, 2002; Padmaja *et al.*, 2013; Gaikpa *et al.*, 2015).

There was a positive association between ELS and LLS as evident in the scatter plot matrix (Fig. 3). The results of the linkage between both diseases and yield are in further agreement with the reports of Vishnuvardhan *et al.* (2012), Ashish *et al.* (2014) and Gaikpa *et al.* (2015). They reported a positive correlation between kernel yield and leaf spot diseases and suggested the linkage of high productivity with leaf spot susceptibility. Therefore, lines identified to be high in resistance with low yield or susceptible with

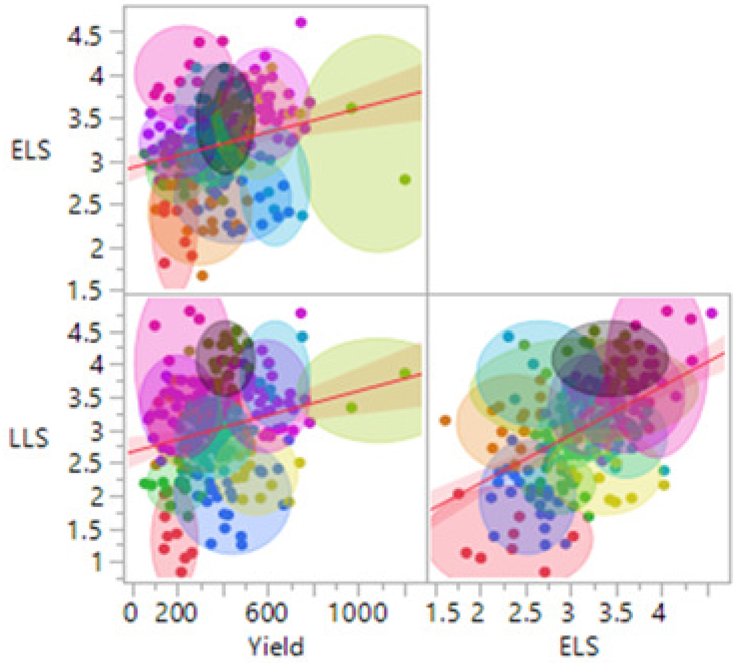

Figure 3. Scatter plot matrix of groundnut mini core yield, early (ELS) and late (LLS) leaf spot diseases.

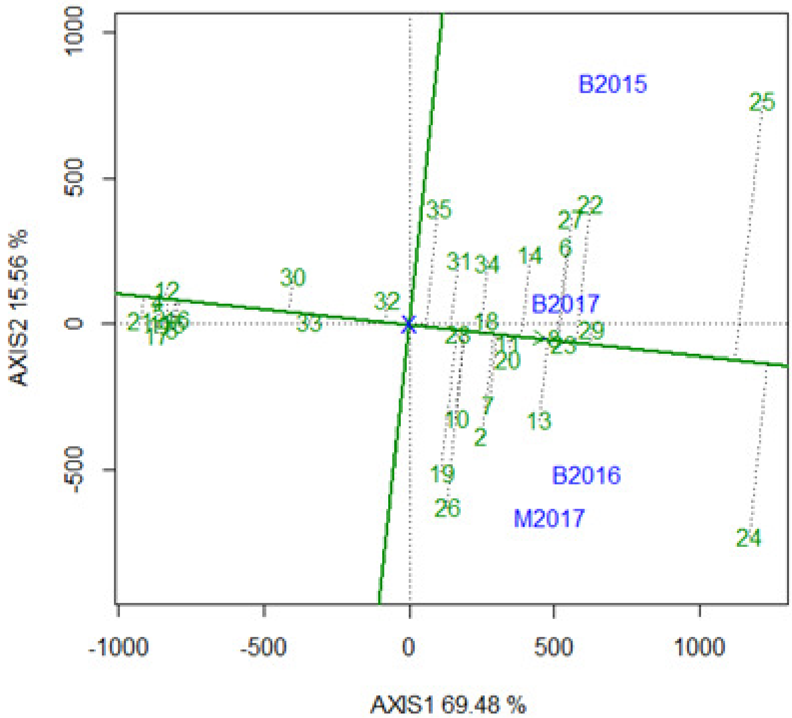

Figure 4. Stability and mean performance of some selected mini core collections based on yield performance across the experimental sites in Kano, Nigeria.

high yield can be improved using special breeding techniques that can decipher the association between these traits.

Stability analysis showed that the two highest yielding lines were very unstable while other lines that yielded above average were stable (Fig. 4). The moderately tolerant lines (ICG 2019, ICG 3312, ICG 8567, ICG 12697, Samnut 24 and Kwankwaso) were stable and had yield performance above average (446.10 kg ha^{-1}); while the moderately resistant lines (ICG 1973, ICG 5236, and Samnut 26) were not very stable with yield performance above average (446.10 kg ha^{-1}).

CONCLUSION

Ample genetic variability exists between the groundnut mini-core collections, and this variability can be utilised to improve breeding programmes and development of ELS and LLS resistant varieties. The mini-core collections showed high diversity in the Savannahs of Nigeria, and the highly resistant lines are the most stable, but with poor yield performance. With a decrease in stability, there is a corresponding increase in yield performance and susceptibility.

A special breeding scheme may be needed to improve some resistant, but low yielding lines as well as susceptible, but high yielding lines that were identified in the present study. It is important to improve high yielding, but susceptible lines because these lines are adapted to the environments and are preferred by farmers. It is also important to note that some lines reported to be susceptible to ELS and LLS by previous studies in other countries are moderately tolerant to both diseases. This shows the need for country-specific evaluation of the mini-core set to ascertain the characteristics of the set.

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