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Evaluating the Tricot Approach: On-farm testing for Groundnut, Pearl millet and Sorghum in Nigeria

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Abstract

The Triadic Comparison of Technology Options (TRICOT) approach has been successfully used to scale up on-farm participatory varietal selection, enabling farmers to evaluate elite crop genotypes under real-world conditions. In this study, we assessed the effectiveness of the TRICOT approach in on-farm testing of elite groundnut (*Arachis hypogaea*), pearl millet (*Pennisetum glaucum*), and sorghum (*Sorghum bicolor*) genotypes across dry-land regions of Nigeria. The study was conducted in five states, with trials established in six communities per state, engaging 900 farmers under the supervision of field agents. The experiment followed the balanced incomplete block design in blocks of three. Data were collected on yield, disease resistance, overall preference and other agronomic traits at different growth stages using the Open Data Kit (ODK) application and submitted to ClimMob for analysis. Results identified the most preferred genotypes for each crop. Genotypes 1680044-B-184-B-2 and ICSX 1680005-B-67-B-1 were most preferred for sorghum, ICGV-IS 14877 and ICGV 196104 for groundnut and LCICMA-1 x TORONIUO and GAM-A-11-14 x SUPERSOSAT for millet. Farmers' overall preferences were primarily influenced by pod yield and grain size in groundnut and grain yield in both pearl millet and sorghum. These findings highlighted the potential of TRICOT in accelerating the adoption of improved varieties, ensuring that breeding programs align with farmers' needs and preferences.

Keywords: Dry-land crops, participatory varietal selection, northern Nigeria.

Introduction

Groundnut *Arachis hypogaea*, pearl millet (*Pennisetum glaucum*), and sorghum (*Sorghum bicolor*) are major dry-land crops that are important for food security in many parts of Africa. These crops are resilient to climate change and can help sustain local communities. They are critical for food and nutrition security in large parts of Africa and Asia. They are grown by millions of smallholder farmers in the dry-lands of Africa and South Asia. The Triadic Comparisons of Technologies (TRICOT) approach is a citizen science method for on-farm testing, originally conceived in 2011 (van Etten, 2011). TRICOT actively involves non-scientists—primarily farmers in data generation and interpretation, aligning with the broader movement of citizen science and participatory agricultural research (Ryan *et al*., 2018; van de Gevel and van Etten *et al*., 2020). By engaging farmers directly, TRICOT enhances the scale and efficiency of on-farm trials, addressing critical limitations of conventional testing methods (Kool*, et al*., 2020). First implemented between 2013 and 2016 for variety trials, TRICOT has since expanded to diverse crops and agricultural inputs, including cereals, legumes, root and tuber crops, perennial crops like cocoa, and even fertilizer trials (van Etten *et al*., 2019; Fadda *et al*., 2020). The approach has proven particularly valuable in dry-land cropping systems, where farmers face significant climatic and agronomic challenges. However, despite its advantages, the limited adoption of improved varieties remains a persistent issue (Walker and Alwang, 2015; Thiele *et al*., 2021).

Traditional breeding and variety selection processes often fail to incorporate farmers' preferences and real-world production constraints, leading to low adoption rates of new varieties. The TRICOT approach offers a cost-effective, scalable, and participatory solution by enabling farmers to evaluate and rank varieties under their field conditions. This method helps breeders and decision-makers understand which varieties are most likely to succeed in farmers' fields and markets. Given the importance of groundnut, pearl millet, and sorghum in Nigeria's dry-land agriculture, evaluating them using the TRICOT approach is crucial. This study seeks to provide evidence on its effectiveness in identifying high-performing genotypes, understanding farmer preferences, and improving variety selection and dissemination strategies. The study aimed to assess the performance of groundnut, pearl millet, and sorghum genotypes through farmer-led evaluations in different agro-ecological zones and identify the key traits driving farmer preferences for these crops, with a focus on yield, disease resistance, and grain quality.

Materials and Methods

The breeding programs of the Nigerian Research Institutes follow a participatory approach, engaging stakeholders in the development of target product profiles (TPPs) to address different market segments. For groundnut, one of the target product profiles focused on medium-duration varieties with high oil content, pod yield, and haulm yield. A total of 17 technologies, including 13 advanced genotypes and four check varieties, were evaluated. For pearl millet, the target product profile included medium maturity, high grain yield, and enhanced Fe and Zn contents. The study assessed 12 technologies, consisting of eight advanced genotypes and four check varieties. For sorghum, the target product emphasized short-duration, open-pollinated varieties (OPVs) with high grain yield and resistance to *Striga* (*Striga hermonthica*). A total of 12 technologies were tested, comprising 10 advanced genotypes and two check varieties. The list of the technologies tested for the three crops is presented in Appendix I.

Location of the study

The study was conducted in 2024 rainy season with 900 farmers across three agro-ecological zones in northern Nigeria, focusing on groundnut, pearl millet, and sorghum. The selected locations spanned five states: Kano, Bauchi, Jigawa, Katsina, and Yobe (Table 1). These locations represent the major production and consumption hubs for the crops in Nigeria (Figure 1). Within each state, districts were chosen based on their high levels of crop production and consumption.

Table 1: Distribution of TRICOT trial locations and their respective states and Districts.

SN	Agroecological zone	State	District
1	Sahel savanna	Yobe	Dagare (11°36'0" N and 11°1'60" E), Damaturu (11°44′40″N and 11°57′40″E), Kalallawa (11° 56' 19" N and11° 51' 20" E), Mazagani (11° 37' 44" N and 11° 1' 50" E), Damagum (11°40′39″N and 11°20′04″E), Kukargadu (12°22′09″N and 10°46′23″E)
2	Sudan savanna	Kano	Gezawa (12.0993046° N and 8.7536237° E), Bichi (12.23417°N and 8.24111°E), Gano (11.9667° N and 8.6500° E) , Tofa (12°06′10″N and 8°19′53″E), Takai (1.5716° N and 9.1096° E), Ajingi (11.97000°N and 9.03917°E)
		Jigawa	Kazaure (12°39′10″N and 8°24′43″E), Babura (12°38′N and 8°58′E), Gumel (12.62833°N and 9.38972°E), Taura (12°15′20″N and 9°23′3″E), Dutse (11.70111°N and 9.34194°E), Kiyawa (1.78472°N and 9.60833°E)
		Katsina	Bindawa (12° 46' 26" N and 7° 54' 18" E), Mani (2°51′22″N and 7°52′28″E), Mashi (2°59′00″N and 7°57′00″E), Zango (13°05′00″N and 8°29′00″E), Sandamu (12.933°N and 8.367°E), Baure (12°50′10″N and 8°44′47″E)
3	Northern Guinea savanna	Bauchi	Jamaare (11° 40' 11" N and 9° 55' 40" E), Dass (10° 1' 0" N and 9° 34' 59"), Misau (11.4671° N and 10.6266° E), Disina (11.48135° N and 9.91903° E), Ningi (11.31° N and 10.15° E), Gubi (10° 26' 16" N latitude and 9° 48' 42" E)

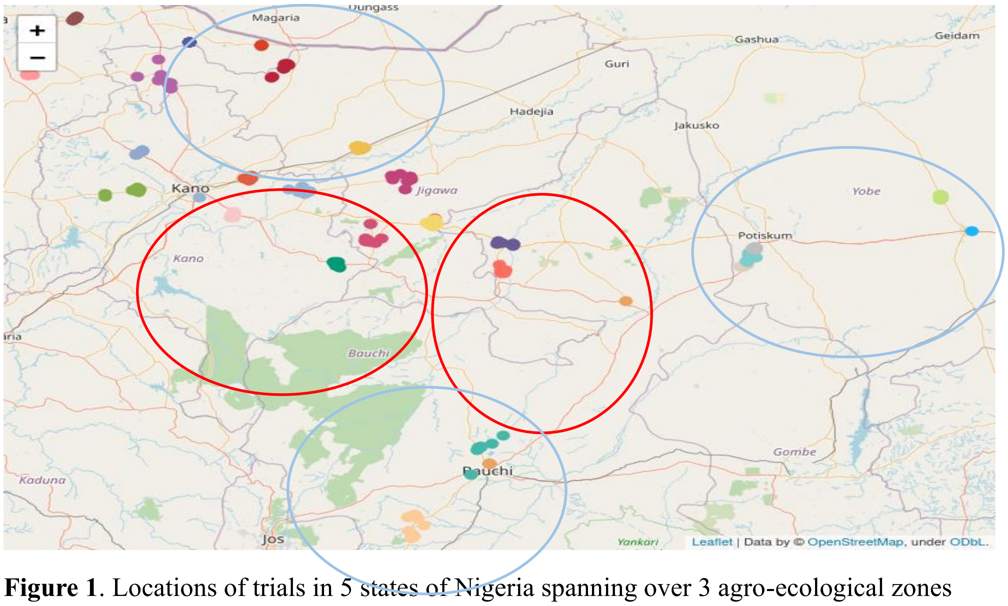

Figure 1. Locations of trials in 5 states of Nigeria spanning over 3 agro-ecological zones

Experimental design and genetic materials

The on-farm trials were implemented using the Tricot approach. Tricot implements principles of decentralized on-farm testing by randomly assigning technologies to each farm (Figures 2, 3, 4). Each Tricot experiment follows the balanced incomplete block design in blocks of three (van Etten *et al*., 2019a; van Etten *et al.,* 2020). This ensures an optimality by connecting all the genotypes in the complete set (de Sousa *et al*., 2024). The elite crop genotype names were masked to anonymize their identity and avoid bias during evaluation. The experiment was designed using the ClimMob platform (Quirós *et al*., 2024), accessible at https://ClimMob.net.

Data analysis

Data were collected from 290 farms for each crop during the vegetative, flowering, and harvest phases of growth and development. The data was processed using the R packages ClimMob Tools (de Sousa and van Etten, 2024) and gosset (de Sousa *et al*., 2023). The data were analyzed using the Plackett–Luce model (Luce, 1959; Plackett, 1975), implemented in the R package Plackett-Luce (Turner *et al*., 2020), and extended with model-based recursive partitioning, which produces Plackett–Luce trees (Zeileis *et al*., 2008). The Plackett–Luce model with recursive partitioning has been applied in several studies analyzing data from Tricot trials (van Etten *et al*., 2019b; Brown *et al*., 2022). The correlation between the 'Overall Preference' and the other traits is estimated using the Kendall tau coefficient (Kendall, 1990). The coefficient is an equivalent of a Pearson's correlation designed for ranking data, ranging from -1 to 1, where 1 denotes correlation and -1 indicates negative association between the pair of variables.

Results and Discussion

Groundnut

The results (Figure 2) showed how the network of groundnut genotypes under study interconnected with genetic similarity, yield performance and adaptability. Highly connected genotypes in the network were considered as more adaptable and had higher yield potential and disease resistance. The existence of check varieties (SAMNUT series) showed benchmarking against industry standards, with well connected genotypes as potential valuable candidates for large production and breeding programs. Highly connected genotypes showed a predictable performance across diverse environments, a property critical for stable yields that are necessary for food security and economic stability. These genotypes can also be used as parental lines in breeding programs to improve stress tolerance, disease resistance, and general productivity. They can also be valued for their drought, high-temperature, and erratic precipitation resistance, which will help to sustain agriculture in the future. Adoption of high-performing genotypes among smallholder farmers will help mitigate production risks and enhances profitability. The findings from the study were in line with earlier research by Nigam *et al*. (2012), who highlighted the importance of genetic diversity for breeding, and Abate *et al*. (2017), stressing the plasticity of strongly bound genotypes.

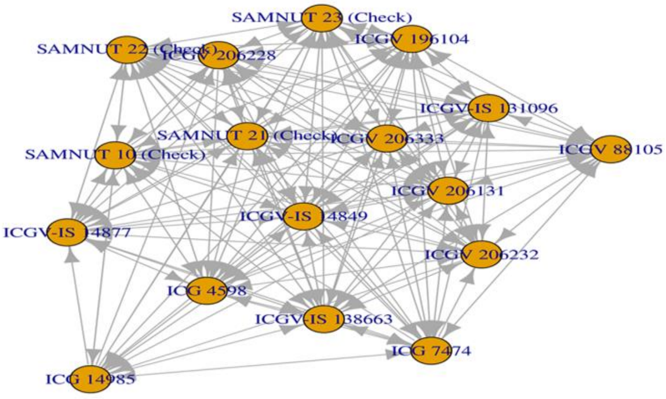

Figure 2. Experimental network representation of groundnut genotypes tested in this experiment. Arrows indicate direct paths of wins and losses between each pair of items, indicating that the item co-occur in at least one experimental block. Genotypes with no direct path are connected using a Bayesian prior.

Table 2. Summary of traits and number of observations (answers) per trait used in testing groundnut genotypes.

Trait	Data collection moment	Question asked	Number of valid answers
Germination	Vegetative	Which option germinated more plants? Which option germinated less plants?	263
Vigor	Vegetative	Which option showed the best vigor? Which option showed the worst vigor?	242
Foliar disease	Reproductive	Which option is more resistant to foliar disease? Which option is more susceptible to foliar disease?	106
Haulm yield (biomass)	Harvest	Which option has the higher haulm yield (biomass)? Which option has the lower haulm yield (biomass)?	211
Flowering	Reproductive	Which option flowered first? Which option flowered last?	248
Pod yield	Harvest	Which option has the higher pod yield? Which option has the lower pod yield?	236
Grain size	Harvest	Which option has the best grain/seed size for the target market? Which option has the worst grain/seed size for the target market?	165
Grain colour	Harvest	Which option has the best grain/seed colour for the target market? Which option has the worst grain/seed colour for the target market?	155
Overall preference	Harvest	Overall, which option was the best? Overall, which option was the worst?	182
Maturity	Harvest	Which option has the earlier maturity? Which option has the later maturity?	227

Performance of groundnut genotypes tested on farm

Analysis of variance showed significant differences ($p<0.05$) among the genotypes tested for vigor, germination, days to 50% flowering and pod yield indicating that at least one genotype had a superior performance when compared to the others for these traits (Table 3).

Table 3. Analysis of variance (ANOVA) for the performance of groundnut genotypes by trait evaluated by 290 farmers in 2024

Trait	Vigor	Germination	Foliar disease	Days to 50% flowering	Maturity	Haulm yield	Pod yield	Grain size	Grain colour	Overall preference
logLik	-396.79	-426.49	-179.98	-428.94	-396.43	-369.10	-404.65	-288.33	-268.75	-321.79
DF	710.00	773.00	302.00	728.00	665.00	617.00	692.00	479.00	449.00	530.00
Statistic	73.63***	89.49***	19.90	30.83*	20.60	17.92	36.41**	14.61	17.95	8.61

*, ** significant at 0.05 and 0.01 respectively

Reliability

The probability of a tested genotype in outperforming a check based on worth estimates from Plackett-Luce model are presented in Appendix 1. Considering the overall preference, ICGV-IS 14877 and ICGV 196104 had the highest probabilities of outperforming all the check varieties (SAMNUT 10, SAMNUT 23, SAMNUT 21 and SAMNUT 22) used (Appendix 1). This indicated that the precision of their 6 estimated worth and their potential response to selection is higher compared to all the check varieties used. Reliability is a breeding metric proposed by Eskridge and Mumm (1992).

Log-worth of genotypes tested

There was no significant difference in log-worth of the genotypes in comparison with the check varieties used (Figure 3). This indicted that the genotypes tested had statistically similar performance with the check varieties.

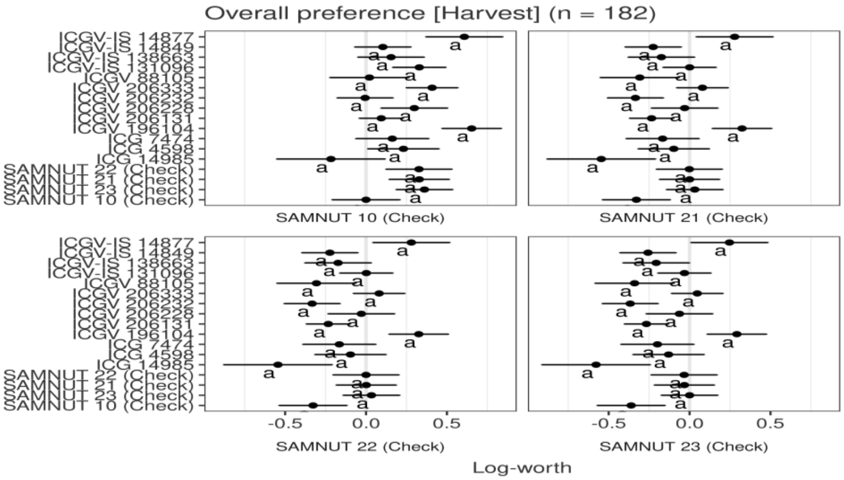

Figure 3. Plackett-Luce Model estimates (log-worth) of tested groundnut genotypes for the reference trait 'Overall Preference' assessed in this trial.

Kendall tau correlation Significant

Significant correlation (p<0.05) was observed between overall preference and grain size, pod yield, grain colour, haulm yield, maturity and germination (Table 4). Kendall tau coefficient of correlation was strongest for grain size (0.45***), while foliar disease (0.12) had the weakest correlation with overall preference. This indicates that grain size had the greatest influence on overall preference followed by pod yield and grain colour.

Table 4. Kendall correlation between 'Overall Preference' and agronomic traits assessed by 290 farmers in 2024.

Trait	Kendall tau
Grain size [Harvest]	0.451***
Pod yield [Harvest]	0.428***
Grain colour [Harvest]	0.388***
Haulm yield (biomass) [Harvest]	0.324**
Maturity [Harvest]	0.203**
Germination [Vegetative]	0.196
Vigor [Vegetative]	0.169
Flowering [Reproductive]	0.157
Foliar disease [Reproductive]	0.122

*, ** significant at 0.05 and 0.01 respectively

Millet

The genotypic network in Figure 3 represents a network of pearl millet genotypes ordered based on genetic relatedness, yield performance, and adaptability across varied environments. Well-connected genotypes like Supersosat, LCICMA-X Supersosat, and LCICMA-X Toroniuo reflect greater adaptability and scope for the production of high-yielding varieties. Pearl millet is predominantly cultivated under semi-arid conditions, so drought tolerance is a desirable attribute. Such genotypes with close interrelations in the figure can show increased tolerance to abiotic stresses such as drought, heat, and poor soil conditions, as well as resistance to diseases, with stable yields.

Clustering of some genotypes indicated common genetic backgrounds, hence suitable for selective breeding programs. Highly interconnected genotypes can be used as parental lines to produce better varieties with increased yield, stress tolerance, and disease resistance. The fact that LCICMA-7X ZANGO and GAM-A-11-14X SUPEROSAT are high-yielding genotypes indicated their potential for large scale production, hence ensuring food security and profitability to farmers. Climate change poses a danger to pearl millet producers, particularly in the sub-Saharan region of Africa and South Asia. High connectivity genotypes will tend to perform well under stress in performance trials and therefore are suitable for climate-resilient breeding schemes. Producers gain from stress-tolerant and high-yielding types that minimize risk and maximize market stability. Conservation studies (Varshney *et al*., 2017; Yadav *et al*., 2018; Gemenet *et al*., 2020; ICRISAT, 2021) refer to network-based selection for the determination of high-performing, climate-tolerant millet varieties and enhance the importance of the study

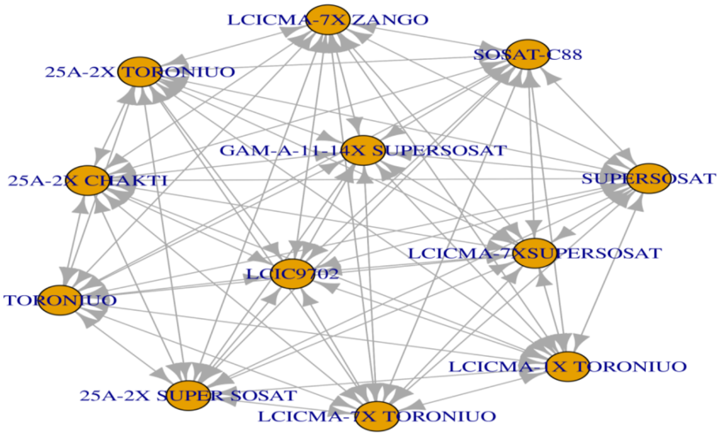

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Figure 4. Experimental network representation of pearl millet genotypes tested in this experiment. Arrows indicate direct paths of wins and losses between each pair of items, indicating that the item co-occur in at least one experimental block. Genotypes with no direct path are connected using a Bayesian prior.

Table 5. Summary of traits and number of observations (answers) per trait used in testing pearl millet genotypes.

Trait	Data collection moment	Question asked	Number of valid answers
Plant survival 1	Vegetative	Which option has the higher plant survival rate?, Which option has the lower plant survival rate?	256
Diseases resistance	Vegetative	Which option is more resistant to diseases?, Which option is more susceptible to diseases?	87
Drought tolerance	Vegetative	Which option is more tolerant to drought?, Which option is more susceptible to drought?	114
Overall preference	Harvest	Overall, which option was the best?, Overall, which option was the worst?	249
Yield	Harvest	Which variety has the highest yield?, Which variety has the lowest yield?	249
Downy mildew	Vegetative	Which option is more resistant to downy mildew?, Which option is more susceptible to downy mildew?	34
Striga resistance	Physiological Maturity	Which option is more resistant to striga?, Which option is more susceptible to striga?	51
Plant survival 2	Physiological Maturity	Which option has the higher plant survival rate?, Which option has the lower plant survival rate?	206

Panicle length	Physiological Maturity	Which option has the larger panicles?, Which option has the smaller panicles?	207
Maturity	Physiological Maturity	Which option has the earlier maturity?, Which option has the later maturity?	209

Performance of pearl millet genotypes tested

Results from an analysis of variance (ANOVA) testing the hypothesis showed that at least one genotype had a superior performance when compared to the others in the set (Table 6). Plant survival 1 (Vegetative Stage) had the highest significance ($p < 0.001$), indicating that early plant survival is a critical trait for selection in the breeding population. Drought tolerance (Vegetative Stage) and Overall preference and Yield (Harvest Stage) were significant at $p < 0.01$, suggesting these traits are important for developing climate-resilient and farmer-preferred varieties. Maturity and Plant survival 2 showed weak significance ($p < 0.05$), indicating their potential importance in final yield stability. The results highlighted Plant survival, Drought tolerance, Yield, and Overall preference as priority traits for pearl millet breeding.

Table 6. Analysis of variance (ANOVA) for the performance of pearl millet genotypes by trait evaluated by 290 farmers in 2024

Trait	logLik	df	Statistic
Plant survival 1 [Vegetative]	-424.701	757	67.978***
Diseases resistance [Vegetative]	-150.626	250	10.514
Drought tolerance [Vegetative]	-188.801	331	30.920**
Overall preference [Harvest]	-431.833	736	28.630**
Yield [Harvest]	-431.833	736	28.630**
Downy mildew [Vegetative]	-55.997	91	9.846
Striga resistance [Physiological maturity]	-86.719	142	9.322
Plant survival 2 [Physiological maturity]	-360.686	607	16.832
Panicle length [Physiological maturity]	-365.007	610	11.774
Maturity [Physiological maturity]	-365.324	616	18.308

*, ** and significant at 0.05, 0.01 and 0.001 respectively

Reliability

The reliability estimates based on the PL model Appendix 2 shows the probability of genotypes outperforming four check varieties (SOSAT-C88, SUPERSOSAT, TORONIUO, and LCIC9702). LCICMA-7X SUPERSOSAT consistently exhibited the highest reliability across all checks, making it the most promising genotype. LCICMA-7X ZANGO also showed high reliability, particularly against SUPERSOSAT and TORONIUO, indicating its selection potential. Meanwhile, LCICMA-7X TORONIUO and LCICMA-1X TORONIUO displayed moderate reliability. Genotype performance varied across checks, with SUPERSOSAT being easier to outperform and SOSAT-C88 serving as the most competitive benchmark.

Log-worth of pearl millet genotypes

The log-worth trait analysis in Figure 1 illustrates the performance of pearl millet genotypes across various agronomic traits against four check varieties (SOSAT-C88, SUPERSOSAT, TORONIUO, and LCIC9702). Genotypes from the TORONIUO population consistently exhibited positive log-worth values, indicating better plant survival under stress conditions and higher yield potential, making them desirable for drought-prone environments. The SUPERSOSAT population showed moderate performance but excelled in panicle length, which could enhance grain yield. However, most genotypes demonstrated poor disease resistance, as reflected by negative log-worth values. The consistent moderate performance of SUPERSOSAT across traits suggested genetic stability, while TORONIUO's superior performance highlighted its breeding potential for stress resilience and farmer preference.

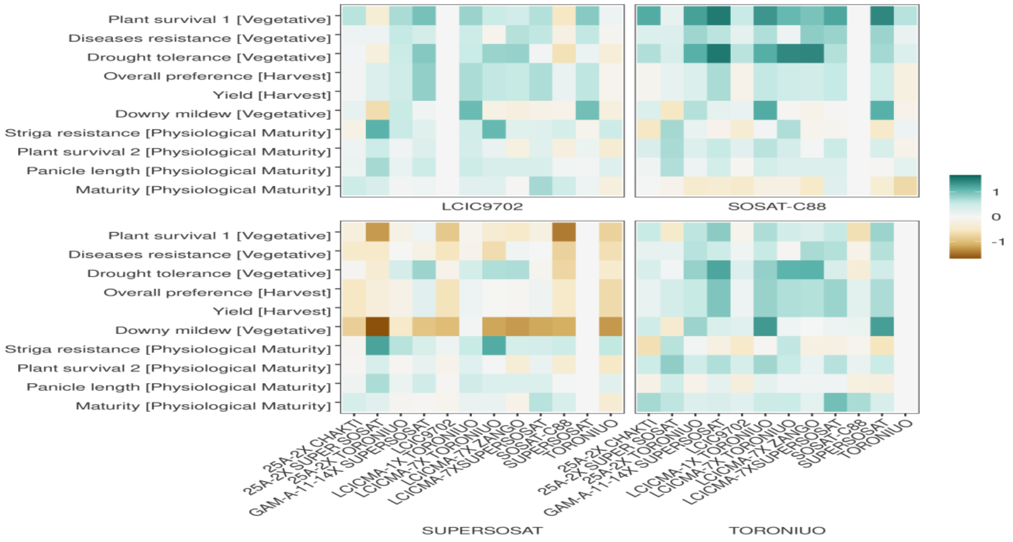

Figure 5. log-worth of genotypes by trait for pearl millet

Kendall tau correlation

The Kendall correlation analysis presented in Table 7 measures the association between Overall Preference and various agronomic traits assessed in the pearl millet trial. The Kendall tau (τ) coefficient ranges between -1 and 1, where positive values indicate a positive correlation, and negative values indicate an inverse relationship. The Kendall correlation analysis indicated that Yield [Harvest] is the primary driver of Overall Preference, with a highly significant and positive relationship. Plant survival at different growth stages also significantly contributed to farmers' preference, reflecting the importance of drought tolerance. However, other traits such as Striga resistance, panicle length, and disease resistance showed weak or no significant correlations, suggesting they played a lesser role in farmers' selection criteria. These findings underscore the importance of prioritizing high yielding and stress-tolerant genotypes in pearl millet breeding programs while integrating additional resistance traits through targeted breeding efforts.

Table 7. Kendall correlation between overall preference and other traits for pearl millet

Trait	Kendall tau
Yield [Harvest]	0.936***
Plant survival 2 [Physiological maturity]	0.287**
Plant survival 1 [Vegetative]	0.221*
Panicle length [Physiological maturity]	0.138
Striga resistance [Physiological maturity]	0.137
Maturity [Physiological maturity]	0.117
Drought tolerance [Vegetative]	0.084
Diseases resistance [Vegetative]	0.013
Downy mildew [Vegetative]	-0.006

*, **, *** significant at 0.05, 0.01 and 0.001 respectively

Sorghum

The genotypic network diagram (Figure 6) displayed performance-based relationships among the tested sorghum genotypes. Well-associated genotypes such as ICSX 1680008-B-56-B-1, ICSX 1680005-B-143 B-1, and ICSX 1680023-B-147-B-2 possessed high breeding value, adaptability, and yield stability. These genotypes can be employed as core parents in hybrid breeding. Benchmark varieties SAMSORG 40 and SAMSORG 4 were placed in the central position due to their application in testing for stress tolerance and yield stability. Clusters' patterns revealed common genetic traits such as disease resistance and drought tolerance.

Sorghum, as a drought-tolerant crop, grows well in semi-arid environments where heat stress and drought affect productivity. Genotypes with hih connectivity have superior yield potential, tolerance to heat and drought, and disease resistance. Their genetic proximity is to blame for breeding programs aimed at the production of better hybrid varieties with optimal agronomic characteristics. Genotype prioritization of large-scale cultivation can increase grain productivity stability, particularly for areas with variable rainfall. Drought-, heat-, and low-fertility-tolerant genotypes must be selected in the breeding programs to ensure long-term sustainability of sorghum (Bernardino *et al*., 2024). Recognition of major parental genotypes facilitates the production of stress-resistant hybrids at high levels of yields.

High-yielding, stress-tolerant varieties minimize risks in production and render farmers more economically viable. They also support the generation of animal feed, contributing to mixed farming systems. Previous studies validate genotype selection through networks. Upadhyaya *et al*. (2019) validate genetic diversity as a key element in breeding efficiency. Haussmann *et al*. (2000) emphasize the utilization of highly linked genotypes due to stability in yield and climate resilience. Future research must validate these correlations using multi environment field trials for effective sorghum breeding. Besides the probability of being ranked first, the reliability of the genotypes, that is, the probability of outperforming the check varieties, were assessed. Using the worth values of the Plackett–Luce model on overall performance at harvest, the reliability of each sorghum genotype was calculated against the check varieties (SAMSORG 40 and 47). The reliability was computed using the gosset package in R (de Sousa *et al*., 2023).

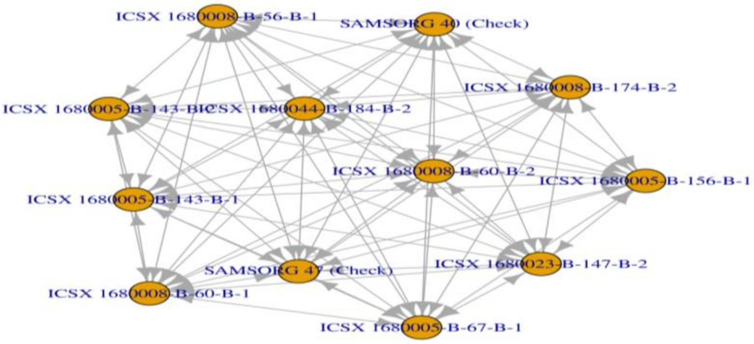

Figure 6. Experimental network representation of sorghum genotypes tested in this experiment. Arrows indicate direct paths of wins and losses between each pair of items, indicating that the item co-occur in at least one experimental block. Genotypes with no direct path are connected using a Bayesian prior.

Performance of sorghum genotypes tested

The result of the analysis of variance (ANOVA) for different traits, determining whether there are significant differences in performance among the tested items (Table 8). The significant differences observed for germination, maturity, plant survival, Striga resistance, yield, and overall preference indicated a strong performance difference across genotypes. 17 The heatmap (Not shown) illustrates the scaled performance of multiple genotypes compared to the checks across various agronomic and farmer-preference traits. The colours represent standardized deviations from the mean: blue-green (+1 to +2) indicates above-average performance, beige (0) represents average performance, and brown (-1 to -2) signifies below-average performance. The yield and overall preference, genotypes 1680044-B-184-B-2 and ICSX 1680005-B-67-B-1 outperformed all other genotypes, including the checks (Figure 7). These two genotypes also had the highest reliability scores over the checks, with significant values of 0.696 and 0.674 (Appendix 3), indicating strong consistency in their superior performance**.**

Table 8. Analysis of variance (ANOVA) for the performance of sorghum genotypes by trait evaluated by 290 farmers in 2024

Trait	Loglik	df	Static
Germination	-420.483	748	65.664**
Plant survival	-306.848	523	24.170*
Striga resistance	-90.321	157	20.036*
Maturity	-323.150	556	30.986**
Panicle length	-305.748	514	15.620
Yield	-381.928	649	24.410*

Threshability	-335.870	556	5.546
Overall preference	-383.452	652	25.054**

Reliability

The probability of a tested genotype outperforming a check based on worth es mates from the Placke-Luce model are presented in Appendix 3. Considering the overall preference, 1680044-B-184-B-2 (0.696**) and ICSX 1680005-B-67-B-1 (0.674**) had the highest significant probabilities of outperforming all the checks (SAMSORGs 40 and 47) varieties. This indicated that the precision of their estimated worth and their potential response to selection is higher compared to all the check varieties used. Reliability is a breeding metric proposed by Eskridge and Mumm (1992).

Log-worth of genotypes tested

Significant differences were observed in log-worth of the genotypes in comparison with the check varieties used (Figure 7). This indicted that the genotypes tested statistically differed in performance with the check varieties. The overall preferred variety being ICSX 1680044-B-184-B-2.

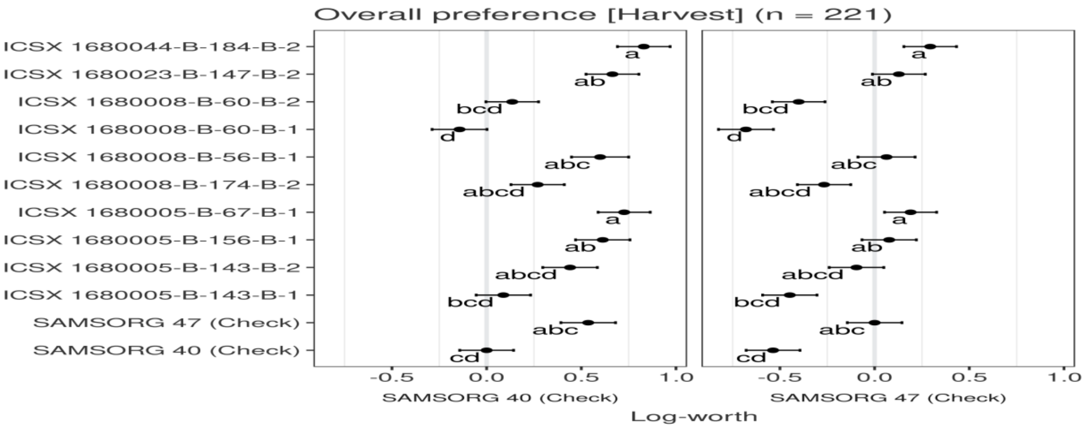

Figure 7. Plackett-Luce Model estimates (log-worth) of tested sorghum genotypes for the reference trait 'Overall Preference' assessed in this trial.

Kendall tau correlation

The Kendall Tau correlation coefficients (Table 9) evaluate the association between overall preference and various sorghum traits, revealing key factors influencing farmer selection. Yield (r = 0.904**) exhibited the strongest and most significant positive correlation with overall preference, emphasizing that grain yield is the primary criterion for farmers when choosing sorghum varieties. Following yield, germination and plant survival (r = 0.347**) also showed significant positive correlations with overall preference. This aligns with the practical needs of farmers, as higher yields translate to higher economic returns, while strong seedling establishment ensures good crop performance. These findings highlighted the need for breeding programs to prioritize high-yielding sorghum varieties with strong seedling vigor and survival rates to align with farmer preferences, enhance adoption rates, and improve productivity in target environments.

Table 9. Kendall correlation between overall preference and other traits for sorghum

Traits	Kendall Tau
Germination	0.347**
Plant survival	0.347**
Striga resistance	0.1120
Maturity	0.102

Panicle length	0.068
Yield	0.904**
Threshability	0.136

Conclusion

The trial identified the most preferred genotypes for each crop. Genotypes 1680044-B-184-B-2 and ICSX 1680005-B-67-B-1 were most preferred for sorghum, ICGV-IS 14877 and ICGV 196104 for groundnut and LCICMA-1 x TORONIUO and GAM-A-11-14 x SUPERSOSAT for millet. Farmers' overall preferences were primarily influenced by pod yield and grain size in groundnut and grain yield in both pearl millet and sorghum. These findings highlighted the potential of TRICOT in accelerating the adoption of improved varieties, ensuring that breeding programs align with farmers' needs and preferences.

Author Contributions

S.G.M.; Conceptualization; investigation; project administration; supervision, validation; review and editing of draft. R.O.A.: Conceptualization; investigation; validation; data curation; formal analysis; methodology; software; writing—review and editing of original draft. M.A.D: Conceptualization; investigation; validation; data curation; formal analysis; methodology; software; writing—review and editing of original draft. H.O.A. Conceptualization; investigation; validation; data curation; formal analysis; methodology; software; writing—review and editing of original draft. A.S: review and editing of draft.

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Declaration

The authors declare no competing interests

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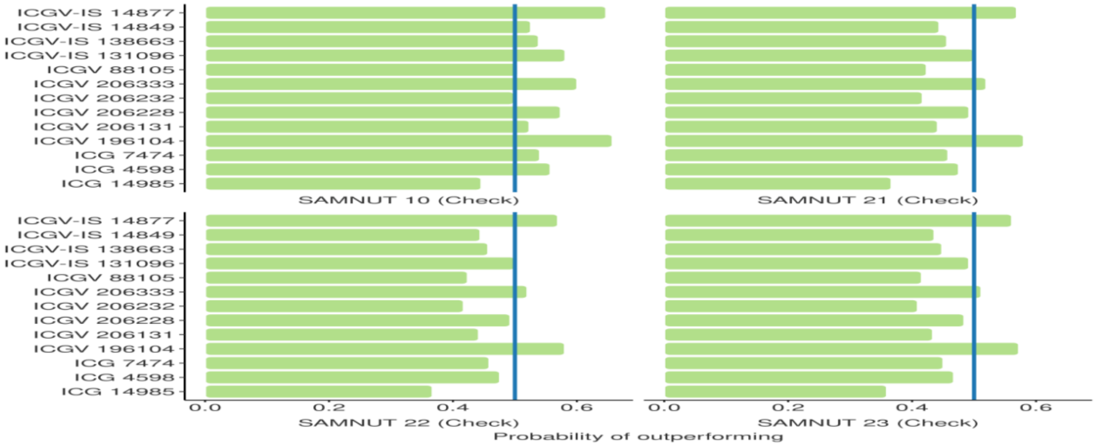
Appendix 1



Appendix 2. Reliability of genotypes over checks for agronomic traits for pearl millet

Genotype	Reliability	Worth	Check
GAM-A-11-14X SUPERSOSAT	0.671**	0.124	SOSAT-C88
25A-2X TORONIUO	0.579	0.084	SOSAT-C88
25A-2X SUPER SOSAT	0.543	0.072	SOSAT-C88
LCICMA-1X TORONIUO	0.641*	0.109	SOSAT-C88
LCICMA-7X ZANGO	0.605	0.093	SOSAT-C88
LCICMA-7X TORONIUO	0.612	0.096	SOSAT-C88
25A-2X CHAKTI	0.481	0.056	SOSAT-C88
LCICMA-7XSUPERSOSAT	0.637*	0.107	SOSAT-C88

GAM-A-11-14X SUPERSOSAT	0.56	0.124	SUPERSOSAT
25A-2X TORONIUO	0.462	0.084	SUPERSOSAT
25A-2X SUPER SOSAT	0.426	0.072	SUPERSOSAT
LCICMA-1X TORONIUO	0.527	0.109	SUPERSOSAT
LCICMA-7X ZANGO	0.489	0.093	SUPERSOSAT
LCICMA-7X TORONIUO	0.495	0.097	SUPERSOSAT
25A-2X CHAKTI	0.366*	0.056	SUPERSOSAT
LCICMA-7XSUPERSOSAT	0.523	0.107	SUPERSOSAT
GAM-A-11-14X SUPERSOSAT	0.720***	0.124	TORONIUO
25A-2X TORONIUO	0.635*	0.084	TORONIUO
25A-2X SUPER SOSAT	0.6	0.072	TORONIUO
LCICMA-1X TORONIUO	0.693**	0.109	TORONIUO
LCICMA-7X ZANGO	0.659*	0.093	TORONIUO
LCICMA-7X TORONIUO	0.665*	0.096	TORONIUO
25A-2X CHAKTI	0.539	0.056	TORONIUO
LCICMA-7XSUPERSOSAT	0.689**	0.107	TORONIUO
GAM-A-11-14X SUPERSOSAT	0.699**	0.124	LCIC9702
25A-2X TORONIUO	0.611	0.084	LCIC9702
25A-2X SUPER SOSAT	0.576	0.072	LCIC9702
LCICMA-1X TORONIUO	0.671*	0.109	LCIC9702
LCICMA-7X ZANGO	0.636*	0.093	LCIC9702
LCICMA-7X TORONIUO	0.642*	0.096	LCIC9702
25A-2X CHAKTI	0.513	0.056	LCIC9702
LCICMA-7XSUPERSOSAT	0.667*	0.107	LCIC9702

**: p≤ 0.01

Appendix 3. Reliability of genotypes over checks for agronomic traits for sorghum

Genotype	Reliability	Reliability S.E	Worth	Check
ICSX 1680005-B-143-B-1	0.522	0.053169	0.059	SAMSORG 40
ICSX 1680005-B-67-B-1	0.674**	0.04629	0.111	SAMSORG 40
ICSX 1680005-B-156-B-1	0.649*	0.049903	0.099	SAMSORG 40
ICSX 1680044-B-184-B-2	0.696**	0.04525	0.123	SAMSORG 40
ICSX 1680008-B-56-B-1	0.645*	0.052717	0.098	SAMSORG 40
ICSX 1680005-B-143-B-2	0.608	0.051914	0.083	SAMSORG 40
ICSX 1680008-B-60-B-1	0.464	0.052884	0.046	SAMSORG 40
ICSX 1680008-B-174-B-2	0.567	0.051794	0.070	SAMSORG 40
ICSX 1680023-B-147-B-2	0.660*	0.047835	0.104	SAMSORG 40
ICSX 1680008-B-60-B-2	0.534	0.051487	0.061	SAMSORG 40
ICSX 1680005-B-143-B-1	0.390	0.049299	0.059	SAMSORG 47
ICSX 1680005-B-67-B-1	0.547	0.05084	0.111	SAMSORG 47
ICSX 1680005-B-156-B-1	0.519	0.053156	0.099	SAMSORG 47
ICSX 1680044-B-184-B-2	0.573	0.051015	0.123	SAMSORG 47
ICSX 1680008-B-56-B-1	0.516	0.055864	0.098	SAMSORG 47
ICSX 1680005-B-143-B-2	0.476	0.052826	0.083	SAMSORG 47
ICSX 1680008-B-60-B-1	0.336*	0.046207	0.046	SAMSORG 47
ICSX 1680008-B-174-B-2	0.434	0.050394	0.070	SAMSORG 47
ICSX 1680023-B-147-B-2	0.532	0.051678	0.104	SAMSORG 47
ICSX 1680008-B-60-B-2	0.401	0.048369	0.061	SAMSORG 47

**: p≤ 0.01