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Additive Main-Effect and Multiplicative Interaction (AMMI) Model and Genotype Plus Genotype-Environment Interaction (GGE) Biplot Analysis of Tillering-Associated Traits for Climate-Smart Dual-Purpose Sorghum Selection in Lesotho

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Introduction

Importance of Sorghum:

- Climate-resilient cereal crop vital for food security.
- Dual-purpose varieties address food and livestock feed demands; daptable to diverse environments;
- Tillering traits influence sorghum productivity and adaptability.

Problem Statement:

- Climate change impacts sorghum farming in Lesotho due to unpredictable rainfall, drought, and shrinking arable land.
- Lack of varietal recommendations tailored to local genotypes hinders productivity during climatic variability.

Study Objectives:

- Examine genotype-by-environment interaction (G×E) on tillering traits.
- Identify stable, high-performing sorghum genotypes.

Study site and Experimental Design

Locations:

- Siloe (South): 1634m elevation, Arenosols.
- Nyakosoba (Central): 2034m elevation, Cambisols.
- Mahobong (North): 1682m elevation, fertile Luvisols.

Climatic Conditions:

- Variation in temperature and rainfall influencing sorghum tillering

Materials:

- Evaluated 33 sorghum accessions from diverse origins.

Experimental Layout:

- Lattice design with three replications.

Measured Traits:

- Number of nodes, number of secondary tillers, internode length

Data Analysis Methods

- Statistical Tools: GenStat software.
- AMMI Analysis: Partitioning genotype, environment, and G×E interaction effects; stability assessment using AMMI Stability Value (ASV).
- GGE Biplot Analysis: Visualizing genotype performance and stability across environments; identifying "winner" genotypes.

Results and Discussion:

AMMI ANOVA

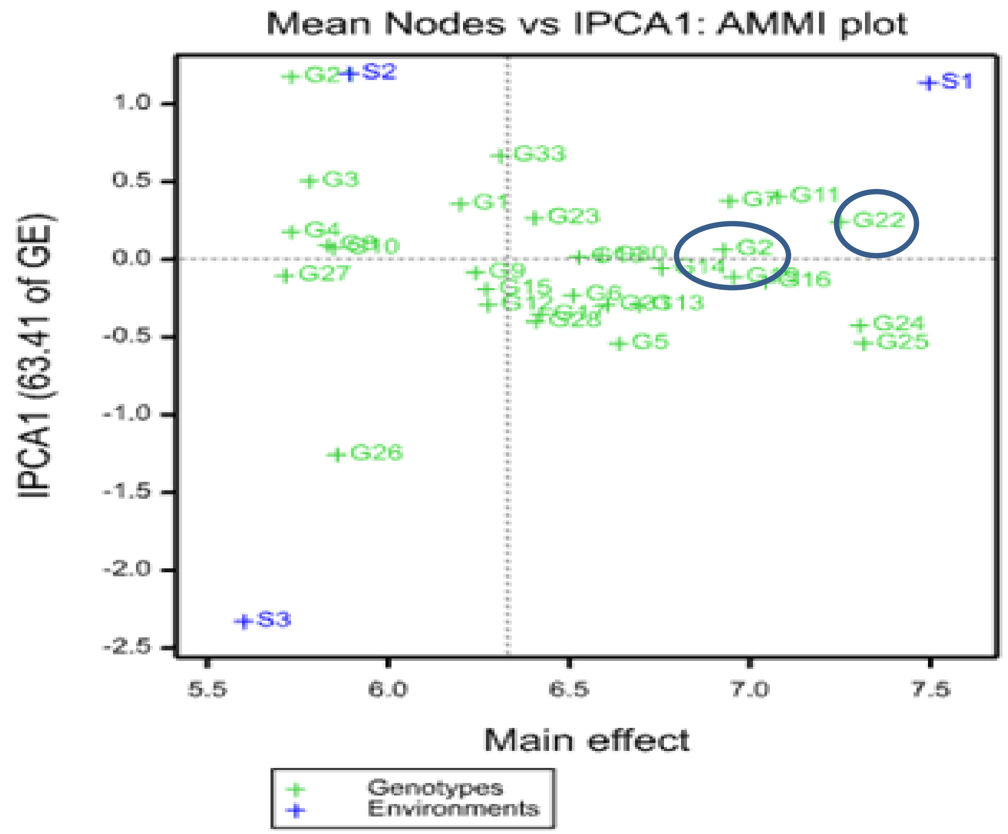
Source of variance	D.f.	Number nodes			number of secondary tillers			Internode length		
		Ss	M.s.	%tv	Ss	M.s.	%tv	Ss	M.s.	%tv
Treatment	98	644.5	6.58***	64.4	89.59	0.914***	76.2	1611.8	16.45***	59.0
Genotype	32	125.4	3.92***	12.5	9.16	0.286**	7.8	594.3	18.57***	36.9
Environment	2	205.5	102.76***	20.5	63.36	31.68***	53.9	244.3	122.15***	8.9
GE interaction	64	313.6	4.9***	31.3	17.07	0.267***	14.5	773.2	12.08***	28.3
IPCA 1	33	198.8	6.03***	63.4	15.60	0.473***	91.4	466.4	14.13***	60.3
IPCA 2	31	114.8	3.7**	36.6	1.47	0.047ns	8.6	306.8	9.9**	39.7
Error	192	340.3	1.77		26.27	0.137		1051.3	5.48	
Total	296	1000.7	3.38		117.57	0.397		2730.3	9.22	

AMMI Biplot

Genotypes on the right side of the grand mean level suggests high mean performance and near to the IPCA=0 line suggest no GE interaction

The environment points are more scattered than genotypes, indicating that environment variability is greater than genotype variability.

Traits	High-performing genotypes	More stable
Number of nodes	G22, G24 and G2	G2 and G14
Number of secondary tillers	G19, G2 and G15	G2 and G18
Internode length	G15, G7 and G6	G6, G7 and G6



AMMI Stability Value (ASV) & Genotype Selection Index (GSI)

- ASV indicates stability of genotypes across environments.
- GSI combines ASV rank and mean performance rank for the genotype selection

Traits	Genotypes	RASV	RGM	GSI
Number of nodes	G2	3	8	11
	G19	6	6	12
	G22	10	3	13
Number of secondary tiller	G4	1	4	5
	G12	2	5	7
	G2	7	2	9
Internode length	G14	2	2	4
	G22	8	1	9
	G2	1	14	15

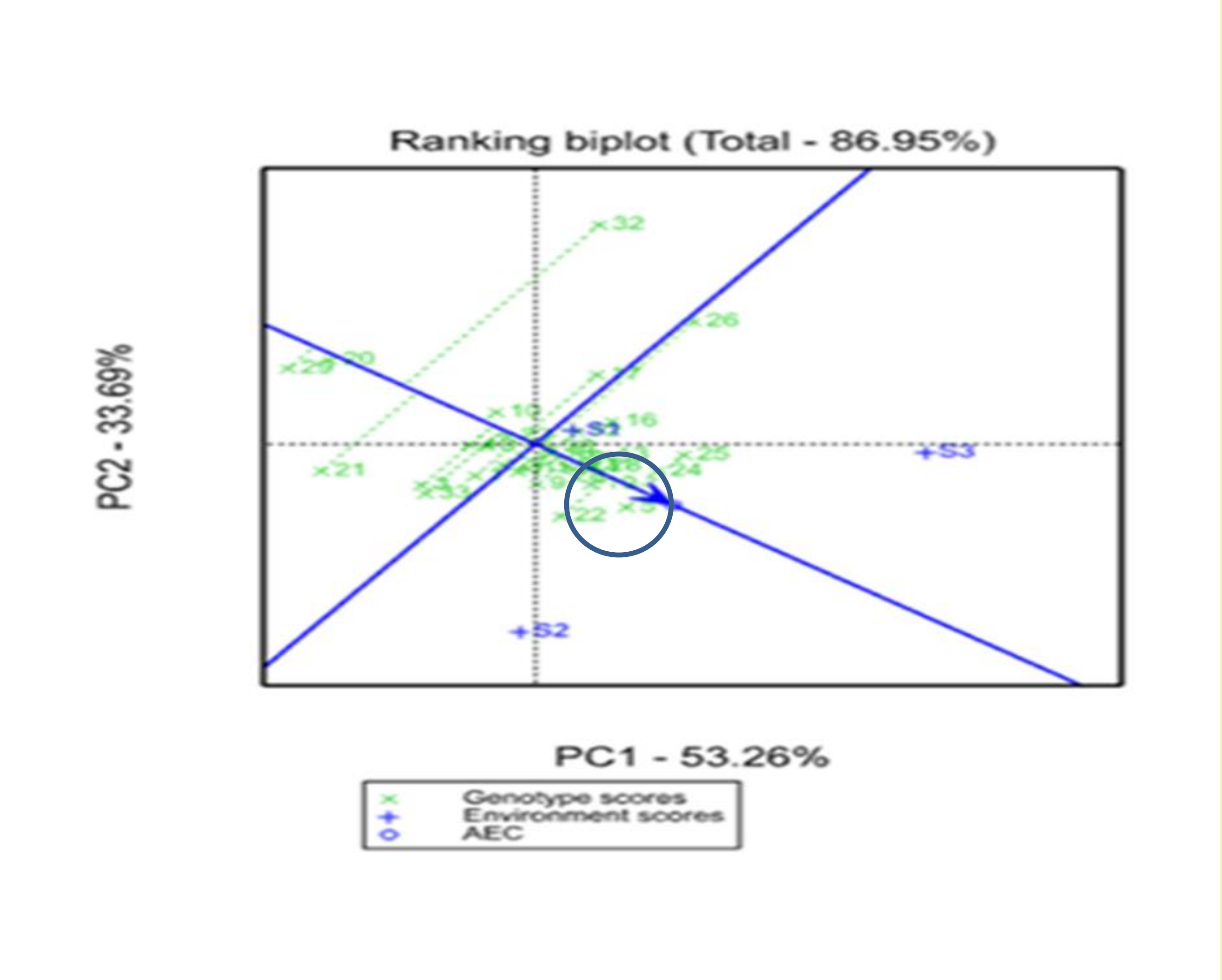
GGE Biplot Analysis: Mean Performance and Stability

Abscissa line which is aligned with the AEA, shows the mean performance of the genotypes.

Genotypes close to the AEA in the direction of arrow have higher average performance. Genotypes closer to this axis are considered stable.

Traits	High-performing genotypes	Most stable genotypes
Number of nodes	G5, G25 and G24	G5
Number of secondary tiller	G22 and G28	G22
Internode length	G31 and G20	G1 and G22

Number of nodes ranking biplot



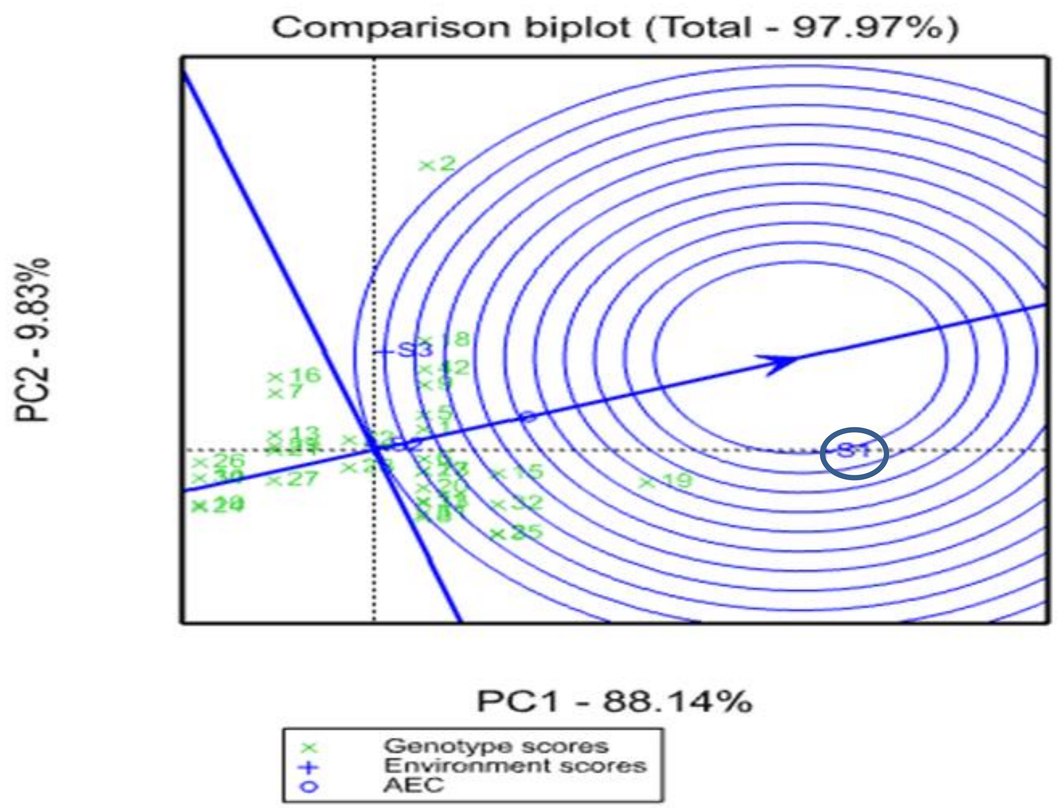
GGE Biplot: Comparison of Test Environments

The ideal environment is positioned closer to the first concentric circle of the AEC and have longer vectors from the biplot origin.

Environment with long vectors are more discriminative.

Traits	Discriminating environment
Number of nodes	Mahobong and Nyakosoba
Number of secondary tiller	Siloe
Internode length	Mahobong

Number of Secondary tillers: Environments comparison biplot

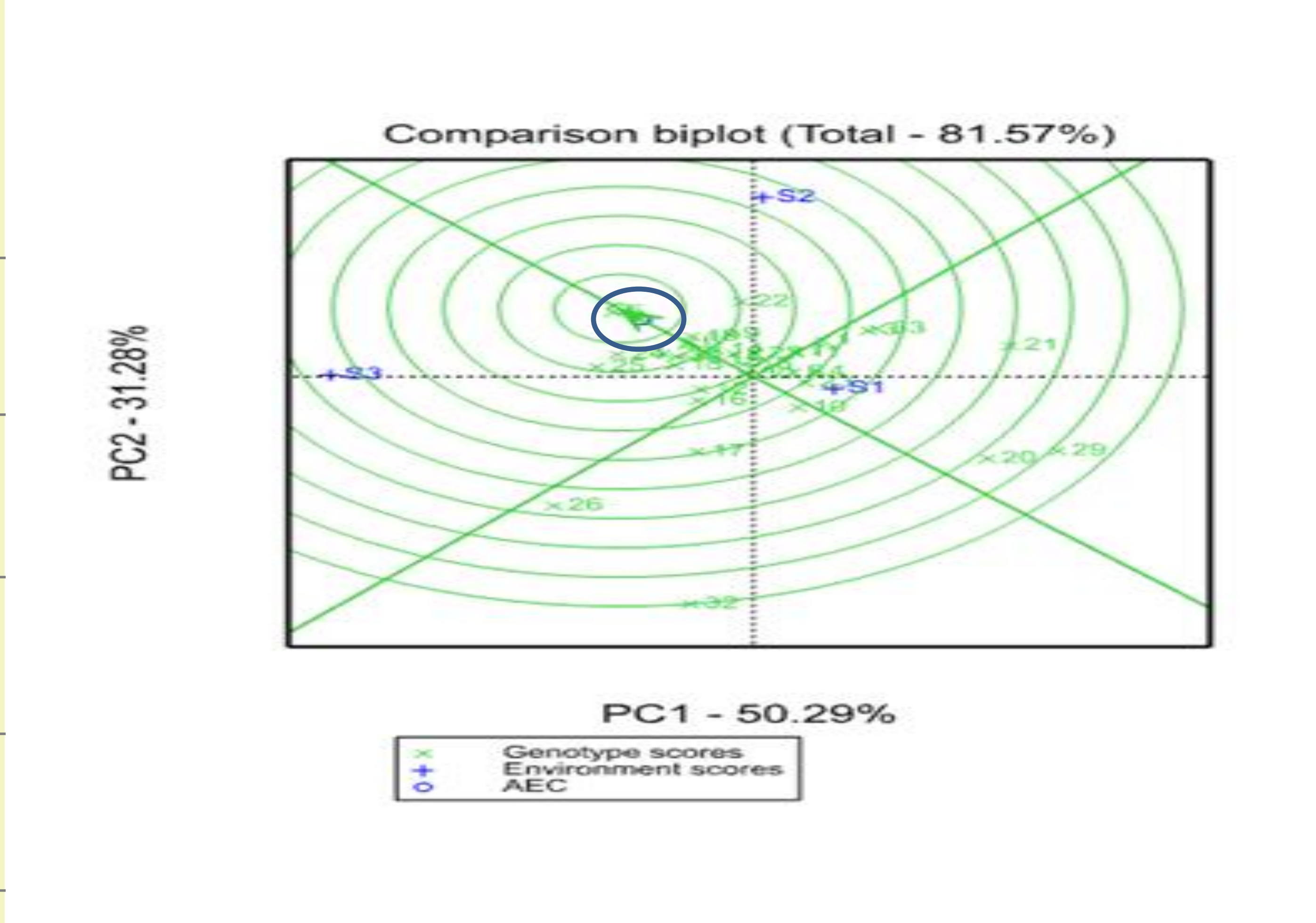


Genotype ranking: best genotype assessment

Genotypes closer to the center of concentric circle are considered high performing and stable across environments (winning genotypes)

Traits	High performing
Number of nodes	G5, G15, G22 and G24
Number of secondary tillers	G22, G25 and G28
Internode length	G19 and G15

Number of nodes: ranking genotypes assessment biplot



Conclusion and recommendations

- **Key Findings**: Genotypes G2 and G22 are stable and high-performing across environments in Lesotho. Siloe and Mahobong are ideal test sites for future trials.
- **Recommendations**: Promote genotypes G22 and G2 for cultivation; conduct further testing under diverse environmental conditions; focus breeding programs on multi-environment trials to enhance adaptability under climate change scenarios .
- **Limitations**: Limited test environments may not generalize findings across all regions in Lesotho.
- **Future Research Areas**: Explore long-term adaptability under climate change scenarios; assess additional sorghum traits like grain quality or biomass yield.

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