RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 60 Issue 8: 1189-1195 (August 2026)

Genetic Parameters of Quantitative Traits in S_4 Maize (*Zea mays* L.) Lines under Two Environmental Conditions on Dryland in West Nusa Tenggara Province, Indonesia

I. Wayan Sudika[1], I. Wayan Sutresna[1], Dwi Ratna Anugrahwati[1], Ni Wayan Sri Suliartini[1] 10.18805/IJARe.AF-1040

ABSTRACT

Background: Evaluation of genetic parameters under contrasting environmental conditions is essential to determine appropriate selection criteria for advancing lines to the fifth generation (S_5) through selfing. This study aims to evaluate the genetic parameters, including genetic diversity, heritability and genotypic correlation of quantitative traits of maize lines under two environmental conditions on dry land.

Methods: The experiment was conducted using a randomized complete block design (RCBD) arranged in a split-plot design (SPD). Environmental condition served as the main plot, while genotype was assigned as the subplot, with two replications for each treatment combination. Observations were recorded on growth traits, harvest age, yield and yield components. Data were analyzed using split-plot analysis of variance for combined environmental conditions and randomized block analysis for each individual environment at a 5% significance level. Genetic parameters, including the coefficient of genetic variation, broad-sense heritability and genotypic correlation coefficient (particularly between leaf angle and yield traits), were subsequently calculated.

Result: The genetic diversity for most quantitative traits was relatively narrow under both environmental conditions. However, cob weight and grain yield under drought-stressed conditions showed moderate genetic variability. Heritability estimates were generally low for most quantitative traits observed accross both environments. No significant genotypic correlation was observed between leaf angle with other traits. In contrast, most traits exhibited positive genotypic correlations with yield, ranging from weak (0.361) to strong (0.995) accross both environmental conditions. Advancement to the generation through selfing should involve selection foor taller plants to improve yield under both drought-stressed and normal environmental conditions.

Key words: Drought stress, Dryland agriculture, Food security, Genetic variability, Heritability, Maize (*Zea mays* L.).

INTRODUCTION

Corn (*Zea mays* L.) is an important cereal crop worldwide. It is used for food, animal feed and industrial raw materials and has significant economic value (Yao *et al.*, 2021). Corn is a source of carbohydrates; it can be used for oil, flour, biofuel, beverages and other products. Corn is also a major source of animal feed (Garg *et al.*, 2026). The carbohydrate content is more than 70 per cent, protein is around 9 per cent and 4 per cent oil (Ayyub and Raheem, 2026). Increasing corn production can be done on dry land, considering that corn is able to adapt widely to various agro-climatic conditions (Reddy *et al.*, 2025). One way to increase production is by using superior varieties. Superior corn varieties for dryland areas are characterized by drought tolerance, super early maturity and high yield potential (Azrai *et al.*, 2016).

Efforts to develop superior hybrid maize varieties with high productivity continue to be intensified (Ogunniyan and Olakojo, 2014). Hybrid varieties generally exhibits higher productivity than open-pollinated or composite varieties due to the heterosis effect (Kandel, 2021). In Indonesia, maize cultivation is predominantly carried out on dry land, accounting for approximately 75.92% of total production area (Yustiningsih *et al.*, 2026). Therefore, breeding programs should prioritize the development of varieties adapted to dryland conditions.

[1]Department of Agroecotechnology, Faculty of Agriculture, University of Mataram, Mataram 83125, Indonesia.

Corresponding Author: I. Wayan Sudika, Department of Agroecotechnology, Faculty of Agriculture, University of Mataram, Mataram 83125, Indonesia. Email: iw sudika@unram.ac.id

How to cite this article: Sudika, I.W., Sutresna, I.W., Anugrahwati, D.R. and Suliartini, N.W.S. (2026). Genetic Parameters of Quantitative Traits in S_4 Maize (*Zea mays* L.) Lines under Two Environmental Conditions on Dryland in West Nusa Tenggara Province, Indonesia. *Indian Journal of Agricultural Research.* **60(8):** 1189-1195. doi: 10.18805/IJARe.AF-1040.

Submitted: 06-03-2026 **Accepted:** 03-07-2026 **Online:** 04-08-2026

One of the essential traits required for dryland adaption is tolerance to drought stress. However, the availability of drought-tolerant maize varieties remains limited, necessitating targeted breeding programs. Drought stress significantly affects maize growth and productivity (Kim and Lee, 2023; Ishfaq *et al.*, 2025). Among abiotic stresses, drought is one of the most critical constraints limiting maize yield, especially in rainfed dryland systems (Adhikari *et al.*, 2019; Abdul Mohsin and Farhood, 2023; Yue *et al.*, 2024). Drought stress during the flowering stage can disrupt pollination and kernel formation, resulting in substantial yield losses (Zhou *et al.*, 2021). These yield reductions can be minimized through the development of drought-tolerant maize varieties (Ao *et al.*, 2020).

The development of drought-tolerant hybrid varieties requires the selection of genetically diverse parents in order to achieve high heterosis. This process requires information on gene action to support breeding programs (Owusu *et al.*, 2022). The targeted characteristics of these superior varieties include drought tolerance, early maturuty (70-80 days), narrow leaf angle (<35°) and high yield potential. Estimation of the genetic components of the base population was conducted by (Adeputri *et al.*, 2023). The results indicated that dominance variance for leaf angle and yield was greater than additive variance. However, additive and dominance variances for harvest age were similar. These findings suggest that hybrid breeding is an appropriate strategy for variety development.

The formation of hybrid varieties begins with the development of pure lines through repeated self-pollination (selfing) for 5-6 generations (Akfindarwan *et al.*, 2023). Sudika *et al.,* 2023 conducted selfing up to the third generation. In 2024, the fourth generation (S_4) lines were developed and evaluated under drought-stressed dryland conditions. Three lines were identified as drought tolerant and nine lines were classified as moderately tolerant (Sudika *et al.*, 2024). Evaluation of genetic parameters under contrasting environmental conditions is essential to determine appropriate selection criteria for advancing lines to the fifth generation (S_5) through selfing. Estimating the genotypic correlation coefficient between other traits and yield is important for indirect selection (Lal *et al.*, 2025). Therefore, the objectives of this study was to to estimate genetic parameters including genetic diversity, heritability and genotypic correlation among quantitative traits, especially their association with leaf angle and yield.

MATERIALS AND METHODS

Location, time and experimental materials

The experiment was conducted on dryland equipped with a functioning pump-well irrigation system in Farmers Group "Lembah Telaga", Amor-Amor Hamlet, Gumantar village, North Lombok Regency. The altitude of the location is approximately 60 m above sea level. The experiment was conducted in 2024 from May to August.

The plant materials consisted of 29 maize (*Zea mays* L.) strains, Phonska and Urea (inorganic fertilizers) and Petroganic (organic fertilizers), Gramoxone 276 SL, Calaris 550 SC, Saromyl 35 SD, Furadan 3 G and Meurtieur 30 SC.

Experimental design

The study employed an experimental method using a randomized complete block design arranged in a split-plot design. The experiment consisted of two factors, namely environmental conditions consist of two levels and genotype consisting of 29 lines. The stress condition was placed as the main plot and the genotype as the subplot. Thus, there was 58 treatment combinations, each twice, resulting in 116 experimental units. A split plot design was used because irrigation of two stress condition treatment, was easier and reduced error in the study.

Experimental procedure

The implementation of the experiment includes seed preparation, land preparation, planting, thinning, irrigation, fertilization, weeding and seasoning, pest and disease control, as well as harvest and post-harvest handling. The seeds were first treated with saromyl 35 SD. The experimental field was sprayed with Gramoxone 276 SL one week before planting. Five days after spraying, the soil was cultivated by plowing and harrowing once each, followed by leveling. The leveled experimental plots were divided into two blocks and each block was further divided into two subplots representing drought-stress and normal conditions. The distance between blocks and between subplots was 1 m. Each subplot contained 29 S_4 lines. Each treatment was planted in two rows, with 25 plants per row. The planting spacing was 20 $\times$ 60 cm.

Irrigation was applied according to the environmental treatment conditions. Under mild drought conditions, the crops were not irrigated for 30 days, from 35 to 65 days DAP. Under normal conditions, irrigation was applied once a week from 14 to 70 DAP, in addition to irrigation one day before planting. In both treatments.

Fertilization was conducted twice: the first application at planting and the second at 28 DAP. Phonska fertilizer was applied at a rate of 150 kg/ha and Urea at 100 kg/ha for each fertilization. Weed control was carried out by spraying Calaris 550 SC at 14 DAP at a concentration of 75 cc per 16 L of water. Manual weeding and earthin-up were performed at 28 DAP by hoeing the soil between rows and heaping the soil around the base of the plants. Pest control was conducted twice, at 35 and 65 DAP, by spraying Meurtieur 30 SC at a concentration of 75 cc per 16 L of water.

Harvesting was carried out whe approximately 85% of the plants in each treatment combination had reached physiological maturity, as indicated by dried husks and silks and hardened kernels.

The observed parameters included plant height, number of leaves per plant, leaf angle, stem diameter, leaf area, harvest age, cob length, cob diameter, weight of harvested dry cob per plant, 1,000-kernel weight and grain yield (weight of dried kernels per plant).

Statistical analysis

Genetic parameters, including genetic diversity, heritability and genotypic correlation of each environmental condition, were estimated based on single-factor analysis of variance at the 5% significance level, following the procedure Gomez and Gomez (1984). Genetic variance, phenotype variance, genetic coefficient of variation and broad-sense heritability were calculated using the following formula (Knight, 1979; Singh and Chaudhary, 1985). The criteria for the genetic diversity, as proposed by Knight (1979), where genetic diversity is classified as broad, > 20.00%; moderate, 10-20% and narrow, KKG <10.00%. The classification of broad-sense heritability (H^2), following Elrod and Stansfield (2002), is cagorized as low, $H^2 < 20\%$; moderate, 20-50% and high, $H^2 > 50\%$.

The closeness of the genetic relationship between traits, particularly between leaf angle and yield, was estimated by calculating the genotypic correlation coefficient according to the formula proposed by Ujianto *et al.* (2020), as follows:

$$r_g = \frac{COV_g\,(X,Y)}{\sqrt{Var_g X \times Var_g Y}}$$

Where

r_g= Genotypic correlation coefficient.

COV_g (X,Y)= Genotypic covariance between traits X and Y.

Var_g X= Genetic variance of trait X.

Var_g Y= Genetic variance of trait Y.

The significance of the correlation coefficient was tested using critical value of $r_{0.05}(27)= 0.312$. Based on these values, the strength of correlation was classified into three categories: weak (0.313-0.542), moderate (0.543-0.772) and strong (> 0.772). All statistical analyses were conducted using the microsoft Excel 2010.

RESULTS AND DISCUSSION

Land conditions of the research site

The research site, rainfall is recorded manually and a thermo-hygrometer is installed to monitor air temperature and relative humidity. The rainfall, temperature and air humidity data recorded during the experimental period are presented in Table 1.

The soil type at the research site is classified as Entisol with a sandy loam texture (Priyono *et al.*, 2019). This soil type is characterized by low water-holding capacity and low organic matter content, making it suitable for evaluating drought stress response in maize genotypes.

Genetic diversity and heritability

The level of genetic diversity is very important for breeders in the selecting traits to obtain superior varieties (Kamara *et al.,* 2024). The values of genetic coefficient of variation (KKG) for each character under each environmental condition are presented in Table 2.

Table 2 shows that all observed characters under both normal and drought-stress conditions exhibit relatively narrow genetic diversity; except for the weight of harvested dry cob per plant and yield (weight of dried kernels per plant), which show moderate genetic diversity under drought-stressed conditions. Characters with narrow genetic diversity provide limited opportunities for breeders to select plants for selfing to form the fifth generation. This finding is consistent with Hasan *et al.* (2025), that the narrower the genetic diversity of a character, the more limited the opportunities for selection; with a genetic coefficient of variation of 8.24%. Similarly, Magar *et al.* (2021) observe for plant height, number of leaves, cob diameter and cob length in several maize varieties.

The characters that can be used as selection criteria for plants to be self-pollinated are those observed before pollination, namely plant height, number of leaves per plant, leaf angle, stem diameter and leaf area. All these characters show narrow genetic diversity under both drought-stress and normal conditions. Therefore, selfing to form the fifth generation can be conducted under either drought-stress or normal conditions. However, in addition to genetic diversity, heritability values must also be considered. According to Devi *et al.* (2024), characters with wide genetic diversity accompanied by high heritability can be directly selected. The broad sense heritability values of all observed characters are presented in Table 3.

Broad-sense heritability describes the proportion of phenotypic variance that is attributable to genetic variance. A high heritability the trait can be more effectively transmitted to the next generation (Modarresi, 2026). In Table 3, the heritability values of most characters under both drought-stress and normal conditions are relatively low. Moderate heritability under drought-stress is observed for stem diameter, leaf area, harvest age, weight of harvested dry cob per plant and 1,000-kernel weight. Under normal conditions, only harvest age shows moderate heritability, while the feamining traits fall into the low category. These results indicate that most characters in both environments are strongly influenced by environmental factors. The lines exhibit relatively small genotypic differences, resulting in low genetic variance, while large environmental variance contributes substantially to phenotypic variation in most observed traits. Ogunniyan and Olakojo (2014), report contrasting results in 15 elite yellow-grain maize lines,

Table 1: Monthly rainfall, temperature and air humidity data during the experimental period.

Month	Rainfall (mm)	Temperature	Air humidity (%)
May	3	26-36	65-75
June	0	23-36	59-84
July	0	23-35	59-77
August	54	23-35	61-75

Remarks: Data are obtained from direct observations at the research site. Drought treatment is imposed from June 22 to July 22, 2024.

showing that heritability for plant height is very high (99.28%), while leaf area shows moderate heritability (21.62%). Hasan *et al.* (2025), also report different findings, indicating that plant height, cob lenght, cob diameter and yield have high heritability are 97.95%, 88.42, 68.60 dan 80.24% respectively. Similarly, Korsa *et al.* (2024), report heritability values of 81.00% of plant height, 43.96% for yield and 28.25% for cob diameter. In contrast, Al-Rawi *et al.* (2024), report moderate heritability for plant height (34.7%) in six inbred maize lines, while several other characters show high heritability.

Genotypic correlation

Genotypic correlation is useful in character selection, particularly for indirect selection in breeding programs. The genotypic correlation coefficient between leaf angle, yield, with other character are presented in Table 4.

The genotypic correlation coefficient reflects the degree of genetic association between traits and is particularly important in indirect selection strategies (Al-Rawi *et al.*, 2024). Table 4 shows that none of the observed characters are significantly correlated with leaf angle under either drought-stress or normal conditions. This indicates that improvement in leaf angle must be achieved through direct selection in both environments.

In contrast, yield shows significant positive genotype correlation with several yield components, including cob length, cob diameter, weight of harvested dry cob per plant, as well as with growth traits such as leaf area and plant height under both environmental conditions. Under drought stress, the genotypic correlation coefficients between yield and cob length, cob diameter and harvested dry cob weight are 0.756, 0.503 and 0.632, respectively. Under normal conditions, the corresponding values are 0.606; 0.435 and 0.995. Similar results are reported by Nzuve *et al.* (2014), who find a positive genotypic correlation (0.63) between yield and plant height.

Under drought stress, yield does not correlate with 1,000-kernel weight (r_g= -0.147), whereas under normal conditions, these two traits show a significant positive

Table 2: Genetic coefficient of variation (KKG) of all plant S_4 maize line characters under two conditions.

Observed characters	Genetic coefficient of variation (KKG)			
	Stress conditions		Normal conditions	
	KKG (%)	Category	KKG (%)	Category
Plant height	1.87	Narrow	3.88	Narrow
Number of leaves per plant	2.73	Narrow	2.39	Narrow
Leaf angle	1.16	Narrow	3.16	Narrow
Stem diameter	4.87	Narrow	1.84	Narrow
Leaf area	9.51	Narrow	3.25	Narrow
Harvest age	0.88	Narrow	1.24	Narrow
Cob length	4.34	Narrow	4.81	Narrow
Cob diameter	1.05	Narrow	4.06	Narrow
Weight of harvested dry cobs per plant	12.77	Medium	5.34	Narrow
1,000-kernel weight	6.82	Narrow	3.88	Narrow
Yield	10.80	Moderate	4.27	Narrow

Table 3: Broad-sense heritability (H^2) values of all characters of S_4 maize lines under two conditions.

Observed characters	Broad-sense heritability (H^2)			
	Stress conditions		Normal conditions	
	H^2 (%)	Category	H^2 (%)	Category
Plant height	7.53	Low	10.95	Low
Number of leaves per plant	17.42	Low	13.22	Low
Leaf angle	2.28	Low	16.06	Low
Stem diameter	28.13	Moderate	5.48	Low
Leaf area	32.10	Moderate	3.76	Low
Harvest age	32.51	Moderate	32.24	Moderate
Cob length	15.07	Low	9.06	Low
Cob diameter	1.32	Low	12.72	Low
Weight of harvested dry cob per plant	22.70	Moderate	12.57	Low
1,000-kernel weight	23.23	Moderate	10.95	Low
Yield	11.82	Low	6.41	Low

Table 4: Genotypic correlation coefficient between leaf angle and yield with other characters of S_4 maize lines under two conditions.

Observed characters	Genotypic correlation coefficient values and criteria			
	Leaf angle		Yield	
	Stress	Normal	Stress	Normal
Plant height	0.211 ns	0.186 ns	0.666 (moderate)	0.361 (weak)
Number of leaves per plant	-0.252 ns	0.093 ns	-0.098 ns	0.525 (weak)
Leaf angle	1.000	1.000	0.411 weak	-0.292 ns
Stem diameter	-0.235 ns	-0.291 ns	0.644 (moderate)	-0.217 ns
Leaf area	0.273 ns	0.158 ns	0.799 (strong)	0.622 (moderate)
Harvest age	0.132 ns	0.271ns	0.302 ns	0.291 ns
Cob length	-0.179 ns	0.219 ns	0.756 (moderate)	0.606 (moderate)
Cob diameter	0.086 ns	0.132 ns	0.503 (weak)	0.435 (weak)
Weight of harvested dry cob per plant	0.068 ns	0.204 ns	0.632 (moderate)	0.995 (strong)
1,000-kernel weight	0.143 ns	0.308 ns	-0.147 ns	0.553 (moderate)
Yield	0.073 ns	-0.290 ns	1.000	1.000

Note: ns= Not significant at 5%

correlation (r_g= -0.553). This suggests that yield under drought-stress depends primarily on cob-related traits (cob weight, cob length and cob diameter), whereas under normal conditions, seed development also contributes substantially to yield performance. Al-Rawi *et al.* (2024), reported similar findings, with no significant correlation between yield and 1,000-kernel weight under drought-stress (r_g= -0.202).

Therefore, increasing yield in the development of fifth-generation lines can be achieved by selecting taller plants, as plant height shows a significant positive genotypic correlation with yield and is relatively easy to measure in field selection. Moreover, leaf angle has already met the (< 35°) in all lines, with mean values 28.40° under drought stress and 28.62° under normal conditions. Similar positive correlations between yield and cob length and cob diameter are reported by Magar *et al.* (2021), with correlation values of 0.671 and 0.573, respectively. Emmanuel (2025) also reported a positive correlation between yield and cob lenght. In contrast, number of leaves per plant does not correlate with yield under drought-stress (r_g= -0.093), which is consistent with the findings of Korsa *et al.* (2024), who reported a low and non-significant correlation (r_g= 0.084).

CONCLUSION

The genetic diversity of all quantitative characters was relatively narrow under both environmental conditions, except for cob weight and yield under drought-stress conditions, which show moderate genetic diversity. Broad-sense heritability was generally low for most of the quantitative characters observed in both environments. No significant genotypic correlation was detected between leaf angle and any other character; however, most characters show positive genotypic correlations with yield, ranging from weak (0.361) to strong (0.995) accross both environmental conditions. For advancing to the fifth generation through selfing, selection should focus on taller plants to enhance yield potential under both drought-stress and normal conditions.

ACKNOWLEDGEMENT

The research team expresses sincere gratitude to the Rector of the University of Mataram, for the financial support provided to conduct this research under PNBP Grant No. 1239/UN18.L1/PP/2024. The team also extends its appreciation to the Dean, Head of LPPM and all staff members for their assistance throughout the administrative process, from proposal submission to reporting of research results.

Conflict of interest

All authors declare that they have no conflict of interest related to the research, authorship and publication of this article.

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