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YIELD PERFORMANCE AND HERITABILITY OF GAMMA-RAY-INDUCED TOMATO MUTANT LINES ACROSS THE DIVERSE LOWLAND ENVIRONMENTS

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SUMMARY

Selection of stable and high-yielding tomato (*Solanum lycopersicum* L.) genotypes is a challenging issue due to genotype-by-environment interactions. This study aimed to evaluate the yield performance and heritability among 10 tomato putative M7-mutant lines derived from gamma-ray irradiation and five commercial cultivars for agronomic and yield-related traits under two lowland environments, Bogor and Kolaka, Indonesia. Fifteen genotypes incurred evaluation in a randomized complete block design (RCBD) with three replications in each environment. The results revealed that genotype-by-environment interactions significantly influenced the agronomic and yield-related traits of tomatoes. Higher fruit yield per plant and fruit number were prominent at Bogor (1069.63 g plant⁻¹ and 44.08 fruits plant⁻¹) than with Kolaka (434.29 g plant⁻¹ and 18.25 fruits plant⁻¹). It indicated that the Bogor environment was more favorable for tomato growth and yield production. The genotype G7 produced the most fruits per plant in both Bogor and Kolaka (95.58 and 30.81 fruits, respectively). Productivity showed a significant positive correlation with fruit weight and fruit diameter. Maximum broad-sense heritability was evident for plant height and fruit weight. The study revealed the potential of mutant tomato lines for developing high-yielding cultivars adapted to lowland environments.

Keywords: Tomato (*S. lycopersicum* L.), genotype-by-environment interactions, genetic parameters, heritability, agronomic and yield traits

Key findings: Genotype-by-environment interactions significantly affect the tomato's (*S. lycopersicum* L.) fruit yield and its components. Tomato genotypes produced a higher fruit number and yield at Bogor than at Kolaka.

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae and has the highest commercial and consumable values in Indonesia and worldwide (Causse *et al.*, 2020). It has the highest economic value for small and medium-scale farmers. However, tomato production is low due to limited cultivation areas and low seed-quality cultivars in Indonesia. Increasing the tomato productivity requires the primary focus to be on the highlands. Tomato crop expansion through lowland cultivation can be an alternative to boost the production. However, the lowlands have relatively extreme temperatures and high light intensity, which revealed tomatoes as susceptible and vulnerable to fruit cracking and bacterial wilt, increasing risks of decreased fruit production and quality. High temperatures and light intensity alter the synthesis of primary and secondary metabolites in tomatoes and other crops (Khan *et al.*, 2024).

The ultimate aim of plant breeding is to develop high-yielding genotypes that can be adaptable to diverse environmental conditions. Selecting a genotype with improved stability can become complicated when a breeder considers the individual's genotype-by-environment interactions and multiple traits for many testing environments (Happ *et al.*, 2021). Since the expression of quantitative traits obtains influences from both genetic and environmental factors, evaluating breeding materials under representative lowland environments is essential to identify promising genotypes with desirable performance. Furthermore, the estimation of genetic parameters, particularly heritability, provides valuable information on the effectiveness of selection and supports the development of improved tomato varieties for lowland cultivation.

The combined effects of genetic and environmental factors pose significant challenges for plant breeders, as these more complicate breeding procedures and limit the usefulness of breeding in different environments (Abebe *et al.*, 2024). Therefore, it is necessary to study the genotypes under various environments and identify the superior

and stable genotypes through differential genotypic responses across the multiple environments, with the aim of achieving yield improvement. Moreover, it contributes to future breeding strategies, helping plant breeders to make informed decisions to optimize breeding methods, testing procedures, and selection intensity (Casals *et al.*, 2021).

Tomato development in lowland environments proceeded using irradiation-induced mutation, with the genotypes selected later by the pedigree method (Anggriansyah *et al.*, 2024). The advanced tomato mutant lines received evaluation for performance in several lowland locations to assess the genotypic response to altitude, climate, soil type, varied temperatures, and especially the genotype-by-environment interaction effects and mutant resistance to fruit cracking. The estimation of genetic parameters, such as heritability, is crucial to determine the extent to which observed traits have the control of genetic factors. Likewise, this will evaluate the influence of genotype $\times$ environment interactions on trait expression and support effective selection responses in subsequent generations. Previous studies in tomatoes reported high heritability values for various yield-related traits, including the number of clusters per plant (99.54%), plant height (99.47%), and average fruit weight (98.91%). High heritability combined with high genetic advance indicates the predominance of additive gene action, suggesting that selection for these traits can be effectively applicable in tomato breeding programs (Yeasmin *et al.*, 2023).

Previous studies reported that gamma-ray irradiation successfully produced promising tomato M5 mutant lines with improved agronomic performance. The mutant lines evaluated in Bogor showed fruit weight per plant, ranging from 470.32 to 1686.35 g, allowing the selection of promising mutant lines with enhanced agronomic traits under lowland conditions (Romadhon *et al.*, 2018). Past studies mainly focused on earlier mutant generations, such as M5, evaluated under contrasting highland and lowland environments. In contrast, the presented study focused on advanced M7 mutant lines using

different control cultivars, which was specifically conducted under two lowland environments. Information regarding agronomic performance and heritability of advanced gamma-ray-induced tomato mutant lines adapted to lowland environments remains limited. The information is valuable because lowland areas in Indonesia characteristically have high temperatures and environmental stress conditions that often reduce tomato productivity and stability. Therefore, this study aimed to evaluate the agronomic performance and heritability of 10 tomato putative M7-mutant lines and five commercial cultivars under two lowland environments, namely Bogor and Kolaka, Indonesia.

MATERIALS AND METHODS

Study sites

The study on tomatoes (*S. lycopersicum* L.) transpired in two different environments: Leuwikopo, IPB University Experimental Field, Bogor, Indonesia (-6.56392°S; 106.72664°E; 250 masl) and Kolaka Experimental Field, National Development University—Veteran, Jawa Timur, Indonesia (-4.073303°S; 121.623687°E; 38 masl). The environments differ biologically for altitude, temperature, humidity, and rainfall patterns, which may influence tomato growth and yield performance. According to data from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) stations, Bogor has features of monthly rainfall, ranging from 213.5 to 406 mm, a relative humidity of 79.8%–86.2%, and temperatures ranging from 25.0 °C to 26.8 °C. In contrast, Kolaka has monthly rainfall ranging from 150.3 to 304 mm, relative humidity of 75.2%–79.7%, and higher temperatures ranging from 27.5 °C to 29.1 °C.

Genetic materials and experimental procedure

The seeds of 15 tomato genotypes comprised 10 putative M7 tomato mutant lines derived from gamma-ray irradiation at doses of 495

and 990 Gy and selected through the pedigree method, along with five commercial cultivars (Tora, Permata, Servo, Mawar, and Warda). These underwent sowing in seedling trays following the method described by Arrufitasari *et al.* (2022). Fertilizer application took place 14 days before planting, with a composition of 2 t ha⁻¹ of dolomite, 300 kg ha⁻¹ of urea, 500 kg ha⁻¹ of SP-36, 300 kg ha⁻¹ of KCL, and 1500 kg ha⁻¹ of manure. The experiment layout was in a randomized complete block design, with three replications in each environment, with genotypes assigned as treatments and replications used as blocks to minimize field variability within each location. The experiment at each location comprised 42 plots as experimental units (5 m × 1 m in size), with a plant spacing of 40 cm × 40 cm and a distance of 70 cm between plots. Each experimental unit consisted of 20 plants, with 10 sample plants being observed. Seedlings selected for better growth are those with green leaves and free of pests and diseases.

Seedlings reached transplanting at 21 days after sowing when the plants had developed four true leaves. A black shade net reducing light intensity by 50% was set up during the seedling stage. Fertilization continued weekly using NPK (16-16-16) at concentrations of 10 g L⁻¹ during the vegetative phase and 15–20 g L⁻¹ during the generative phase. Standard crop management practices, including irrigation, pruning, and pest and disease control, ensued at uniform application across all treatments. Harvesting commenced when the fruits reached the red-ripe stage (Krismawati *et al.*, 2021).

Data recorded and analysis

Data recorded on several agronomic and yield-related traits progressed to evaluate the performance of genotypes across different environments. The observed traits included yield per plant, the number of fruits per plant, fruit weight, fruit flesh thickness, fruit diameter, fruit length, productivity, and plant height. The effect of environments sustained analysis using a combined analysis of variance (ANOVA) in SAS software. Genetic parameters, variance components, broad-sense heritability,

and genotype-by-environment interactions bore estimates using fixed models. Treating genotypes and environments as random effects enabled the estimation of variance components and broad-sense heritability across environments. The study determined the significance of differences among treatments by Fisher's least significant difference test (LSD) at 5%.

The following formulas are:

$$\sigma^2G = (M3-M1) / rE$$

$$\sigma^2GXE = (M2-M1) / r$$

$$\sigma^2e = M1$$

$$\sigma^2P = \sigma^2G + (\sigma^2 GXE / E) + (\sigma^2e / rE)$$

$$h^2 (bs) = (\sigma^2G / \sigma^2P) \times 100\%$$

Where σ^2G = genotypic variance; $\sigma^2G \times E$ = genotype $\times$ environment interaction variance; σ^2e = environmental (error) variance; σ^2P = phenotypic variance; $h^2(bs)$ = broad-sense heritability; r = number of replications; E = number of environments; $M1$ = mean square error (galat/error); $M2$ = mean square genotype $\times$ environment ($G \times E$); and $M3$ = mean square genotype.

RESULTS AND DISCUSSION

The combined analysis of variance revealed that tomato (*S. lycopersicum* L.) genotypes significantly affected agronomic and yield-related traits, indicating the presence of

considerable genetic variation among evaluated tomato genotypes (Table 1). Environmental effects were significant for the number of fruits per plant and fruit flesh thickness, suggesting that these traits receive influences from differences in lowland growing conditions between Bogor and Kolaka. Additionally, significant genotype $\times$ environment interactions were notable for yield per plant, fruit diameter, fruit weight, and the number of fruits per plant, indicating differential genotype responses across environments. These results demonstrate the importance of multi-environment evaluation to identify stable and high-yielding tomato genotypes adapted to lowland conditions. Similar findings were in previous reports, showing environmental conditions influencing tomato growth and yield performance (Lubis, 2020).

The results emphasized the importance of conducting multi-location trials in tomato breeding programs, particularly for the M7-mutant lines with the highest yield potential. The significant genotype-by-environment interaction revealed that genotypes respond differently across the two lowland environments. Therefore, selecting superior genotypes cannot rely solely on performance in a single location. Some genotypes performed optimally in Bogor but showed reduced productivity in Kolaka, while other genotypes may exhibit the opposite trend. Thus, a selection approach that considers both genotypic genetic potential and yield stability across the environments is essential. According to Reckling *et al.* (2021), determining yield stability cannot be accurate from a single field

Table 1. Mean squares for various traits of tomato genotypes evaluated under two lowland environments using combined analysis of variance.

Source	d.f.	Mean squares							
		NFT	YP	FW	TFF	FD	FL	P	PH
Environments	1	13166**	10909642.34**	444.93 ^{ns}	30.38*	67.92 ^{ns}	38.50 ^{ns}	230.72 ^{ns}	6876.10 ^{ns}
Rep (Env.)	4	614.24**	235177.78**	182.46**	0.61 ^{ns}	46.15**	128.15*	94.59**	1875.42**
Genotypes	14	408.49*	159838.62**	607.44**	2.30*	153.95**	475.90**	314.90**	4172.51**
G $\times$ E	14	136.29 ^{ns}	183286.85**	38.11 ^{ns}	0.70 ^{ns}	13.93**	38.76 ^{ns}	19.75**	226.45 ^{ns}
Error	56	671.51**	47959.39**	205.65 ^{ns}	0.55*	54.50 ^{ns}	123.54 ^{ns}	106.62 ^{ns}	1905.02 ^{ns}
CV (%)		29.33	26.70	12.29	22.72	6.22	18.59	12.29	13.97

Note: CV: Coefficient of Variance; Rep: Replication; Env: Environment; GXE: Genotype $\times$ Environment; ** significant at level of 1%; * significant at level 5%; ns: nonsignificant. YP: yield per plant, NFT: number of fruits per plant,; FW: fruit weight, TFF: thick fruit flesh, FD: fruit diameter, FL: fruit length, P: productivity, and PH: plant height.

trial conducted in a single year. Therefore, the said phenomenon needs evaluation through yield data collected across multiple years and different locations. The use of various statistical methods sought to estimate yield stability by analyzing yield variations across diverse environments.

The genotype-by-environment interaction had a considerable and significant effect on the observed characters (Table 1), indicating that tomato genotypes responded differently across the two lowland environments. The significant interaction for yield-related traits also suggested the presence of crossover interaction for several characters, where genotype performance and ranking varied between Bogor and Kolaka. The condition could influence the effectiveness of genotype selection across environments and indicate differences in genotype adaptation to specific lowland conditions. Quantitative characteristics, such as fruit yield, have great economic and agronomic importance and have strong influences from $G \times E$ interactions. Fruit yield, as a quantitative trait, has become a commonly used selection criterion in plant breeding (Wang *et al.*, 2021). The coefficient of variation in this experiment ranged from 6.22% to 29.33%, with the highest coefficient of variation observed for fruits per plant,

presumably due to differences in environmental conditions affecting crop performance and yield stability.

Yield per plant is the primary trait because of its direct association with overall productivity. The results revealed that for fruit yield per plant, the tomato genotypes ranged from 933.19 to 1246.85 g at Bogor, while 297.15 to 694.96 g at Kolaka (Table 2). On average, the genotype Permata showed the highest yield per plant (868.43 g) across both environments. The genotype G7 has the most fruits per plant at both locations (95.58 and 30.81 fruits per plant, respectively). Overall, the tomato genotypes showed a higher yield per plant and fruits per plant at Bogor than in Kolaka. At Kolaka, on average, the genotypes considerably displayed the lower fruits per plant and yield, indicating that genotype-by-environment interaction altered the fruit setting. For instance, the genotype G3 dropped to just 11.83 fruits per plant in Kolaka despite its highest productivity in Bogor.

The results further revealed that some tomato genotypes can be more suitable to the agroecological conditions in Bogor, such as soil fertility, temperature, and relative humidity, which may influence the fruits' development and retention (Delgado-Vargas *et al.*, 2023).

Table 2. Yield per plant and fruits per plant of tomato genotypes evaluated under two lowland environments.

Genotypes	Yield per plant (g)		Means	Fruits per plant		Means
	Bogor	Kolaka		Bogor	Kolaka	
G1	974.63	540.72	757.68	47.21	26.20	38.16
G2	933.19	373.82	653.51	33.18	13.70	23.44
G3	1175.87	282.42	853.78	58.36	11.83	35.10
G4	990.93	402.13	696.53	45.67	17.16	31.42
G5	1080.78	334.25	707.52	42.74	18.16	30.45
G6	1047.41	376.68	712.05	54.27	23.10	38.68
G7	1109.28	297.15	703.22	95.58	30.81	63.19
G8	1187.43	398.59	793.01	33.03	17.36	25.20
G9	1063.40	480.23	771.82	52.21	22.09	37.15
G10	1133.39	343.10	738.25	33.88	13.33	23.61
Servo	1095.55	494.48	795.01	28.21	14.13	21.17
Permata	1041.90	694.96	868.43	32.10	20.17	26.13
Tora	1030.56	355.35	692.95	37.96	11.30	24.63
Mawar	1246.85	423.52	835.19	40.12	16.73	28.43
Warda	1058.03	467.65	762.84	26.64	14.77	20.70
Mean	1069.63	434.29		44.08	18.25	
LSD _{0.05}	476.96	198.96		18.50	9.80	

Tomato cultivation at temperature zones above the optimal range negatively affects plant growth and, eventually, productivity. Elevated temperatures disrupt essential physiological functions, including assimilate distribution, plant growth, and development. With heat stress conditions, both source and sink activities decline, resulting in a significant reduction in overall growth and development, crop yield, and harvest index (Amrutha and Beena, 2020).

The genotypic differences in traits of fruits per plant and yield per plant across two locations were considerably be due to environmental conditions that affect the genotypes' performance. In tomatoes, environmental factors mostly influence agronomic traits. Environmental contribution to the total phenotypic variance was 41% for yield, 18% for fruit cracking, and 32% for fruit weight (Casals *et al.*, 2021). The correlation coefficients showed that fruit weight had a positive effect from air temperature from planting to the beginning of flowering (Oliva-Ruiz *et al.*, 2023).

On average, the genotype Warda showed the best fruit weight and diameter across both environments, with 52.27 g fruit weight and 51.16 mm fruit diameter (Table 3).

This phenomenon was presumably in association with the location's humidity, rainfall, and temperature. For instance, some tomato genotypes, such as Servo and G6, exhibited better performance at Bogor than at Kolaka, highlighting the influence of local environmental conditions on yield-related traits. Genotypes with larger fruit size tended to exhibit lower fruit number per plant, indicating a possible trade-off between fruit size and fruit production among the evaluated tomato genotypes. Previous studies reported fruit weight had a negative correlation to the average number of fruits per plant, which was in accordance with the results of many authors (Susic *et al.*, 2002; Gomez, 1987; Gomez and Velazquez, 1988).

In general, the genotypes grown at Bogor had longer fruits than those grown at Kolaka. Similar results were noteworthy for productivity, and the genotype Warda provided the highest productivity (Table 4). Production heightened with relative humidity between 75% and 95%. Although a sharp increase in yield was evident at relative humidity ranging from 75% to 85%. However, tomato yields declined unpredictably when the relative humidity peaked at around 100%, which hinders production in the field. Extreme

Table 3. Fruit weight and fruit diameter of tomato genotypes evaluated under two lowland environments.

Genotypes	Fruit weight (g)		Means	Fruit diameter (mm)		Means
	Bogor	Kolaka		Bogor	Kolaka	
G1	27.21	24.45	25.83	33.50	33.90	33.70
G2	33.03	30.48	31.76	36.15	37.43	36.79
G3	25.23	26.54	25.89	32.64	34.58	33.61
G4	28.11	24.93	26.52	37.62	37.79	37.71
G5	30.68	21.58	26.13	41.66	35.06	38.36
G6	26.87	19.79	23.33	39.82	32.88	36.35
G7	15.75	10.50	13.13	29.14	25.76	27.45
G8	27.62	26.97	27.30	35.20	36.67	35.93
G9	25.65	24.25	24.95	39.49	38.92	39.20
G10	38.61	31.10	34.86	39.37	36.37	37.87
Servo	46.16	40.05	43.10	42.66	39.55	41.10
Permata	38.97	33.57	36.27	38.23	37.92	38.07
Tora	43.48	50.07	46.78	39.36	41.11	40.23
Mawar	40.36	25.52	32.94	44.02	38.98	41.50
Warda	56.65	47.89	52.27	53.22	49.10	51.16
Mean	33.63	29.18		38.80	37.07	
LSD _{0.05}	5.71	7.12		4.18	3.70	

Table 4. Fruit length and productivity of tomato genotypes evaluated under two lowland environments.

Genotypes	Fruit length (mm)		Means	Productivity (t ha ⁻¹)		Means
	Bogor	Kolaka		Bogor	Kolaka	
G1	39.07	35.22	37.15	19.59	17.61	18.60
G2	41.33	37.16	39.25	23.78	21.95	22.86
G3	39.17	37.02	38.1	18.17	19.11	18.64
G4	30.37	26.48	28.43	20.24	17.95	19.09
G5	27.09	24.57	25.83	22.09	15.54	18.81
G6	26.16	24.85	25.51	19.35	14.25	16.80
G7	29.41	25.62	27.52	11.34	7.56	9.45
G8	32.59	30.99	31.79	19.89	19.42	19.65
G9	24.75	25.90	25.33	18.47	17.46	17.96
G10	43.09	56.47	49.78	27.80	22.39	25.10
Servo	46.63	47.15	46.89	33.23	28.84	31.04
Permata	44.10	41.64	42.87	28.05	24.17	26.11
Tora	49.88	51.81	50.85	31.31	36.05	33.68
Mawar	36.14	25.19	30.67	29.06	18.37	23.72
Warda	31.47	31.55	31.51	40.79	34.48	37.63
Mean	36.08	34.77		24.21	21.01	
LSD _{0.05}	7.20	13.81		4.11	5.13	

weather fluctuations occur at various crop growth stages, negatively affecting productivity (Beillouin *et al.*, 2020). Continuously increasing temperatures have considerably reduced the tomato yield, pollen viability, fruit number, and productivity (Ayankojo and Morgan, 2020).

Tomato genotypes G5 and G7 were prominent with weaker performance at both environments, indicating limited adaptability. The apparent differences in fruit length and productivity between Bogor and Kolaka also emphasized the role of microclimate in determining the crop's outcomes. The results suggested breeding programs should focus on developing genotypes with stable performance under fluctuating environmental conditions, particularly humidity and rainfall, which can significantly influence tomato productivity (Mohammed *et al.*, 2025).

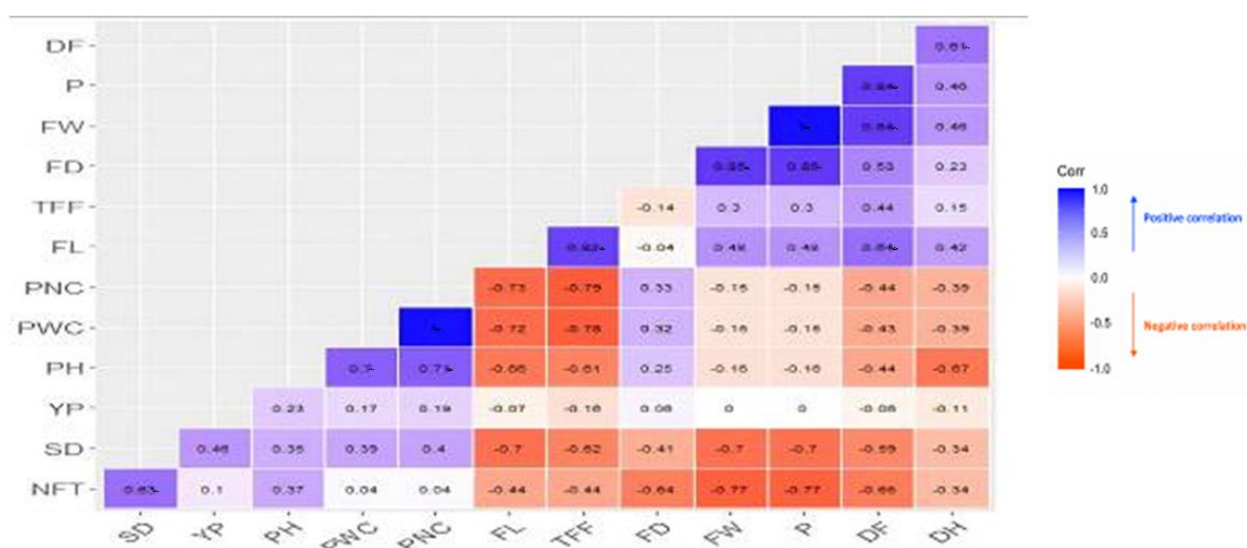
Determining heritability is an essential factor in incorporating a trait of interest into a breeding program (Acevedo-Siaca *et al.*, 2021). Heritability does not represent the probability of an inherited phenotype; rather, it represents the percentage of the phenotype that can be ascribable to the genotype and not the influence of the environment. The heritability can have three types of categories: low (0%–30%), moderate (30%–60%), and high ($\geq 60\%$) (Johnson *et al.*, 1955).

Heritability values for the 10 observed traits ranged from 17.55% to 94.94% and received the appropriate classification as per criteria. In this study, the recorded highest heritability was for plant height, followed by fruit weight, fruit diameter, weight of cracking fruits, and fruit length (Table 5). Similar findings have reached reports for various yield-related components in tomatoes (Mahmudul *et al.*, 2020). High heritability indicated that the observed trait gained stronger influence from genetic factors and could have better potential for phenotypic selection. However, heritability estimates alone might not fully explain selection efficiency without additional genetic parameters, such as genetic advance. Similar findings have come out for various yield-related traits in tomatoes.

In contrast, in the traits with low heritability, selection should start at the F3–F4 generation to avoid bias during selection (Mawasid *et al.*, 2019). The traits with higher heritability revealed the weaker influence of environmental factors on the genotypes (Hassan *et al.*, 2021). Low heritability arises when variable environmental conditions contribute substantially to the total phenotypic variance, thereby obscuring the genetic contribution. Under such circumstances, the expression of traits signified more influences

Table 5. Estimation of genetic parameters of tomato genotypes evaluated under two lowland environments.

Character	σ^2_e	σ^2_{GXE}	σ^2_G	σ^2_p	h^2_{bs} (%)	Criteria
Yield per plant (g)	455.65	0	0	7594.17	0.00	Low
Fruits per plant	98.57	61.2	68.83	105.66	65.14	High
Fruit weight (g)	15.2	8.49	90.96	96.32	94.43	High
Fruit diameter (mm)	5.73	3.01	24.34	26.30	92.55	High
Fruit length (mm)	45.36	0	67.03	79.80	90.53	High
Weight of cracking fruits (%)	83.72	33.51	242.37	267.49	90.61	High
Number of cracking fruits (%)	485.83	0	45.9	126.87	36.18	Moderate
Thick fruit flesh (mm)	0.75	0	0.2	0.33	61.54	High/
Plant height (cm)	203.25	12.62	707.39	745.47	94.89	High
Productivity (t ha ⁻¹)	46.21	0	0	7.70	0.00	Low

**Figure 1.** Correlation coefficients among different yield and yield-attributing characters in 15 tomato genotypes. *significant at level of 5%, SD: stem diameter, YP: yield per plant, PH: plant height, PWC: percentage weight of cracking fruits, PNC: percentage number of cracking fruits, FL: fruit length, TFF: thick fruit flesh, FD: fruit diameter, FW: fruit weight, P: productivity, DF: days of flowering, DH: days to harvest, and NFT: number of fruits per plant.

from environmental factors than from the genotypic potential (Rasheed *et al.*, 2023). In the presented study, yield per plant showed the low heritability, which contrasted to previous studies. The traits of yield per plant, plant height, canopy width, the number of marketable fruits per plant, and fruit weight were remarkable with the highest heritability. The estimated heritability values for yield per plant, plant height at harvest, and fruits per plant were moderate (30%–60%) (Mahmudul *et al.*, 2020).

Correlation analysis is an essential component of every breeding program because trait selection has an association with yield-related traits (Hassan *et al.*, 2021). The influence of each trait on final yield can undergo evaluation through correlation studies, which quantify the extent of the relationship between the traits and ultimate outcomes. Figure 1 exhibited positive and negative relationships among yield and yield-attributing traits in 15 tomato genotypes. Positive correlations were distinct with blue shade,

whereas negative correlations were an orange indicator. A darker blue represented a stronger positive correlation among traits, while a darker orange indicated a stronger negative correlation. Productivity (P) showed a significant positive correlation with fruit weight (FW) ($r = 1$) and fruit diameter (FD) ($r = 0.85$), implying that increased plant productivity tended to be an association with increased fruit weight and fruit diameter. Previous findings revealed substantial positive correlations of yield per plant with other yield-related traits in tomatoes (Islam *et al.*, 2022). According to Liu *et al.* (2023), environmental stresses, such as high temperature, light intensity, and vapor pressure deficit, can impair photosynthetic efficiency, stomatal conductance, and carbon assimilation in tomato leaves, thereby reducing biomass accumulation and fruit yield.

CONCLUSIONS

The results showed significant effects of genotype-by-environment interactions (GEI) on the tomato (*S. lycopersicum* L.) fruit yield, with the genotypes observed with varied responses at both environmental conditions. Overall, the tomato genotypes performed well at Bogor compared with Kolaka, highlighting the robust influence of existing environmental conditions on the productivity. The genotype G7 produced the most fruits per plant in both Bogor and Kolaka (95.58 and 30.81 fruits, respectively), suggesting it as a promising candidate for broader adaptation. The highest broad-sense heritability was evident for plant height (94.89%) and fruit weight (94.43%). Tomato genotypes Warda, Tora, and Mawar displayed larger fruit size and the highest yield, while the genotype Permata achieved the highest average fruit yield across both environments.

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