



Genotype-dependent response of soybean (*Glycine max* L.) to the vermicompost application in the lowland agroecosystem

Naja Ananda Putri¹ | Nilahayati Nilahayati^{1,*} | A. G. Rosnina¹

¹ Department of Agroecotechnology, Faculty of Agriculture, Universitas Malikussaleh, Jl. Cot Tgk. Ni Reuleut Timu, Aceh Utara 24355, Indonesia

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*Corresponding author:

Nilahayati Nilahayati
Email: nilahayati@unimal.ac.id

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Abstract

Soybean (*Glycine max* L.) productivity in Indonesia remains insufficient to meet national demand, necessitating improvements in both genetic potential and nutrient management strategies. This study aimed to evaluate the growth and yield performance of four soybean genotypes under different vermicompost doses in lowland agroecosystems. The experiment was conducted in Paloh Lada Village, Dewantara District, North Aceh, using a factorial randomized block design with two factors: four soybean genotypes (Anjasmoro, Dena 1, Denasa 2, and M.1.1.3 line) and three vermicompost doses (0, 5, and 10 t ha⁻¹). Data were analyzed using ANOVA followed by Duncan's Multiple Range Test at 5% significance level. Results showed that genotype significantly affected all observed variables except leaf area. The M.1.1.3 line consistently produced the highest yield (up to 4.12 t ha⁻¹, compared with 10 t ha⁻¹ vermicompost). Vermicompost application significantly increased plant height, root nodules, filled pods, seed weight per plant, seed weight per plot, and yield. Significant genotype × vermicompost interactions were observed for plant height, nodulation, seed weight, and yield. The optimal dose was 10 t ha⁻¹. These findings demonstrate that integrating responsive genotypes with appropriate organic fertilization enhances soybean productivity in lowland environments.

Keywords: Dena 1, Denasa 2, M.1.1.3-line, yield, vermicompost

Introduction

Soybean (*Glycine max* L.) is one of the most economically important food crops in Indonesia, valued for its high nutritional value and broad utilization. Soybean seeds contain approximately 34% protein and 16–20% lipid, along with essential minerals such as calcium, iron, and phosphorus, and B-complex vitamins that contribute significantly to human nutrition (Suhaeni, 2023). Soybeans are widely processed into traditional and industrial food products such as tempeh, tofu, soy sauce, and soy milk.

Despite its strategic importance, national soybean production remains insufficient to meet domestic demand. According to Pusat Data dan Sistem Informasi Pertanian



(2024), national soybean production reached 349.10 thousand tons of dry beans in 2023. Nevertheless, domestic demand substantially exceeds local production capacity, leading to soybean imports of approximately 8.02 million tons in 2022. This condition highlights the urgent need to enhance domestic soybean productivity through improved genetic materials and optimized nutrient management.

Productivity improvement can be achieved through the integration of superior genotypes and appropriate fertilization strategies. Crop performance is strongly influenced by genetic potential and environmental conditions, including soil fertility and nutrient availability (Nilahayati & Purba, 2021). Therefore, evaluation of different genotypes under specific nutrient management systems is essential to maximize yield potential.

In Indonesia, several improved soybean varieties such as Anjasmore, Dena 1, and Denasa 2 have been widely cultivated due to their high yield potential and adaptability. These varieties serve as important commercial standards for evaluating the performance of newly developed lines. In addition to conventional breeding, mutation breeding using gamma irradiation has been applied to generate genetic variability and improve agronomic traits in soybean. Nilahayati (2025) stated that one of the promising mutant lines developed through gamma irradiation is the M.1.1.3 line, which has been selected based on its superior morphological and agronomic characteristics. However, comparative information regarding the performance of this mutant line relative to established varieties such as Anjasmore, Dena 1, and Denasa 2 under organic fertilization systems remains limited.

Organic fertilization has gained attention as a sustainable approach to improving soil fertility and crop productivity. Among various organic fertilizers, vermicompost is widely recognized for its ability to improve soil physical, chemical, and biological properties (Mansyur et al., 2021). Vermicompost enhances soil structure, aeration, microbial activity, and nutrient availability. It contains essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), and micronutrients that support plant growth and yield formation.

Vermicompost is produced through the decomposition of organic materials by earthworms, which act as soil ecosystem engineers. Through digestion, earthworms convert organic residues into nutrient-rich granular casts that improve soil aggregation and nutrient availability (Saryanto & Sopandi, 2021). These improvements contribute to enhanced root development and nutrient uptake efficiency.

Previous studies have demonstrated that vermicompost application significantly improves soybean growth and yield. However, most studies have focused on individual varieties, and limited information is available regarding genotype-dependent responses, particularly when comparing mutant lines with widely cultivated commercial varieties. Understanding the interaction between genotype and vermicompost application is essential to determine whether the mutant line M.1.1.3 exhibits superior adaptability and nutrient use efficiency compared with Anjasmore, Dena 1, and Denasa 2.

Therefore, this study aimed to evaluate the agronomic performance and yield response of a gamma-induced soybean mutant line (M.1.1.3) in comparison with Anjasmore, Dena 1, and Denasa 2 under different vermicompost application rates in lowland conditions. terhadap pertumbuhan stek nilam (Burhanuddin & Nurmansyah, 2010).



Methods

Experimental site and soil characteristics

The field experiment was conducted from February to June 2023 in Paloh Lada Village, Dewantara Subdistrict, North Aceh Regency, Indonesia, located at an altitude of approximately 8 m above sea level. Lowland tropical conditions characterize the area. Laboratory analyses were performed at the Agroecotechnology Laboratory, Faculty of Agriculture, Universitas Malikussaleh.

Experimental design and treatments

The experiment was arranged in a factorial Randomized Complete Block Design (RCBD) with three replications. Two experimental factors were evaluated. The first factor consisted of four soybean genotypes: Anjasmoro, Dena 1, Denasa 2, and the gamma-induced mutant line M.1.1.3. The second factor was vermicompost application rate, comprising three levels: 0 t ha⁻¹, 5 t ha⁻¹ (800 g plot⁻¹), and 10 t ha⁻¹ (1600 g plot⁻¹).

The combination of four genotypes and three vermicompost levels resulted in 12 treatment combinations, which were replicated three times, giving a total of 36 experimental units. Each experimental unit consisted of a raised bed measuring 1.60 m × 1.00 m (1.6 m²) with a height of 30 cm. The spacing between plots was 30 cm, and the spacing between blocks was 50 cm. Soybean seeds were planted at a spacing of 40 cm × 20 cm, resulting in 16 plants per plot after thinning.

Land preparation and fertilization

The field was cleared of weeds and plant residues before soil tillage. Raised beds were prepared according to the experimental layout. Vermicompost was applied two weeks before planting and thoroughly incorporated into the topsoil (0–15 cm depth) according to the designated treatment rates. A basal inorganic fertilizer (NPK 16:16:16) was applied at planting at a rate of 100 kg ha⁻¹, equivalent to 50% of the recommended dose, to ensure minimum nutrient availability across all treatments.

Planting and crop management

Seeds were selected based on uniform size and shape before planting. Two seeds were planted per hole. Thinning was conducted at 7 days after sowing (DAS) to maintain one healthy plant per planting hole. Irrigation was performed twice daily (morning and afternoon) or adjusted according to plant water requirements to maintain optimal soil moisture. Weeding was conducted manually whenever necessary to prevent competition. Pest management was carried out preventively and curatively. Carbofuran (Furadan 3GR) was applied around the planting holes at sowing and again at approximately three weeks after planting to control ant pests (Formicidae).

Harvesting and yield determination

Harvesting was conducted at physiological maturity, as indicated by yellowing leaves, brown pods, and hardened stems. Plants were carefully uprooted to minimize pod shattering. Harvested plants were sun-dried until constant weight was achieved. Seeds were manually separated from pods, cleaned, and weighed.

Observed variables

Growth and yield-related parameters were recorded to evaluate the response of soybean genotypes to vermicompost application. Growth variables included plant height, leaf area, days to flowering, and days to harvest. Yield components included



the number of productive branches per plant, the number of root nodules per plant, the number of filled pods per plant, seed dry weight per plant, the 100-seed weight, the seed weight per plot, and total seed yield per hectare.

Statistical analysis

Data were subjected to two-way analysis of variance (ANOVA) appropriate for a factorial RCBD. Significance was determined at the 5% probability level ($p \leq 0.05$). When significant differences were detected, mean separation was performed using Duncan's Multiple Range Test (DMRT) at the 5% level. Statistical analyses were performed using the SAS software program.

Results and discussion

Plant height

Genotype significantly affected plant height at 4 MST and highly significantly at 6 and 8 MST. At 4 MST, the highest plant height was recorded in G4 (M.1.1.3 line) at 26.92 cm, which was significantly higher than G1 (22.69 cm), G3 (21.75 cm), and G2 (19.66 cm). At 6 MST, G1 (47.00 cm) and G4 (46.44 cm) were statistically similar and significantly higher than G3 (44.48 cm) and G2 (40.52 cm). At 8 MST, G4 produced the tallest plants (62.57 cm), exceeding G3 (52.88 cm) and slightly surpassing G1 (60.51 cm) and G2 (60.57 cm). Detailed mean comparisons are presented in Table 1.

The increasing divergence among genotypes from 4 to 8 MST indicates progressive expression of genetic potential during the vegetative phase. The results of this study are consistent with Nilahayati et al. (2022), who reported that the tallest plants were

Table 1

Mean plant height of soybean as affected by several genotypes and vermicompost application. Values followed by the same letter within the same treatment and variable are not significantly different according to Duncan's multiple range test (DMRT) at the 5% level. (WAP = weeks after planting).

Treatment	Plant height (cm)			
	2 WAP	4 WAP	6 WAP	8 WAP
Genotype (G):				
G ₁ (Anjasmore)	9.84 a	22.69 b	47.00 a	60.51 b
G ₂ (Dena 1)	8.81 a	19.66 c	40.52 c	60.57 b
G ₃ (Denasa 2)	9.20 a	21.75 b	44.48 b	52.88 c
G ₄ (Galur M.1.1.3)	10.31 a	26.92 a	46.44 a	62.57 a
Vermicompost (P):				
P ₀ (0 kg/plot)	9.46 a	21.67 a	39.77 c	55.96 c
P ₁ (800 g/plot)	9.35 a	22.36 a	44.46 b	59.34 b
P ₂ (1600 g/plot)	9.82 a	24.24 a	49.60 a	62.10 a



observed in the Anjasmoro variety, whereas the best yield characteristics were found in the M.1.1.3 line.

Vermicompost significantly influenced plant height at 6 and 8 MST. Application of 1600 g/plot (P2) increased plant height to 49.60 cm at 6 MST and 62.10 cm at 8 MST, compared with 39.77 cm and 55.96 cm under control conditions. The complete data are summarized in Table 1. The application rate of 1600 g plot⁻¹ resulted in a marked increase in plant height compared to the control treatment. This improvement can be attributed to the rich nutrient composition of vermicompost, which supplies essential macro- and micronutrients required for vegetative growth. Enhanced plant height under improved nutrient availability is consistent with the findings of Sihalo et al. (2015), who reported that plant height increment is closely associated with soil fertility status and adequate nutrient supply. Vermicompost acts as a readily available nutrient source that enhances soil biological activity and nutrient mineralization, thereby promoting plant growth (Nusantara et al., 2010).

A significant genotype × vermicompost interaction was observed for plant height at 6 and 8 weeks after planting (WAP), as presented in Table 2. At 6 WAP, all genotypes showed a consistent increase in plant height with increasing vermicompost dosage. Under control conditions (P0), plant height ranged from 34.75 cm (G2) to 43.17 cm (G1). Application of 1600 g plot⁻¹ (P2) increased plant height to 50.50 cm in G1, 45.91 cm in G2, 48.41 cm in G3, and 53.58 cm in G4. The highest value (53.58 cm) was recorded in

Table 2

Interaction between genotype and vermicompost application on plant height (cm) at 6 and 8 WAP. Mean followed by the same uppercase letter within the same row and the same lowercase letter within the same column are not significantly different according to Duncan's multiple range test (DMRT) at the 5% significance level.

Treatment	Plant height 6 WAP		
	P0	P1	P2
G1	43.17 C a	47.33 B a	50.50 A b
G2	34.75 C a	40.91 B b	45.91 A b
G3	40.53 C a	44.50 B a	48.41 A b
G4	40.63 C a	45.12 B a	53.58 A a
	Plant height 8 WAP		
	P0	P1	P2
G1	57.72 B a	61.08 A a	62.75 A b
G2	58.75 A a	60.33 A a	62.64 A b
G3	50.91 A b	52.75 A b	55.00 A c
G4	56.45 C A	63.22 B a	68.03 A a



G4 (M.1.1.3 line) under P2, which was significantly different based on DMRT at 5%.

A similar trend was observed at 8 WAP. Under P0, plant height varied between 50.91 cm (G3) and 58.75 cm (G2), whereas under P2 it increased to 62.75 cm (G1), 62.64 cm (G2), 55.00 cm (G3), and reached a maximum of 68.03 cm in G4. The value obtained by G4 under P2 (68.03 cm) was statistically superior to the other treatment combinations.

Collectively, these results demonstrate that although all genotypes benefited from vermicompost application, the growth enhancement was most pronounced in the M.1.1.3 line. The larger response amplitude observed in G4 suggests greater nutrient use efficiency and higher physiological plasticity under improved soil fertility conditions. This interaction underscores that the effectiveness of organic fertilization strategies depends strongly on genotype-specific growth potential.

Leaf area

Leaf area was not significantly affected by genotype at any observation stage. However, vermicompost significantly influenced leaf area at 2 and 6 MST. At 2 MST, P2 produced the largest leaf area (15.10 cm²) compared with 10.59 cm² under P0. Similarly, at 6 MST, leaf area reached 59.44 cm² under P2, significantly higher than 45.35 cm² under control conditions. These data are provided in Table 3.

The increase in leaf area under vermicompost application indicates improved nitrogen supply and enhanced vegetative growth. Nutrients in vermicompost are more readily available because partial decomposition occurs during its production process (Rosnina et al., 2024). In addition, vermicompost improves soil structure and water retention, thereby increasing nutrient absorption efficiency (Maulana et al., 2023).

Table 3

Mean leaf area of soybean as affected by several genotypes and vermicompost application. Values followed by the same letter within the same treatment and variable are not significantly different according to Duncan's multiple range test (DMRT) at the 5% level. (WAP = weeks after planting).

Treatment	Leaf area (cm)			
	2 WAP	4 WAP	6 WAP	8 WAP
Genotype (G):				
G ₁ (Anjasmoro)	13.03 a	40.38 a	59.75 a	71.22 a
G ₂ (Dena 1)	13.04 a	34.65 a	45.23 a	52.86 a
G ₃ (Denasa 2)	12.18 a	31.17 a	49.27 a	61.93 a
G ₄ (Galur M.1.1.3)	11.69 a	30.38 a	49.37 a	65.31 a
Vermicompost (P):				
P ₀ (0 kg/plot)	10.59 b	30.57 a	45.35 b	58.39 a
P ₁ (800 g/plot)	11.77 b	32.19 a	47.92 b	59.20 a
P ₂ (1600 g/plot)	15.10 a	39.68 a	59.44 a	70.91 a



Enhanced leaf expansion directly increases photosynthetic surface area, contributing to greater assimilate production for reproductive development.

Days to 50% flowering and days to harvest

Genotype exerted a highly significant effect on flowering and harvest age. Denasa 2 (34.44 days) and Dena 1 (34.88 days) flowered earlier than Anjasmoro (36.66 days) and M.1.1.3 (37.33 days). Regarding maturity, M.1.1.3 required 95.11 days to harvest, significantly longer than G1 (88.44 days), G3 (87.11 days), and G2 (81.77 days). Vermicompost did not significantly affect flowering or harvest age, confirming that phenological traits are predominantly genetically controlled. A complete summary is presented in Table 4.

The findings of Nilahayati and Putri (2015) and Nilahayati and Ramadania (2023) also demonstrated a significant effect of varietal differences on soybean flowering time. Flowering time is closely related to physiological maturity, as Trihantoro (2010) stated, noting that crop duration is largely determined by flowering rate. Environmental factors such as sunlight, rainfall, humidity, and local climate also influence crop duration (Asnawi, 2013).

Productive branches, root nodules, and filled pods

Both genotype and vermicompost significantly affected the number of productive branches, root nodulation, and filled pods. These results are presented in Table 5. Genotype significantly affected the number of productive branches (Table 5). The highest value was recorded in G4 (M.1.1.3 line) with 7.33 branches per plant, which was significantly higher than G1 (3.72 branches), G2 (3.30 branches), and G3 (3.13 branches) based on DMRT at the 5% level. The three released varieties did not differ

Table 4

Mean days to flowering and days to harvest of soybean as affected by genotype and vermicompost application. Values followed by the same letter within the same treatment and variable are not significantly different according to Duncan's multiple range test (DMRT) at the 5% level. (WAP = weeks after planting).

Treatment	Days to flowering	Description	Days to harvest	Description
Genotype (G):				
G ₁ (Anjasmoro)	36.66 a	35.7-39.4	88.44 b	85.5-92.5
G ₂ (Dena 1)	34.88 b	35	81.77 c	78
G ₃ (Denasa 2)	34.44 b	33	87.11 b	78
G ₄ (Galur M.1.1.3)	37.33 a	36-37	95.11 a	77-83
Vermicompost (P):				
P ₀ (0 kg/plot)	36.00 a		88.58 a	
P ₁ (800 g/plot)	36.16 a		87.00 a	
P ₂ (1600 g/plot)	36.33 a		88.75 a	



Table 5

Mean number of productive branches, root nodules, and pods of soybean as affected by genotype and vermicompost application. Values followed by the same letter within the same treatment and variable are not significantly different according to Duncan's multiple range test (DMRT) at the 5% level. (WAP = weeks after planting).

Treatment	Number of productive branches	Root nodules	Pods of soybean
Genotype (G):			
G ₁ (Anjasmore)	3.72 b	112.36 a	117.52 b
G ₂ (Dena 1)	3.30 c	103.16 c	118.36 b
G ₃ (Denasa 2)	3.13 c	106.25 bc	116.50 b
G ₄ (Galur M.1.1.3)	7.33 a	111.13 ab	133.83 a
Vermicompost (P):			
P ₀ (0 g/plot)	3.64 a	87.08 c	116.41 c
P ₁ (800 g/plot)	4.41 a	110.72 b	122.08 b
P ₂ (1600 g/plot)	5.06 a	126.87 a	126.16 a

markedly from one another, indicating relatively similar branching capacity among Anjasmore, Dena 1, and Denasa 2.

In contrast, vermicompost application did not significantly influence the number of productive branches, as all treatments (P₀ = 3.64; P₁ = 4.41; P₂ = 5.06 branches) were statistically similar according to DMRT 5%. Although a numerical increase was observed with higher vermicompost rates, the differences were not statistically significant.

The markedly higher branching observed in G₄ suggests stronger vegetative vigor and greater potential for sink formation compared to the released varieties. Productive branches are important yield components because they determine the potential number of nodes available for pod formation. The absence of a significant vermicompost effect indicates that branching in this study was predominantly controlled by genetic factors rather than nutrient availability. These results confirm that the M.1.1.3 line possesses superior architectural traits that may contribute to its higher reproductive performance. According to Yustiningsih (2019), branching capacity is influenced by genetic potential and the plant's efficiency in utilizing nutrients and light.

Genotype had a significant effect on the number of filled pods (Table 5). The highest number of filled pods was recorded in G₄ (M.1.1.3 line) with 133.83 pods per plant, which was significantly higher than G₁ (117.52 pods), G₂ (118.36 pods), and G₃ (116.50 pods) based on DMRT at the 5% level. The three released varieties (Anjasmore, Dena 1, and Denasa 2) did not differ significantly from each other.



Vermicompost application also significantly increased the number of filled pods. Under control conditions (P0), plants produced 116.41 filled pods, which increased to 122.08 pods with 800 g plot⁻¹ (P1) and reached 126.16 pods with 1600 g plot⁻¹ (P2). The highest dose (P2) was significantly superior to P0 and P1.

The superior performance of G4 indicates a higher reproductive capacity compared to the released varieties. The greater pod formation in this genotype may be associated with enhanced assimilate partitioning toward reproductive organs. Increased pod number under vermicompost application suggests improved nutrient availability, particularly phosphorus and potassium, which play essential roles in flowering, pod setting, and seed filling. Adequate nutrient supply during the reproductive phase supports better pod retention and reduces flower or pod abortion.

Vermicompost at P2 increased filled pods to 126.16 compared with 116.41 under P0. Adequate phosphorus and potassium availability support pod formation and seed filling (Mayani et al., 2021). Increased empty pods may reduce final yield (Monggesang & Pinaria, 2022).

A significant genotype × vermicompost interaction was observed for root nodule number (Table 6), indicating differential nodulation responses among genotypes. Root nodule number increased consistently with vermicompost application across all genotypes. Under control conditions (P0), nodulation ranged from 80.16 nodules (G3) to 102.75 nodules (G4). Application of 1600 g plot⁻¹ (P2) increased nodulation to 139.33 nodules in G1, 122.08 in G2, 124.25 in G3, and 121.83 in G4. The highest value (139.33 nodules) was recorded in G1 under P2 and was significantly superior based on DMRT at the 5% level.

Among genotypes, G1 showed the greatest increase in nodulation (from 82.75 to 139.33 nodules), whereas G4 exhibited the highest baseline nodulation but a more moderate response to vermicompost. These results confirm that nodulation response to organic fertilization is genotype-dependent. Soil properties strongly influence

Table 6

Interaction between genotype and vermicompost application on root nodules. Means followed by the same uppercase letter within the same row and the same lowercase letter within the same column are not significantly different according to Duncan's multiple range test (DMRT) at the 5% significance level.

Treatment	Root nodules		
	P0	P1	P2
G1	82.75 C	115.00 B	139.33 A
	B	a	a
G2	82.66 C	104.75 B	122.08 A
	B	a	b
G3	80.16 B	114.33 A	124.25 A
	b	a	b
G4	102.75 B	108.83 B	121.83 A
	a	a	b



nodulation (Hardjowigeno, 2012), while temperature, pH, and nutrient availability affect nodule formation (Suryantini, 2015). and nitrogen availability from vermicompost stimulates Rhizobium infection (Mayani et al., 2021).

100-seed weight, seed weight, and yield

The variables of 100-seed weight, dry seed weight per plant, dry seed weight per plot, and yield were significantly influenced by genotype, while vermicompost application significantly affected dry seed weight per plant, dry seed weight per plot, and yield but did not significantly influence 100-seed weight. Detailed mean comparisons are presented in Table 7.

Genotype exerted a strong effect on 100-seed weight. Denasa 2 (G3) produced the heaviest seeds (18.29 g), significantly higher than Anjasmoro (15.36 g) and Dena 1 (15.40 g), whereas the M.1.1.3 line (G4) recorded the lowest value (12.66 g) based on DMRT at 5%. This finding confirms that seed size is largely genetically controlled, as reported by Nurlisan et al. (2014). However, larger seed size did not necessarily translate into higher yield performance in this study.

Despite having the smallest seed size, G4 produced the highest dry seed weight per plot (615.92 g) and yield (3.84 t ha⁻¹), significantly surpassing G1 (2.33 t ha⁻¹), G2 (2.91 t ha⁻¹), and G3 (2.29 t ha⁻¹). This indicates that yield formation was more closely associated with yield components, such as pod number and plant architecture, rather than with individual seed weight. Varietal genetic potential plays a primary role in determining yield performance (Susanto & Adie, 2010), which explains the superior productivity of the M.1.1.3 line.

Table 7

Mean 100-seed weight, dry seed weight per plant, dry seed weight per plot, and yield of soybean as affected by several genotypes and vermicompost application. Values followed by the same letter within the same treatment and variable are not significantly different according to Duncan's multiple range test (DMRT) at the 5% level. (WAP = weeks after planting).

Treatment	100-seed weight (g)	Dry seed weight per plant (g)	Dry seed weight per plot (g)	Yield
Genotype (G):				
G ₁ (Anjasmoro)	15.36 b	40.98 a	373.74 c	2.33 c
G ₂ (Dena 1)	15.40 b	41.36 a	467.14 b	2.91 b
G ₃ (Denasa 2)	18.29 a	40.00 b	367.97 c	2.29 c
G ₄ (Galur M.1.1.3)	12.66 c	40.98 a	615.92 a	3.84 a
Vermicompost (P):				
P ₀ (0 kg/plot)	15.20 a	39.94 c	435.89 c	2.72 c
P ₁ (800 g/plot)	15.34 a	40.85 b	458.11 b	2.86 b
P ₂ (1600 g/plot)	15.73 a	41.64 a	474.59 a	2.96 a



Vermicompost application significantly increased dry seed weight per plant from 39.94 g (P0) to 41.64 g (P2), dry seed weight per plot from 435.89 g (P0) to 474.59 g (P2), and yield from 2.72 t ha⁻¹ (P0) to 2.96 t ha⁻¹ (P2). Similar improvements in dry seed weight following vermicompost application were reported by Herlina et al. (2016). The yield enhancement under organic fertilization is attributed to improved soil fertility, increased microbial activity, and greater nutrient-use efficiency, as documented by Yadav et al. (2018).

Vermicompost application significantly increased dry seed weight per plant from 39.94 g (P0) to 41.64 g (P2), dry seed weight per plot from 435.89 g (P0) to 474.59 g (P2), and yield from 2.72 t ha⁻¹ (P0) to 2.96 t ha⁻¹ (P2). However, 100-seed weight was not significantly affected by vermicompost, with values ranging from 15.20 to 15.73 g across treatments. These results indicate that vermicompost enhanced overall productivity primarily by increasing biomass accumulation and reproductive output rather than altering seed size.

A significant interaction between genotype and vermicompost was observed for dry seed weight per plant, seed weight per plot, and yield (Table 8). At the plant level, G1 and G2 showed significant increases in dry seed weight under P2 (42.24 g and 42.58 g, respectively) compared with P0, whereas G3 and G4 were relatively stable across treatments. However, a stronger interaction pattern appeared at the plot level and yielded. Genotype G4 (M.1.1.3) exhibited the highest responsiveness to vermicompost, increasing seed weight per plot from 572.12 g (P0) to 659.18 g (P2) and yield from 3575.72 to 4119.89 kg ha⁻¹ (≈ 4.12 t ha⁻¹), significantly outperforming other genotypes based on DMRT 5%. In contrast, G1 and G3 showed only slight, non-significant improvements, while G2 showed moderate gains. These results indicate that although vermicompost improved productivity, the magnitude of response was genotype-dependent, with G4 demonstrating superior nutrient responsiveness and yield potential.

These differences are likely associated with genetic potential and varietal adaptability. Each genotype possesses distinct genetic capacities for flower, pod, and seed formation, as well as differences in photosynthetic efficiency and in assimilate partitioning to reproductive organs. Genotypes with superior assimilate translocation efficiency tend to accumulate greater reproductive biomass, thereby increasing yield. This finding is consistent with Susanto and Adie (2010), who stated that varietal genetic potential is a primary determinant of yield performance, although environmental factors influence its expression.

In addition to genotype effects, vermicompost application significantly affected seed weight per plot and yield. The highest dosage (1600 g plot⁻¹) increased seed weight per plot (474.59 g in the main effect) and yield (2.96 t ha⁻¹), with the strongest response observed in the G4P2 combination. This improvement is attributed to the gradual supply of macro- and micronutrients, enhanced soil structure, improved water retention capacity, and stimulated microbial activity provided by vermicompost. These improvements support optimized photosynthesis and more efficient assimilate distribution to seeds. Similar findings were reported by Yadav et al. (2018), who observed significant increases in seed weight following vermicompost application due to improved soil fertility and nutrient use efficiency.

Furthermore, Mustaanullah et al. (2022) reported that 7.5 t ha⁻¹ of vermicompost increased soybean yield by up to 1.47 t ha⁻¹ compared with other doses. Enhanced populations of beneficial microorganisms, such as *Azotobacter* sp., and improved edamame soybean yield were also documented by Setiawati et al. (2018). Likewise, Arif et al. (2019) and Rahman et al. (2020) confirmed that vermicompost significantly



Table 8

Interaction between genotype and vermicompost application on seed weight per plant, seed weight per plot, and yield. Means followed by the same uppercase letter within the same row and the same lowercase letter within the same column are not significantly different according to Duncan's multiple range test (DMRT) at the 5% significance level.

Treatment	Seed weight per plant		
	P ₀	P ₁	P ₂
G1	39.75 C	40.96 B	42.24 A
	a	a	A
G2	40.07 C	41.43 B	42.58 A
	a	a	A
G3	39.77 A	40.03 A	40.21 A
	a	b	B
G4	40.16 A	41.00 A	41.56 A
	a	a	A
	Seed weight per plot		
G1	366.11 A	374.51 A	380.61 A
	c	c	c
G2	446.34 A	473.28 A	481.82 A
	b	b	b
G3	359.00 A	368.18 A	376.74 A
	c	c	c
G4	572.12 C	616.49 B	659.18 A
	a	a	a
	Yield		
G1	2288.19 A	2340.68 A	2378.83 A
	c	c	c
G2	2789.64 A	2957.97 A	3011.39 A
	b	b	b
G3	2243.77 A	2301.14 A	2354.64 A
	c	c	c
G4	3575.72 C	3846.37 B	4119.89 A
	a	a	a



enhances soybean productivity through improved nutrient availability and soil physical properties.

The superior performance of G4, combined with higher vermicompost dosage, suggests that yield formation in this study was driven by improved assimilate partitioning and enhanced sink capacity. Organic fertilization likely improved soil nutrient availability and root activity, supporting pod development and seed filling. Thus, yield performance was determined by the interaction between genetic potential and improved soil fertility, with the M.1.1.3 line demonstrating the highest productivity under enhanced nutrient conditions.

Conclusion

Genotype significantly influenced all variables except leaf area, with the M.1.1.3 line exhibiting the best overall performance. Vermicompost significantly enhanced growth and yield components, with the optimum response achieved at 1600 g plot⁻¹ (10 t ha⁻¹). Significant genotype × vermicompost interactions for plant height, nodulation, seed weight, and yield indicate that productivity responses were genotype-dependent.

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