

The role of nano fertilizers and compost in improving agricultural soil properties and their impact on faba bean productivity

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Abstract. The research aimed to assess the effects of NPK nano-fertilizers and compost, with or without NPK mineral fertilizers, on soil properties and the productivity of local beans. The results showed that when nano-fertilizers and compost were applied, there were increases in plant height (cm), number of branches per plant, number of pods per plant, pod weight (ton/acre), and 100-seed weight compared to when mineral fertilizers were used at different concentrations. The interaction of NPK nano-fertilizers with organic manure, along with NPK mineral fertilizers, increased protein levels with the increasing rate of NPK mineral fertilizers. Additionally, the interaction of NPK nano-fertilizers with organic manure increased proline content in seeds with the increasing rate of different mineral fertilizers. Overall, the application of NPK nano-fertilizers was found to improve soil fertility and increase crop productivity.

1 Introduction

The faba bean (*Vicia faba*) is regarded as one of the most important winter legume crops, characterized by its high protein content in the human diet, making it a source of green protein. As a result, it plays a significant role, particularly for people with low means, in addition to boosting soil fertility through the biological nitrogen fixation process [1]. Faba beans are primarily grown from green pots and dried seeds. They are rich in nutritional value, containing about 28% protein, 58% carbohydrates, vitamins, and other beneficial compounds. This makes them an important component of both human food and animal feed [2]. Additionally, according to [3], beans are an excellent source of protein for human consumption, as well as a good source of iron, zinc, calcium, vitamin B complex, health-beneficial antioxidants, plant sterols, and dietary fiber. Furthermore, beans contribute to crop yield, soil texture, and fertility through atmospheric nitrogen fixation by *Rhizobium leguminosarum* [4]. The crop planted in Egypt covered approximately 88,000 acres (1 feddan = 4,200 square meters) in 2015, with a total seed production of about 153,000 tons [5]. Grain legume crops are well-known for providing valuable ecosystem services in arable cropping systems. These services include the following:

- 1- The capacity to fix atmospheric nitrogen.

- 2- Reducing greenhouse gas emissions and carbon footprints from agricultural rotations.
- 3- Reducing the reliance on mineral fertilizers.
- 4- Diversifying arable crop cycles to promote above- and below-ground biodiversity while reducing weed, insect, and disease pressure in succeeding crops [6].

Faba beans are best suited for loam, clay loam, loamy clay, and clay soils, while lupins and peas are recommended for grain legume production on lighter soils [7]. In 2005, [8] conducted a study to determine that adding phosphate fertilizer to the soil from different sources (superphosphate fertilizer, triple superphosphate fertilizer, and phosphate rock) yielded the highest value for the faba bean crop and its component vegetative characteristics. These further raised the uptake of nitrogen and phosphorus, especially upon using the superphosphate fertilizer with 52.0% P_2O_5 , then the single superphosphate fertilizer with 20% P_2O_5 . The superphosphate fertilizer supplied 802.2 mg N/plant and 802.2 mg P/plant while the single superphosphate fertilizer supplied 850.2 mg N/plant and 822.8 mg P/plant. The study was a classic account of the importance of phosphorus to cell activity and division, hence increasing the plant height, number of branches, and weight of plant dry matter. [9] indicated that adding phosphate fertilizer to the soil at rates of 0, 200 and 200 kg P_2O_5 /ha significantly increased the faba bean plant's dry weight and phosphorus concentration. One such study was conducted by [10] to determine the effects of applying different levels of phosphate derived from two sources (TSP and DAP) at 0, 20 and 280 kg P/ha on the growth characteristics of faba bean plants. The results showed that increasing one type of phosphate source significantly increased plant height, number of branches, and dry weight of faba bean plants. A further study was made to determine the effect of phosphate and zinc fertilization on the growth parameters of the faba beans. Nanotechnology involves manipulating and controlling matter at the nanoscale, which is in the range of 1-100 nm. This allows for unique phenomena and novel applications [11]. Currently, nanotechnology is being utilized in agriculture and related industries. Key areas of focus for nanotechnology in agricultural research include agricultural diagnostics, nano-biosensors, nano-bio farming, nano-pesticides, nano-herbicides, and the controlled release of nano-fertilizers and nano-compounds [12]. Moreover, overdoses of mineral fertilizers are an energy-wasting issue leading to a reduction in nutrient use efficiency. Around 50-70% of the conventional chemical fertilizers applied are lost in the environment related to several concerns: economic, agronomical, environmental issues, and health risks. This way, innovative approaches in vegetable fertilization should be used to enhance food production. Therefore, new options for environmentally friendly, cost-effective, and sustainable agriculture nano-fertilizers may act as slow- or controlled-release fertilizers when applied to the soil [13]. The application of NPK nano-fertilizers to soil significantly contributes to the growth and yield of cotton by producing total open bolls per plant, boll weight, and seed-cotton yield, besides reducing fertilizer cost. Also, it minimizes environmental pollution [14]. In the study carried out by [15], it was reported that the most notable increased value of TSS is related to applying 25% nano-phosphorus and 50% monopotassium. The highest values of total sugars were recorded for the mono treatment at a 50% rate in both seasons. Also, when applied at rates of 50% in the two seasons, nano-phosphorus and nano-potassium markedly raised the P and K contents in heads. The control, NPK conventional, however, gave the highest values of head nitrate content above any other nano-treatment in both seasons. The application of composted organic matter to soil may have a significant impact on plant growth, yield, and quality [16]. When compost is combined with mineral nitrogen in saline soil, it has been shown to increase the availability of nitrogen, phosphorus, potassium, iron, zinc, and manganese in the soil. This results in increased uptake of nitrogen, phosphorus, potassium, iron, zinc, and manganese in the straw and grain of the plants [17]. [18] revealed that the foliar application of Nano-fertilizers was increase proteins (%) content in the grain. In a study by [19], it was found that the use of organic fertilizers or NPK fertilizers had a notable impact on the iron

concentration in seeds. However, zinc and manganese did not show a significant effect. Furthermore, the combination of applying organic fertilizer and foliar spraying of NPK fertilizers resulted in a noteworthy increase in the concentrations of iron, manganese, and zinc in seeds as the rates of NPK mineral fertilizers increased.

2 Martial and methods

A field experiment was conducted in the winters of 2023 and 2024 in Sirs El-Layin, Menoufia Governorate. The study aimed to test the effect of organic fertilizers, nano-fertilizers (NPK), and compost on soil properties and the production of faba beans. The experimental design used was a complete random block with three replicates. Before planting, the physical and chemical properties of the soil were determined using the methods described by [20]. The mechanical and chemical properties of the upper subsoil (0-30 cm) and the available phosphorus of the soil were also determined before planting in both seasons. These findings are summarized in Table (1).

Table 1. Physical and chemical properties of the experimental soil for upper 30 cm layer in two growing seasons.

Sites	Texture	Physical properties				Chemical properties											
		Coarse	Fine	Silt	Clay	CaCO ₃ %	Cations ml/100 g				Anions/ml/100 g				N%	P%	K%
							Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻			
1	Sandy clay	1.4	50.2	24	17	2.1	2.9	1.3	1.2	0.50	–	1.0	1.5	2.00	0.15	0.13	0.05
2	Sandy clay	2.0	51.1	25	19	2.3	1.3	1.4	1.3	0.55	0.5	1.2	1.8	1.30	0.21	0.17	0.07

Compost analysis followed the standard methods described by [21]. The chemical composition of the compost used is presented in Table (2). The nano of NPK was obtained from Nano FAB Technology Company, 4 Saraya Building, 6 October City, Cairo, Egypt.

Table 2. The chemical composition of the compost utilized in this experiment.

pH	Bulk density (g/cm ³)	Organic carbon content %	Organic matter %	Total macronutrients (%)		
				N	P	K
7.68	0.45	25	39.00	1.90	0.83	1.90

The Giza A. Mohsen faba bean cultivars were obtained from the Crops Research Institute, Agricultural Research Center, Giza, Egypt. The experiment was designed according to a completely randomized block design, with three replicates, and the results were analyzed using the statistical Program [22], where the means were compared using the least significant difference (LSD) test at the 5% level.

Data were obtained first by harvesting the broad bean for the following traits: plant height, branch number, pod number/plant, 100-seed weight (g), and weight of seed yield (tons/acre).

After harvesting from each treatment, topsoil samples (0-30 cm) were taken to determine the EC (organic matter, calcium carbonate, and available N, P, K, Fe, Mn, Zn and Cu) in the samples.

2.1 Chemical properties:

Both straw and pods were air-dried and dried in an oven at 70°C for 48 h to constant weight. A crop of straw was produced that was dry. Oven-dried straws or seeds were milled and stored in plastic bags pending chemical analysis. 0.5 g of each oven-dried plant sample was digested. Nitrogen, phosphorus, potassium, iron, manganese, and zinc contents in plant digests were determined, and proline content was estimated. The percentage protein content of the seeds was calculated by multiplying the percentage of nitrogen by a factor of 6.25 determined according to [23].

3 Results

The results obtained demonstrated 2022-2023 the impact of NPK and compost fertilizers, in addition to mineral fertilizers, on the productivity of faba beans (Table 3a and Figure 1). The data revealed that using nano-fertilizers and compost led to an increase in plant height (cm), number of branches per plant, number of pods per plant, and weight of 100 seed (g) and seed yield/plot, resulting in improved crop characteristics and yield compared to mineral fertilizers. Treatments with different concentrations of nano-fertilizers resulted in higher yields compared to compost and mineral fertilizers. Specifically, the treatments with nano-fertilizers showed a 110 cm increase in plant height, a 3.9% increase in the number of branches per plant, an 18.3% increase in the number of pods per plant, and a 77% increase in the weight of 100 seeds. The compost also improved crop characteristics at all concentrations.

Table 3a. The effect of applications of nano-fertilizers and compost on some growth and yield parameters in faba broad bean plants under the right conditions during 2022/2023.

Treatments	NPK kg (fed)	Plant height (cm)	No. of branches/plant	No. of pods/plant	Weight of 100 seed (g)	Seed yield (kg)/plot
Mineral	0	98.0 ^d	2.9 ^b	11.9 ^f	65.0 ^f	1.4 ^a
	25	102.0 ^{bcd}	3.0 ^{ab}	12.1 ^f	67.0 ^{ef}	1.6 ^a
	50	104.0 ^{abcd}	3.2 ^{ab}	12.5 ^f	70.0 ^{cde}	1.7 ^a
	100	105.0 ^{abcd}	3.4 ^{ab}	12.7 ^{ef}	72.0 ^{bcd}	1.7 ^a
Nano (NPK)	0	100.0 ^{cd}	3.3 ^{ab}	14.0 ^{de}	71.0 ^{cd}	1.81 ^a
	25	105.0 ^{abcd}	3.6 ^{ab}	15.0 ^{cd}	73.0 ^{bc}	1.91 ^a
	50	108.0 ^{ab}	3.7 ^{ab}	17.0 ^{ab}	75.0 ^{ab}	1.93 ^a
	100	110.0 ^a	3.9 ^a	18.0 ^a	77.0 ^a	1.95 ^a
Compost	0	99.0 ^d	3.1 ^{ab}	13.0 ^{ef}	69.0 ^{de}	1.5 ^a
	25	103.0 ^{abcd}	3.2 ^{ab}	14.0 ^{de}	70.0 ^{cde}	1.7 ^a
	50	107.0 ^{abc}	3.4 ^{ab}	14.6 ^{cd}	72.2 ^{bcd}	1.75 ^a
	100	108.0 ^{ab}	3.5 ^{ab}	15.6 ^{bc}	73.0 ^{bc}	1.81 ^a
LSD at 5%		7.57	0.99	1.46	3.92	0.74

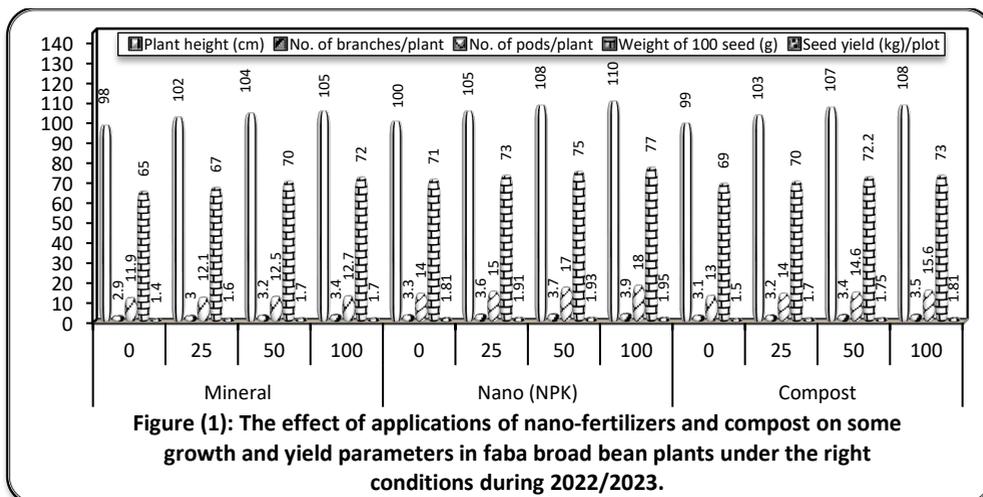


Figure (1): The effect of applications of nano-fertilizers and compost on some growth and yield parameters in faba broad bean plants under the right conditions during 2022/2023.

In the 2023-2024 season, three types of treatments, namely mineral fertilizers, nano-fertilizers, and compost, were found to have a positive impact on the productivity of faba beans. It was observed that higher concentrations of these treatments resulted in improved crop characteristics (Table 3b and Figure 2). Specifically, the use of nano-fertilizers led to an increase in plant height (centimeters), the number of branches per plant, the number of pods per plant, Weight of 100 seed and Seed yield (kg)/plot. These findings indicate that the use of nano-fertilizers contributed to enhancing the overall characteristics of the crop.

Table 3b. The effect of applications of nano-fertilizers and compost on some growth and yield parameters in faba broad bean plants under the right conditions during 2023/2024.

Treatments	NPK kg (fed)	Plant height (cm)	No. of branches/plant	No. of pods/plant	Weight of 100 seed (g)	Seed yield (kg)/plot
Mineral	0	95 ^f	2.5 ^b	10.90 ^e	63.0 ^d	1.1 ^a
	25	98 ^{cdef}	2.7 ^{ab}	10.95 ^e	64.0 ^{cd}	1.2 ^a
	50	100 ^{bcd}	2.9 ^{ab}	11.20 ^{de}	64.0 ^{cd}	1.3 ^a
	100	101 ^{abcd}	3.0 ^{ab}	11.50 ^{de}	65.0 ^{bcd}	1.4 ^a
Nano (NPK)	0	98 ^{cdef}	3.0 ^{ab}	12.0 ^{cde}	69.0 ^{abc}	1.4 ^a
	25	101 ^{abcd}	3.2 ^{ab}	12.50 ^{bcd}	70.1 ^{ab}	1.5 ^a
	50	103 ^{ab}	3.3 ^a	13.50 ^{ab}	70.50 ^a	1.6 ^a
	100	105 ^a	3.4 ^a	14.50 ^a	72.0 ^a	1.65 ^a
Compost	0	96 ^{ef}	2.7 ^{ab}	11.0 ^e	67.0 ^{abcd}	1.2 ^a
	25	97 ^{def}	2.75 ^{ab}	12.0 ^{cde}	69.0 ^{abc}	1.3 ^a
	50	101 ^{abcd}	2.81 ^{ab}	13.0 ^{bc}	70.0 ^{ab}	1.35 ^a
	100	102 ^{abc}	2.90 ^{ab}	13.50 ^{ab}	71.0 ^a	1.4 ^a
LSD at 5%		4.18	0.75	1.38	5.17	0.70

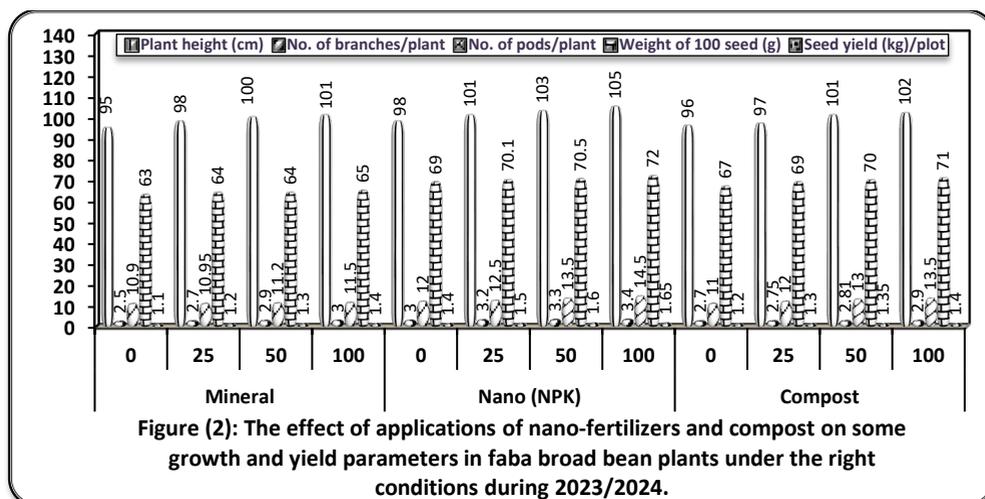


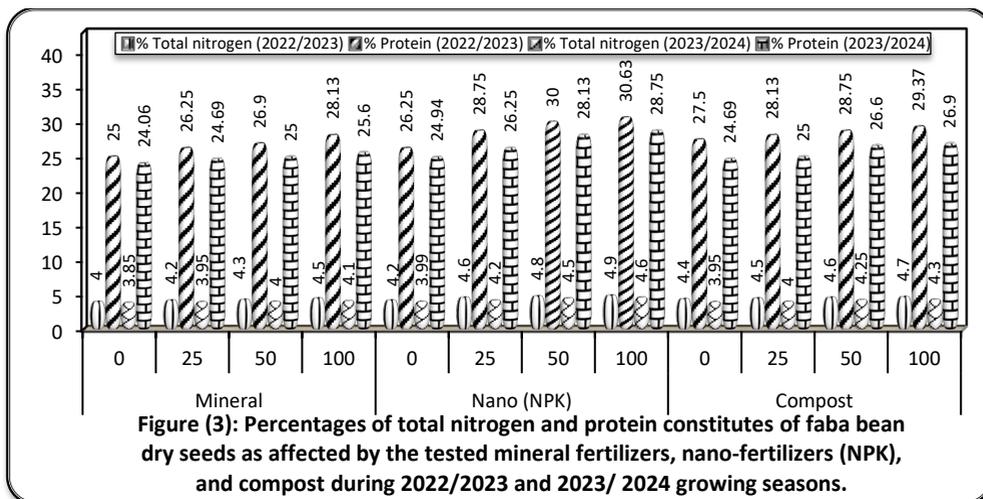
Figure (2): The effect of applications of nano-fertilizers and compost on some growth and yield parameters in faba broad bean plants under the right conditions during 2023/2024.

3.1 Effect of mineral fertilizers, nano-fertilizers (NPK) and compost on total nitrogen and protein in dry faba bean seeds:

The data presented in Table (4) and Figure (3) show that all tested treatments significantly increased total nitrogen and crude protein content in faba bean seeds compared to untreated treatments. Nano-fertilizers recorded higher total nitrogen and crude protein, followed by organic fertilizers (compost) in both seasons. Meanwhile, mineral fertilizers recorded lower results than nano-fertilizers and organic fertilizers.

Table 4. Percentages of total nitrogen and protein constitutes of faba bean dry seeds as affected by the tested mineral fertilizers, nano-fertilizers (NPK), and compost during 2022/2023 and 2023/2024 growing seasons.

Treatments	NPK kg (fed)	2022/2023		2023/2024	
		% Total nitrogen	% Protein	% Total nitrogen	% Protein
Mineral	0	4.0 ^a	25.00 ^g	3.85 ^a	24.06 ^g
	25	4.20 ^a	26.25 ^{fg}	3.95 ^a	24.69 ^{fg}
	50	4.30 ^a	26.90 ^{ef}	4.00 ^a	25.00 ^{efg}
	100	4.50 ^a	28.13 ^{cde}	4.10 ^a	25.60 ^{def}
Nano (NPK)	0	4.20 ^a	26.25 ^{fg}	3.99 ^a	24.94 ^{fg}
	25	4.60 ^a	28.75 ^{bcd}	4.20 ^a	26.25 ^{cde}
	50	4.80 ^a	30.00 ^{ab}	4.50 ^a	28.13 ^{ab}
	100	4.90 ^a	30.63 ^a	4.60 ^a	28.75 ^a
Compost	0	4.40 ^a	27.50 ^{def}	3.95 ^a	24.69 ^{fg}
	25	4.50 ^a	28.13 ^{cde}	4.00 ^a	25.00 ^{efg}
	50	4.60 ^a	28.75 ^{bcd}	4.25 ^a	26.60 ^{cd}
	100	4.70 ^a	29.37 ^{abc}	4.30 ^a	26.90 ^{bc}
LSD at 5%		1.10	1.46	1.01	1.30

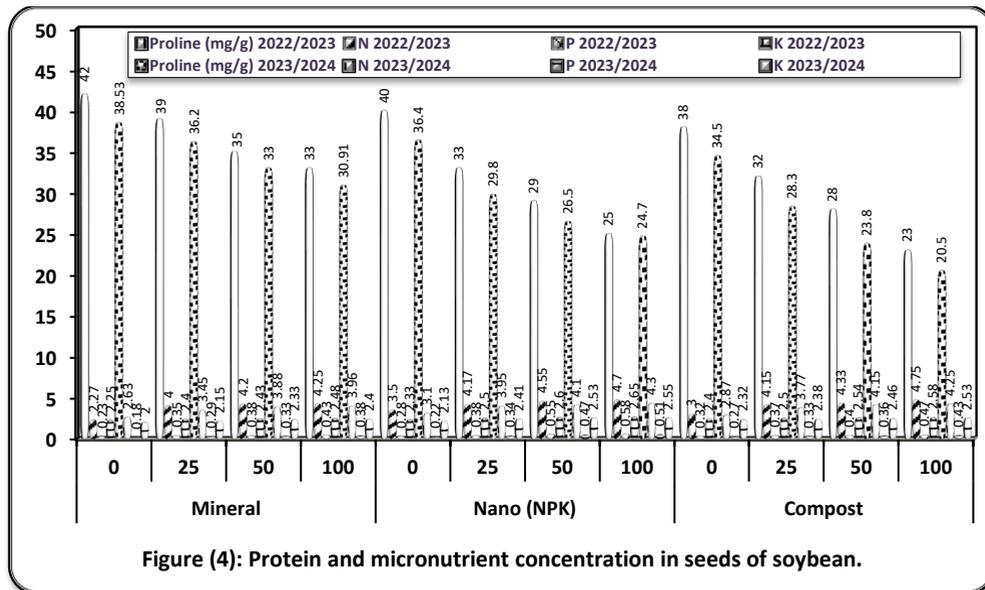


3.2 Proline content (mg/gm D.m) in soybean seeds:

The data in Table (5) and Figure (4) indicated that treatment with mineral fertilizers, NPK nano-fertilizers, and compost at different rates positively affected the decrease in seed proline content. The study revealed that the concentration of primary elements in the seeds notably increased after being treated with nano-fertilizers, followed by compost, and then mineral fertilizers. Additionally, it was observed that as the concentration of fertilizers increased, the percentage of elements in the seeds also increased.

Table 5. Protein and micronutrient concentration in seeds of soybean.

Treatments	NPK kg (fed)	2022/2023				2023/2024			
		Proline (mg/g)	Micronutrients (%)			Proline (mg/g)	Micronutrients (%)		
			N	P	K		N	P	K
Mineral	0	42.0 ^a	2.27 ^d	0.23 ^g	2.25 ^a	38.53 ^a	2.63 ^c	0.18 ^h	2.00 ^a
	25	39.0 ^b	4.00 ^{abc}	0.35 ^{de}	2.40 ^a	36.2 ^b	3.45 ^{abc}	0.29 ^{efg}	2.15 ^a
	50	35.0 ^c	4.20 ^{abc}	0.38 ^{cd}	2.43 ^a	33.0 ^d	3.88 ^{ab}	0.33 ^{def}	2.33 ^a
	100	33.0 ^{cd}	4.25 ^{ab}	0.43 ^{bc}	2.48 ^a	30.91 ^e	3.96 ^{ab}	0.38 ^{cd}	2.40 ^a
Nano (NPK)	0	40.0 ^{ab}	3.50 ^{bc}	0.28 ^{fg}	2.33 ^a	36.4 ^b	3.10 ^{abc}	0.22 ^{gh}	2.13 ^a
	25	33.0 ^{cd}	4.17 ^{abc}	0.38 ^{cd}	2.50 ^a	29.8 ^e	3.95 ^{ab}	0.34 ^{def}	2.41 ^a
	50	29.0 ^e	4.55 ^{ab}	0.55 ^a	2.60 ^a	26.5 ^g	4.10 ^a	0.47 ^{ab}	2.53 ^a
	100	25.0 ^f	4.70 ^{ab}	0.58 ^a	2.65 ^a	24.7 ^h	4.30 ^a	0.51 ^a	2.55 ^a
Compost	0	38.0 ^b	3.00 ^{cd}	0.32 ^{ef}	2.40 ^a	34.5 ^c	2.87 ^{bc}	0.27 ^{fg}	2.32 ^a
	25	32.0 ^d	4.15 ^{abc}	0.37 ^{de}	2.50 ^a	28.3 ^f	3.77 ^{abc}	0.33 ^{def}	2.38 ^a
	50	28.0 ^e	4.33 ^{ab}	0.40 ^{cd}	2.54 ^a	23.8 ^h	4.15 ^a	0.36 ^{cde}	2.46 ^a
	100	23.0 ^f	4.75 ^a	0.47 ^b	2.58 ^a	20.5 ⁱ	4.25 ^a	0.43 ^{bc}	2.53 ^a
L.S.D. at 5%		2.38	1.22	0.06	0.55	1.30	1.20	0.07	0.70



4 Conclusion

From the study, it is evident that using nano-fertilizers and organic manure increased soil organic matter, nitrogen, phosphorous, and potassium content. The results explicitly show that nano-fertilizers increased broad beans not only in yield but also in nutritional quality. Thus, this study has established that nano-fertilizers enhance soil fertility and nutrient quality in grains.

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