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IMPROVING THE QUALITY CHARACTERISTICS OF TWO VARIETIES OF SOYBEAN BY ADDING PHOSPHATE FERTILIZER

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Soybean (*Glycine max* L.) is one of the most important leguminous crops globally, serving as a vital industrial and food crop. Its significance lies in the unique nutritional profile of its seeds, which are among the few plant-based sources that provide most of the essential amino acids required for both human and animal nutrition (Rana *et al.*, 2014). In 2019, global soybean production reached approximately 342.5 million metric tons (FAO, 2020; FAOSTAT, 2021). The qualitative traits of soybean, particularly seed oil and protein content, are influenced by genotypic variation, environmental conditions, and genotype-by-environment interactions (Nget *et al.*, 2022). These traits are critical not only for yield but also for meeting consumer demands for high-quality protein and oil in leguminous crops (Limede *et al.*, 2018).

Previous studies have documented considerable variability among soybean genotypes with respect to these qualitative traits. For example, Salwa *et al.* (2011) reported significant differences in oil and protein content among three Egyptian varieties (Giza22, Giza35, and Giza111). Similar findings were reported by Isaac *et al.* (2016), who observed substantial variation among four inbred lines and a locally adapted cultivar. Further studies by Kareem *et al.* (2019), Mandić *et al.* (2020), Nget *et al.* (2022), Shea *et al.* (2023), Abdulqader *et al.* (2021), Ali *et al.* (2021) and Ali *et al.* (2023) have all confirmed significant genotypic differences in seed quality parameters.

Phosphorus plays a critical role in plant metabolic processes, including flowering, pod development, and seed maturation. Approximately 60% of the phosphorus requirement occurs between flowering and seed filling stages (Sihaloho *et al.*, 2015). However, 75-90% of phosphorus in soil becomes immobilized due to interactions with iron, calcium, and aluminum, rendering it unavailable to plants (Turan *et al.*, 2006; Tiwari *et al.*, 2022). Phosphorus deficiency adversely affects photosynthesis and leaf expansion, ultimately impairing seed quality.

Given the global emphasis on reducing chemical fertilizer usage and the increasing need for sustainable agricultural practices, nanotechnology presents a promising alternative. Nano-fertilizers, particularly nano-phosphorus, have demonstrated similar efficacy to conventional phosphorus fertilizers while possibly mitigating environmental harm (Liu and Lal, 2014; Soliman *et al.*, 2016; Kumar *et al.*, 2016; Olkhovych *et al.*, 2016). Foliar application of nano-phosphates has been reported to significantly improve seed protein content (Jesper *et al.*, 2018), oil percentage, and both oil and protein yields (Yacoub *et al.*, 2020; Ali *et al.*, 2021; Abdulqader *et al.*, 2021; Abdelrazzaq and Ali, 2022; Ali *et al.*, 2023a).

The present study was undertaken to evaluate the effects of different rates of nano-phosphate fertilization on selected qualitative traits (seed oil and protein content) in two soybean varieties, with the aim of identifying the optimal application rate for enhancing seed quality.

This study was conducted during the 2023-2024 summer growing seasons. The experiment followed a factorial arrangement within a Randomized Complete Block Design (RCBD) with three replications. The experimental factors included two soybean (*Glycine max* L.) varieties, Industrial 2 and Iman, and four levels of nano-phosphate fertilizer: 0, 7, 14, and 21 ppm. The fertilizer was applied as a foliar spray at two growth stages: two weeks after seedling emergence and at flowering. Each experimental unit consisted of four rows, each 2.5 meters in length, with 25 cm intra-row spacing and 60 cm inter-row spacing. Sowing was carried out on May 15 in both 2023 and 2024, while harvesting took place on October 30, 2023, and November 1, 2024, respectively. The following traits were measured: Test Weight (kg hL^{-1}): Calculated as [weight of 100 cm^3 of seeds (g) x 10 x 100] / 1000. Oil Percentage (%): Determined according to AOAC

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(198), Oil Yield (kg ha⁻¹: calculated as (Oil % × Seed Yield) / 100, Protein percentage (%): Determined by the Micro-Kjeldahl method (AOAC, 1980). Protein yield (kg ha⁻¹): Calculated as Protein % × Seed Yield / 100.

Test weight (kg hL⁻¹)

Test weight was significantly affected by both soybean variety and nano-phosphate fertilizer levels across both growing seasons (Table 1). The variety *Industrial 2* consistently demonstrated superior performance, recording test weights of 71.48 kg·hL⁻¹ in 2023 and 71.38 kg·hL⁻¹ in 2024, compared to 70.94 kg·hL⁻¹ and 71.06 kg·hL⁻¹ for the *Iman* variety. These findings are consistent with previous studies (Abdulqader *et al.*, 2021; Ali *et al.*, 2021; Ali *et al.*, 2023b; Shea *et al.*, 2023), and are possibly attributable to genotypic differences influencing seed density and composition. Foliar application of nano-phosphate fertilizer significantly improved test weight at the 14 ppm and 21 ppm levels. In 2023, test weights at these concentrations reached 71.53 kg·hL⁻¹ and 71.45 kg·hL⁻¹, respectively, while in 2024, values further increased to 71.84 kg·hL⁻¹ and 71.66 kg·hL⁻¹, compared to the control treatments, which recorded 70.62 kg·hL⁻¹ (2023) and 70.07 kg·hL⁻¹ (2024). The interaction between variety and nano-phosphate levels revealed that *Industrial 2* in combination with 14 ppm and 21 ppm nano-phosphate achieved the highest test weights in 2023 (71.70 and 71.65 kg·hL⁻¹, respectively). In 2024, all nano-phosphate treatments applied to *Industrial 2* resulted in significantly higher test weights compared to the control, further confirming the variety's strong responsiveness to nano-phosphorus application.

Oil percentage

Significant differences in oil percentage were observed between the two soybean varieties across both seasons (Table 2). The *Iman* variety recorded significantly higher oil contents, 18.69% in 2023 and 18.02% in 2024, compared to *Industrial 2*, which yielded 17.53% and 17.28%, respectively. These results are consistent with earlier findings by Salwa *et al.* (2011), Isaac *et al.* (2016), Kareem *et al.* (2019), and Mandić *et al.* (2020), and can be attributed to genotypic variation and genotype-by-environment interactions (Nget *et al.*, 2022). Nano-phosphate fertilizer also had a significant impact on oil percentage. The highest fertilizer level (21 ppm) produced the greatest oil content in both seasons, 19.56% in 2023 and 19.58% in 2024, while the control treatment resulted in the lowest oil values (16.21% and 15.52%, respectively). This enhancement can be attributed to phosphorus's vital role in cell nucleus development and the translocation of photosynthates from leaves to developing seeds (Marschner, 2002).

Interaction effects between variety and fertilizer level revealed that the combination of *Iman* with 21 ppm nano-phosphate yielded the highest oil content (19.89%) in 2023, followed by *Industrial 2* at the same fertilizer level (19.24%). A similar trend was observed in 2024.

Oil yield (kg ha⁻¹)

Oil yield was significantly affected by both soybean variety and nano-phosphate fertilizer level across both growing seasons (Table 3). The *Iman* variety consistently outperformed *Industrial 2*, producing oil yields of 604.77 kg·ha⁻¹ and 596.99 kg·ha⁻¹ in 2023 and 2024, respectively, compared to 365.50 kg·ha⁻¹ and 543.84 kg·ha⁻¹ for *Industrial 2*. These findings align with those reported by Mandić *et al.* (2020) and

Table 1. Effect of varieties and phosphate nano fertilizer levels on the test weight (kg hL⁻¹) during 2023 and 2024

Average of varieties	Phosphate nano fertilizer (ppm)				Varieties
	21	14	7	0	
			2023		
71.48ᵃ	71.70ᵃ	71.65ᵃ	71.50ᵇ	71.07ᶜ	Industrial 2
70.94ᵇ	71.36ᵇᶜ	71.25ᵇᶜ	71.00ᶜ	70.17ᵈ	Iman
	71. 53ᵃ	71.45ᵃ	71.25ᵇ	70.62ᶜ	Average of phosphate nano fertilizer
			2024		
71.38ᵃ	71.91ᵃ	71.83ᵃ	71.64ᵃᵇ	70.14ᶜ	Industrial 2
71.06ᵇ	71.78ᵃ	71.50ᵇ	70.99ᵇ	70.00ᶜ	Iman
	71.84ᵃ	71.66ᵃ	71.31ᵇ	70.07ᶜ	Average of phosphate nano fertilizer

Within a column means values followed by same alphabet do not differ significantly at $p \leq 0.05$

Table 2. Effect of varieties and phosphate nano fertilizer on the percentage of oil in the seeds for years

Average of varieties	Phosphate nano fertilizer (ppm)				Varieties
	21	14	7	0	
			2023		
17.53b	19.24a	18.45b	16.99c	15.46d	Industrial 2
18.69a	19.89a	19.34a	18.57b	16.97c	Iman
	19.56a	18.89b	17.78c	16.21d	Average of phosphate nano fertilizer
			2024		
17.28b	19.41a	18.33b	16.34d	15.04e	Industrial 2
18.02a	19.75a	18.64b	17.69c	16.00d	Iman
	19.58a	18.48b	17.01c	15.52d	Average of phosphate nano fertilizer

Within a column means values followed by same alphabet do not differ significantly at $p \leq 0.05$

Table 3. Effect of varieties and phosphate fertilizer on oil yield (kg.h^{-1}) for years

Average of varieties	Phosphate nano fertilizer (ppm)				Varieties
	21	14	7	0	
			2023		
365.50b	574.20b	496.20c	397.77e	359.37e	Industrial 2
604.77a	687.65a	674.95a	599.54b	456.97d	Iman
	630.92a	572.07b	498.65c	406.67d	Average of phosphate nano fertilizer
			2024		
543.84b	612.34b	587.32ab	539.47b	436.24c	Industrial 2
596.99a	677.77ab	676.25a	534.62b	499.34b	Iman
	645.05a	631.78ab	537.04b	467.79c	Average of phosphate nano fertilizer

Within a column means values followed by same alphabet do not differ significantly at $p \leq 0.05$

Yacoub *et al.* (2020), and can be attributed to genetic variation influencing seed composition and productivity (Nget *et al.*, 2022).

Nano-phosphate fertilizer had a significant effect on oil yield. The highest application level (21 ppm) produced the greatest oil yields in both years, 630.92 kg·ha^{-1} in 2023 and 645.05 kg·ha^{-1} in 2024. This increase is directly related to the corresponding rise in oil percentage at this fertilizer level (Table 2), highlighting phosphorus's critical role in enhancing seed oil accumulation. The interaction between variety and fertilizer level further demonstrated that combining *Iman* with 14 ppm and 21 ppm nano-phosphate resulted in the highest oil yields. In 2023, these combinations yielded 674.95 kg·ha^{-1} and 687.65 kg·ha^{-1}, respectively. A similar pattern was observed in 2024, with yields of 676.25 kg·ha^{-1} and 677.77 kg·ha^{-1}, confirming the consistent and synergistic effect of phosphorus fertilization on oil productivity in high-performing genotypes.

Seed protein percentage (%)

Significant differences in seed protein percentage were observed between the two soybean varieties across both growing seasons (Table 4). The *Industrial 2* variety exhibited a significantly higher protein content than *Iman*, with values of 36.16% and 36.91% in 2023 and 2024, respectively, compared to 35.42% and 36.05% for *Iman*. These results are consistent with previous findings (Isaac *et al.*, 2016; Yacoub *et al.*, 2020; Nget *et al.*, 2022) and are largely attributed to genotypic differences and the efficiency of starch-to-protein conversion during seed development. Among the fertilizer treatments, the highest protein percentages were recorded at the 21 ppm nano-phosphate level, reaching 37.13% in 2023 and 38.31% in 2024. This improvement is due to phosphorus's essential role in amino acid formation and protein synthesis (Jesper *et al.*, 2018;

Table 4. Effect of varieties and phosphate nano fertilizer on the percentage of protein for years

Average of varieties	Phosphate nano fertilizer (ppm)				Varieties
	21	14	7	0	
			2023		
36.16[a]	38.79[a]	36.47[b]	35.01[c]	34.37[cd]	Industrial 2
35.42[b]	36.34[b]	36.31[b]	35.00[c]	34.04[d]	Iman
	37.13[a]	36.39[b]	35.00[c]	34.20[d]	Average of phosphate nano fertilizer
			2024		
36.91[a]	38.98[a]	37.47[b]	35.97[d]	35.24[d]	Industrial 2
36.05[b]	37.64[b]	36.57[c]	35.35[d]	34.65[e]	Iman
	38.31[a]	37.02[b]	35.66[c]	34.94[d]	Average of phosphate nano fertilizer

Table 5. Effect of varieties and phosphate nano fertilizer on protein yield (kg h^{-1})

Average of varieties	Phosphate nano fertilizer (ppm)				Varieties
	21	14	7	0	
			2023		
1020.97[a]	1253.21[a]	999.20[c]	934.25[c]	897.25[cd]	Industrial 2
945.11[b]	1102.64[b]	954.68[c]	900.01[cd]	823.14[d]	Iman
	1177.92[a]	976.94[b]	917.13[bc]	860.19[c]	Average of phosphate nano fertilizer
			2024		
1105.07[a]	1296.35[a]	1197.25[b]	1025.45[c]	901.25[d]	Industrial 2
1059.98[b]	1234.15[a]	1103.64[b]	1004.74[c]	897.41[d]	Iman
	1265.25[a]	1150.44[b]	1015.09[c]	899.33[d]	Average of phosphate nano fertilizer

Yacoub *et al.*, 2020). The interaction between variety and fertilizer level revealed that *Industrial 2* treated with 21 ppm nano-phosphate achieved the highest protein content in both years, 38.79% in 2023 and 38.98% in 2024. These results align with previous studies reporting significant genotypic responses to phosphorus fertilization (Ali *et al.*, 2021; Abdulqader *et al.*, 2021; Abdelrazzaq and Ali, 2022;).

The *Industrial 2* variety exhibited significantly higher protein yields compared to the *Iman* variety, producing 1020.97 kg ha^{-1} in Al-2023 and 1105.07 kg ha^{-1} in 2024, while *Iman* recorded 945.11 and 1059.98 kg ha^{-1}, respectively (Table 5). This superior performance is primarily attributed to the higher inherent protein content of the *Industrial 2* variety (Table 4), corroborating earlier findings by Salwa *et al.* (2011) and Mandić *et al.* (2020). Among the fertilizer treatments, the 21 ppm phosphorus concentration yielded the highest protein output across both sites, 1177.92 and 1265.25 kg ha^{-1}, highlighting the critical role of phosphorus in optimizing nutrient balance, promoting flowering, and enhancing seed development and protein accumulation (Turan *et al.*, 2006; Sihaloho *et al.*, 2015; Yacoub *et al.*, 2020; Tiwari *et al.*, 2022). The interaction between the *Industrial 2* variety and the 21 ppm phosphorus level resulted in the maximum protein yield (1253.21 kg ha^{-1}) in the Al-2023 region. In 2024, this synergistic effect between variety and phosphorus level was even more pronounced, further emphasizing the importance of genotype-nutrient interactions in optimizing protein production.

Conflicts of interest

Author declares that there are no conflicts of interest.

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LITERATURE CITED

AOAC 1980. *Official methods of analysis* (13th edn).

Association of Official Analytical Chemists, Washington DC, USA.

AOAC 1984. *Official methods of analysis* (14th edn). Association of Official Analytical Chemists, Washington, DC. USA.

Ali M A 2021. Response selection and path analysis in naked barley. *Plant Cell Biotechnol Mol Biol* **22**(11): 8-15. https://www.ikprress.org/index.php/PCBMB/article/view/5978

Ali M A, Abdulqader O A and Aziz M M 2021. Influence of seed size and planting depth on some growth and quality characters of local broad bean (*Vicia faba* L.). *Int J Agric Stat Sci Suppl* **1**(16): 1815-19. https://connectjournals.com/03899.2020.16.1815

Ali M A, Khaleel A T H, Al-Chalabi A M and Al-Barwary A S 2023a. Effect of jelly and planting depths on the traits of two barley verities. IOP Conference Series: *Environ Earth Sci* **1**, 012041. doi:10.1088/1755-1315/1214/1/012041

Ali M A, AL-kikani K I, AL-Mashhadany A M and Al-Obaidi A H 2023b. Response of field crop seeds to stimulators improve germination and growth. *Tikrit J Agric Sci* **23**(3): 103-11. https://doi.org/10.25130/tjas.23.3.12

Abdelrazzaq R A and Ali M A 2022. Response of some laboratory traits of two chickpea varieties and treated with different soaking treatments. *Int J Agric Stat Sci Suppl* **18**(1): 1793-97. https://connectjournals.com/03899.2022.18.1793

Abdulqader O A, Ali M A and Aziz M M 2021. Effect of volcanic rock dust and Fe-EDTA on the root nodule bacteria and the growth and yield of broad bean plants. *Agronomia Colombiana* **39**(2): 243–51. http://dx.doi.org/10.15446/agron.colomb.v39n2.92541

FAO 2020. Food and Agricultural Organization.

FAOSTAT 2021. Food and Agricultural Organization of the United Nations. Retrieved from http://www.fao.org/faostat/en/#data/QC

Isaac O T, Seweh E A, Apuri S, Banful B K and Amoah S 2016. Effect of storage periods on seed quality characteristics of three soybean (*Glycine max* (L) Merrill) varieties. *Int J Sci Res Sci Eng Technol* **2**(4): 823-31.

Jesper T N K, Florentine M H, Janro O, Riaan B, Michael B Z, Ismail C and Anne F G 2018. Nano- and pheroid technologies for development of foliar iron fertilizers and iron biofortifcation of soybean grown in South Africa. *Chem Biol Technol Agric* **5**: 26-36. https://doi.org/10.1186/s40538-018-0138-8

Kareem A R, Hasan Serin and Khalid K A 2019. The role of fragmentation of plant densities in the growth and yield of three varieties of soybean (*Glycine max* L). *Tikrit J Agric Sci* **19**(1): 142-53.

Kumar R, Rathore D K, Singh M, Kumar P and Khippal A 2016. Effect of phosphorus and zinc on growth and yield of fodder cowpea. *Legume Res* **39**(2): 262-67.

Limede, A C, Carlos E S O, Andre Z, Alan M Z, Fabio S and Tiago Z 2018. Effects of seed size and sowing depth in the emergence and morphophysiological development of soybean cultivated in sandy texture soil. *Australian J Crop Sci* **12**(1): 93-98.

Liu R and Lal R 2014. Synthetic apatite nano-particles as a phosphorus fertilizer for soybean. *Sci Rep* **4**, 5686.

Mandi´c V, Snežana Đ, Nikola Đ, Zorica B, Vesna K, Maja P and Milan B 2020. Genotype and sowing time effects on soybean yield and quality. *Agriculture* **10**(502): 1-9.

Marschner H 2002. *Mineral nutrition of higher plants*. Elsevier Science Ltd.

Nget R, Aguilar E A, Cruz P C S, Reaño C E, Sanchez P B, Reyes M R and Prasad P V V 2022. Responses of soybean genotypes to different nitrogen and phosphorus sources: Impacts on yield components, seed yield, and seed protein. *Plants* **11**, 281. https://doi.org/10.3390/plants11030298

Olkhovych O, Volkogon M, Taran N, Batsnova L and Kravchenko I 2016. The effect of copper and zinc nanoparticles on the growth parameters, contents of ascorbic acid and acylcarnitines in *Pistia stratiotes* (Araceae L.). *Nano-scale Res Let* **11**, 218.

Rana M, Lahoty P and Sharma N 2014. Effect of PSB, rhizobium and phosphorus levels on growth parameters and benefit cost ratio of soybean (*Glycine max* (L.) Merr.). *J Ind Pollut Cont* **30**: 263-66.

Salwa A I E, Taha M B and Abdalla M A M 2011. Amendment of soi fertility and augmentation of the quantity and quality of soybean crop by phosphorus and micronutrients. *Int J Acad Res* **3**(2): 800-08.

Shea Z, Singer W M, Rosso L, Song Q and Zhang B 2023. Determining genetic markers and seed compositions related to high test weight in *Glycine max*. *Plants* **12**(16), 2997. https://doi.org/10.3390/plants12162997

Sihaloho N, Rahmawati N and Princess L A 2015. Response of growth and production of soybean varieties detam 1 against the provision of vermicompost and fertilizer P. *J Agroteknol* **3**(4): 1591-1600.

Soliman A S, Hassan M, Abou-Elella F, Ahmed A H and El-Feky S A 2016. Effect of nano and molecular phosphorus fertilizers on growth and chemical composition of Baobab (*Adansonia digitata* L.). *J Plant Sci* **11**(4): 52-60.

Turan M, Ataoglu N and Sahin F 2006. Evaluation of the capacity of phosphate solubilizing bacteria and fungi on different forms of phosphorus in liquid culture. *J Sustainable Agric* **28**: 99-108.

Tiwari K N, Yogendra K, Tarunendu S and Nayak R K 2022. Nano technology based P fertilizers for higher efficiency and agriculture sustainability. *Ann Plant Soil Res* **24**(2): 198-207.

Yacoub *et al*. 2020. The effect of using nanoparticles phosphorus and zinc on quality and quantity of soybean (*Glycine max* L.). *Plant Arch* **20**(2): 8863-76.