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MINERAL AND NANO-POTASSIUM FERTILIZATION EFFECTS ON GROWTH AND YIELD TRAITS OF FABA BEAN (*VICIA FABA* L.)

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SUMMARY

A field experiment, carried out in 2021-2022, determined the effect of different mineral and nano-potassium fertilizer combinations on the growth and yield traits of the faba bean (*Vicia faba* L.) at the District Al-Rumaytha, Iraq. The experiment in a randomized complete block design (RCBD) had a split-plot arrangement and three replications. The main plots consisted of fertilizer application once and twice—first at planting, and the other at the beginning of flowering. The subplots comprised four fertilizer combinations of traditional recommendation and nano-potassium: 75% traditional + 25% nano-potassium, 50% traditional + 50% nano-potassium, 25% traditional + 75% nano-potassium, and nano-potassium recommendation. With the fertilizer level of 75% traditional + 25% nano, the average pods per plant, seed yield, and protein percentage were 23.08, 5466, and 30.67%, respectively. The nano recommended level averaged 24.17 cm, superior for pod length. However, the number of seeds per pod and 100-seed weight did not differ across the different fertilizer levels. With the second addition phase, the pods per plant, seed yield, and protein percentage emerged significantly enhanced with values of 20.47, 4850 kg ha^{-1}, and 27.66%, respectively.

Keywords: Faba beans, fertilizer level, nano-potassium, growth and yield traits

Key findings: The fertilizer combination of 75% traditional + 25% nano-potassium produced more pods per plant and seed yield than other fertilizer combinations in faba beans (*Vicia faba* L.). The fertilizer's second addition phase outperformed the first for pods per plant and seed yield. The highest seed yield occurred with 75% conventional + 25% nano-fertilizer at twice addition.

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INTRODUCTION

The faba bean (*Vicia faba* L.), a member of the legume family Fabaceae, is a global essential winter food crop. Faba beans are important being a premier dietary source, containing a good percentage of protein, ranging from 28% to 36% of seed content, as well as amino acids, vitamins, fiber, minerals, and carbohydrates (42%–47%) in some broad bean cultivar seeds (Khalil *et al*., 2015). Faba beans also improve soil chemical and physical properties by significantly contributing through atmospheric nitrogen fixation; its roots contain nitrogen-fixing rhizobia bacteria that form root nodules (Abbas, 2012).

Faba bean is an important food crop worldwide; however, insufficient soil nutrients for its crop can limit production. Mineral and nanofertilizers can enhance its production, but their optimal fertilizer combination and application timing require better understanding. Increasing bean production came up with various methods, including mineral fertilizers—adding nutrients to the soil and nanofertilizers with foliar application on vegetative parts. It has an indispensable impact in improving crop growth and development, and eventually, seed production. The combination and utilization of these fertilizers significantly affected plant growth and development (Al-Zubaidi and Saba, 2015).

Potassium is a major nutrient that faba beans need for plant growth through its contribution to photosynthesis and respiration. Potassium is a macro-element controlling the opening and closing of stomata. It transports manufactured nutrients and activates various critical enzymes in biological processes, such as increasing leaf efficiency. It is also vital in plants' growth and reproduction stages (Malvi, 2011). Leaf fertilization is one of the principal methods that complement soil fertilization. Appropriate timing for foliar feeding is also crucial, as it determines when plants are more responsive and efficient in utilizing nutrients, improving growth and seed yield (Aljana *et al*., 2022).

In crop plants, increasing productivity is achievable by adding optimal nutrients in balanced proportions and making these nutrients unlimited at ideal times for plant growth. The addition of appropriate fertilizers accompanies yield increase, including other best factors are available. The presented study pursued investigating the most optimal traditional and nano-potassium fertilizer combination and the number of applications that effectively boost the faba bean crop's growth and seed yield.

MATERIALS AND METHODS

During the crop season 2021–2022, the faba bean field experiment proceeded in the District Rumytha, Muthanna Governorate, Iraq (Latitude: 31.5283, Longitude: 45.2036). Field preparation comprised tillage, smoothing, and leveling. The sowing of seeds commenced on October 17, 2021, with a row and plant spacing of 75 cm and 25 cm, respectively (Al-Tawki, 2015). The experiment aimed to determine the effects of different traditional and nano-potassium fertilizer combinations and the number of times applying fertilizer on the growth and yield-related traits of the faba bean crop. Random soil samples came from various parts of the experimental field with a depth of 0 to 30 cm. Developing a composite soil sample consisted of mixing all the samples to approximate the experimental field before planting. The study field necessitated a series of chemical and physical analyses conducted and presented in Table 1.

Experiment design and factors

The study used a randomized complete block design (RCBD) with a split-plot arrangement and three replications. The main plots comprised two fertilizer application stages—the first (M1) at planting and the second (M2) at the beginning of flowering. The subplots encompassed four different combinations of mineral and nanofertilizers. These combinations included the conventional recommendation: a) 75% conventional fertilizer combined with 25% nanofertilizer, b) 50% conventional fertilizer combined with 50% nanofertilizer, c) 25% conventional fertilizer combined with 75% nanofertilizer, and d) the

Table 1. Physical-chemical properties of the field soil.

Attributes		Values	Units
pH		7.5	
E.C.		3.18	des M^{-1}
CEC		20.3	Cm (+) kg^{-1}
Nitrogen Av.		18	mg kg^{-1} soil
Phosphorus Av.		8.1	
Potassium Av.		167	
Analysis	sand	205	Kg kg^{-1}
	gluten	465	
	clay	330	
Soil Texture		Silty clay loam	

nanofertilizer recommendation. In the fertilizer recommendations, the applied nitrogen used urea fertilizer (46% N) at 80 kg N ha^{-1}.

Phosphorus application began before planting at 80 kg P_2O_5 ha^{-1} (46% P) as triple superphosphate fertilizer. Applying potassium before planting had a rate of 80 kg K ha^{-1} (Abedi, 2011). The Iranian company Biozar produces a nano-potassium fertilizer. The foliar application of nano-fertilizer continued throughout the evening period using a backpack sprayer. A dispersant helped reduce the surface tension of the water, facilitated complete wetting of the leaves, and enhanced the overall efficacy of the fertilizer application, improving the spray solution's efficiency.

Data recorded

Yield-related traits

Pod length measurement at maturity used a measuring tape. The average length of five pods came from each plant taken randomly and from 10 plants from the middle lines of each experimental unit. The number of pods per plant calculation started at maturity. The average number of pods taken from 10 plants had the five used to calculate the fertilization rate, and the other five taken randomly from the middle lines of each experimental unit. Twenty-five pods, taken randomly after harvest, came from the yield of the middle two lines of each experimental unit, with the average number per pod calculated.

After harvesting and drying the seeds to the appropriate dryness, a random sample of 100 seeds taken from the yield of the middle two lines of each experimental unit reached weighing using a sensitive electric scale. The harvest proceeded after signs of full maturity, such as yellowing of the leaves and blackening of stems and pods. The remaining plants in the middle two lines of each experimental unit gained full harvest. The seeds underwent screening, cleaning, and drying to the appropriate dryness. Adding the yield of the collected 10 plants earlier taken from each unit received bagging. With the weight recorded, adjusting the seed yield to a moisture content of 15% continued conversion to kg ha^{-1}.

Protein content in seeds

The protein (%) analysis transpired in the Laboratory of the Graduate Studies, College of Agriculture, Muthanna University, Iraq. Random seed samples came from the seed yield of each experimental unit. The seeds incurred grinding, with 0.2 g of the ground sample digested using concentrated sulfuric and perchloric acids. The samples' transfer to volumetric flasks with a capacity of 50 mL had the volume completed with distilled water. Then, nitrogen determination used a micro Kjeldahl apparatus, as described by Page *et al*. (1982). The protein content calculation applied the following equation:

$$\text{Protein \%} = \text{N concentration in seeds} \times 6.25.$$

Statistical analysis

All the recorded data analysis used the GenStat statistics program. The $LSD_{0.05}$ test helped to evaluate the means comparison and separation (Al-Rawi and Khalaf, 2000).

RESULTS AND DISCUSSION

Pod length

The treatment nano-potassium recommendation showed the highest mean for pod length (24.17 cm) (Table 2). However, it was not significantly different from the other treatment 75% traditional + 25% nano-potassium, with a mean pod length of 22.17 cm. Traditional potassium recommendation gave the lowest mean pod length (17.17 cm). This may be due to the efficient absorption of nanofertilizer through the leaves, contributing to an increased accumulation of net photosynthesis in the sink, represented by pod length. This result agrees with past findings, indicating an increase in pod length by spraying with potassium in bean crops (Nosser, 2011; Al-Zubaidi, 2024; Merhij *et al*., 2024; Sarhan *et al*., 2024). Nonsignificant differences were apparent in the number of spray treatments and the interaction between the conventional and nano-additions and the number of spray applications for this trait (Table 2).

Pods per plant

The fertilizer levels indicated a considerable impact on the quantity of pods per plant (Table 3). The maximum mean for this feature, specifically 23.08 pods $plant^{-1}$, was visible in treatment 75% traditional + 25% nano-potassium, while the lowest mean of 16.33 pods $plant^{-1}$ appeared in treatment traditional potassium recommendation. The reason is the fertilizer level of 75% traditional + 25% nano-potassium provided sufficient nutrients the roots absorbed, and the spraying of potassium increased photosynthesis' food production. Its positive reflection manifests in transferring the manufactured materials from the source to the sink, contributing to increased pods. These results align with studies of EL-Bramawy and Shaban (2010) and Nosser (2011), showing that an increase in the number of pods elevates with increasing potassium concentrations in the bean crop.

Table 2. Effect of the number of spraying and the combinations of nano- and conventional potassium fertilizers and their interaction on pod length in faba beans.

Spraying stages	Fertilizer combinations					Means (cm)
	Potassium 100%	P75%+Nano-potassium 25%	P50%+Nano-potassium 50%	P25%+Nano-potassium 75%	Nano-potassium 100%	
M_1	19.00	20.67	17.00	19.33	23.00	19.80
M_2	15.33	23.67	20.67	17.00	25.33	20.40
Means (cm)	17.17	22.17	18.83	18.17	24.17	

$LSD_{0.05}$ Spraying stage: N.S, Combinations of fertilizers: 3.19, Interaction: N.S

Table 3. Effect of the number of spraying and the combinations of nano- and conventional potassium fertilizers and their interaction on pods per plant in faba beans.

Spraying stages	Fertilizer combinations					Means (pods $plant^{-1}$)
	Potassium 100%	P75%+Nano-potassium 25%	P50%+Nano-potassium 50%	P25%+Nano-potassium 75%	Nano-potassium 100%	
M_1	17.00	20.83	14.83	17.67	18.50	17.77
M_2	15.67	25.33	20.67	17.00	23.67	20.47
Means (pods $plant^{-1}$)	16.33	23.08	17.75	17.33	21.08	

$LSD_{0.05}$ Spraying stage: 2.41, Combinations of fertilizers: 1.94, Interaction: 3.62

The addition stages significantly affected the number of pods per plant; with treatment M2 giving the highest mean for this trait at 20.47 pods plant^{-1}; however, the treatment M1 gave the lowest mean of 17.77 pods plant^{-1}. This increase may be because the addition stage M2 provided a larger amount of potassium ready for absorption by the plant due to the increased number of fertilizer applications compared with addition stage M1, reducing the chance of waste. This outcome is similar to the findings by Noaema *et al*. (2020), who showed that spraying stages led to an increase in the number of pods on the plant when dividing the addition into the bean crop. The interaction was significant, with the combination 75% traditional + 25% nano-potassium × M2 giving the highest mean for the number of pods at 25.33 pods plant^{-1}, and the combination 50% traditional + 50% nano-potassium × M1 had the lowest mean for this trait at 14.83 pods per plant (Table 3).

100-seed weight

The results revealed a nonsignificant difference between the fertilizer levels and their addition stages for 100-seed weight (Table 4). However, the interaction showed notable variations between the study factors in 100-seed weight. The results in the same table showed a significant interaction between two study factors, with the fertilizer combination (75% traditional + 25% nano-potassium × M1) giving the topmost mean of 100-seed weight (115.00 g), while the fertilizer combination (Traditional potassium recommendation × M1) gave the lowest mean for the said trait (85.70 g).

Seed yield

Potassium fertilizer levels differed significantly in total seed yield, with fertilizer level 75% traditional + 25% nano-potassium providing the maximum mean of 5,466 kg ha^{-1} (Table 5). The traditional potassium recommendation gave the minimum mean of 3,852 kg ha^{-1}. The reason may be the fertilizer level 75% traditional + 25% nano-potassium outperformed one of the yield components, pod number per plant (Table 3), contributing positively to increasing total seed yield. In addition to its effectiveness on many vital activities, such as cell division and expansion, nitrate reduction, and pollen tube growth, it works to increase the nutritional value of crops as it augments the seed weight and size. It

Table 4. Effect of the number of spraying and the combinations of nano- and conventional potassium fertilizers and their interaction on the 100-seed weight in faba beans.

Spraying stages	Fertilizer combinations					Means (g)
	Potassium 100%	P75%+Nano-potassium 25%	P50%+Nano-potassium 50%	P25%+Nano-potassium 75%	Nano-potassium 100%	
M_1	85.70	115.00	89.60	91.30	92.00	94.70
M_2	112.30	74.30	109.30	111.70	100.3	101.60
Means (g)	99.00	94.70	99.5	101.50	96.20	

$LSD_{0.05}$ Spraying stage: N.S, Combinations of fertilizers: N.S, Interaction: 21.77

Table 5. Effect of the number of spraying and the combinations of nano- and conventional potassium fertilizers and their interaction on seed yield in faba beans.

Spraying stages	Fertilizers combinations					Means (kg ha^{-1})
	Potassium 100%	P75%+Nano-potassium 25%	P50%+Nano-potassium 50%	P25%+Nano-potassium 75%	Nano-potassium 100%	
M_1	3880	4821	3543	3900	4225	4074
M_2	3825	6112	4987	4033	5292	4850
Means (kg ha^{-1})	3852	5466	4265	3967	4758	

$LSD_{0.05}$ Spraying stage: 427.80, Combinations of fertilizers: 592.20, Interaction: 772.00

also improves the crop's quality, raising production (Britto and Kronzucker, 2008). Moreover, results from Jasim *et al*. (2016) achieved an upsurge in total yield by the enhanced application of potassium to the bean crop.

The number of times adding the fertilizer significantly affected the total seed yield, with the twice-addition stage giving the ultimate mean of 4,850 kg ha^{-1}, but the once-addition stage gave the lowest mean of 4,074 kg ha^{-1}. This may be because the twice-addition stage provided a larger amount of potassium available for absorption, contributing to photosynthetic activity augmentation and subsequent translocation of its assimilates from the source to the sink, increasing overall seed productivity. Alternatively, the increase in total seed yield may refer to an increased pod number (Table 3), an important yield component contributing to raising total yield. Hassan (2019) and Noaema *et al*. (2020) also reported that fertilizers adding at different growth stages showed the better seed yield than adding fertilizer once to bean crops. The interaction between the potassium level and the number of times adding the fertilizer was also significant. The combination 75% traditional + 25% nano-potassium × M2 obtained the supreme mean seed yield of 6,112 kg ha^{-1}, while the combination 50% traditional + 50% nano-potassium × M1 revealed the lowest average for the said trait (3,543 kg ha^{-1}).

Protein content in seeds

Noteworthy variations were evident among the different fertilizer treatments for seeds' protein content (Table 6). The 75% traditional + 25% nano-potassium concentration had the highest average, at 30.67%, while the traditional potassium recommendation concentration had the lowest average, at 23.66%. It may refer to the critical role of potassium in plant physiology. Potassium helps increase leaf efficiency by contributing to photosynthesis, transporting manufactured materials, and respiration. It also activates enzymes that are essential in carbohydrate metabolism and proteins' formation. They may have contributed to the increase in protein content in seeds. These results are consistent with past findings revealing an increase in protein percentage when raising potassium concentration sprayed on the bean crop (Khattab *et al*., 2016).

The addition stages also significantly affected the seeds' protein content. The M2 addition stage had the maximum average, at 27.66%, while the M1 addition stage had the minimum average, at 25.16%. The reason may be dividing the fertilizer into two stages, the second stage applied during the flowering period helped improve photosynthesis efficiency. This is because the second stage of fertilizer application maintained leaf activity in forming ATP, vital for nitrogen absorption and protein synthesis. It may have contributed to the rise in protein content in seeds. The interaction between the study factors was nonsignificant in the protein content of seeds.

Table 6. Effect of the number of spraying and the combinations of nano- and conventional potassium fertilizers and their interaction on protein content in faba bean seeds.

Spraying stages	Fertilizer combinations					Means (%)
	Potassium 100%	P75%+Nano-potassium 25%	P50%+Nano-potassium 50%	P25%+Nano-potassium 75%	Nano-potassium 100%	
M_1	24.00	28.67	23.83	25.33	24.00	25.16
M_2	23.33	32.67	28.67	24.00	29.67	27.66
Means (%)	23.66	30.67	26.25	24.66	26.83	

$LSD_{0.05}$ Spraying stage: 2.91, Combinations of fertilizers: 2.07, Interaction: N.S

CONCLUSIONS

The results of this study suggest that the combination of 75% conventional and 25% nano-potassium fertilizer, applied twice during the growing season, is the most effective for improving the growth and yield of faba beans. This combination resulted in the highest number of pods per plant, total seed yield, and the longest pods.

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