

Effect of Mineral, Nano NPK and Chitosan on Growth Characteristics and Biomass of Two Faba Bean (*Vicia faba* L.) Varieties in Wadi Atba, Libya

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تأثير التسميد المعدني، النانوي والشيتوزان على صفات النمو والكتلة الحيوية لصنفين من الفول البلدي في منطقة وادي عتبة، ليبيا

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Received: February 14, 2026

Accepted: March 25, 2026

Published: April 12, 2026



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Abstract:

Faba bean (*Vicia faba* L.) is a critical leguminous crop that plays a vital role in food security; however, its productivity under semi-arid conditions is limited because of low nutrient use efficiency. In the 2024/2025 growing season, a field experiment was conducted in Wadi Atba, southern Libya, to evaluate the effect of mineral, nano NPK fertilizer and chitosan on the growth and biomass production of two types of faba bean (local and imported).

The experiment was arranged in a factorial randomized complete block design (RCBD) with three replications and seven fertilization treatments: control, mineral NPK (NPK min), nano NPK (NPK Nps), chitosan, 50% nano NPK + 50% mineral NPK, mineral NPK + chitosan, and nano NPK + chitosan.

The results revealed that fertilization treatments and their interactions with cultivar had a significant impact on all the variables studied. The combined application of nano NPK and chitosan consistently recorded the highest values in terms of plant height, number of leaves, leaf area, fresh and dry biomass, biological yield and straw yield in both varieties with the imported cultivar showing higher performance compared to the local one. Followed by a 50% nanoNPK+ 50% mineral NPK.

The findings show that nano fertilizers when used together with chitosan enhances nutrient use efficiency, vegetative growth and biomass productivity of faba bean in semi-arid conditions. This approach represents a promising and sustainable strategy for reducing reliance on the conventional mineral fertilizers and improving crop productivity.

Keywords: Biomass, Bio Stimulant, Chitosan, Faba Bean, NPK Nano Fertilizers.

المخلص

القول البلدي يعتبر من المحاصيل البقولية المهمة التي لها دور حيوي في تحقيقي الامن الغذائي، ولكن انتاجيته في الظروف الشبه جافة محدودة بسبب انخفاض كفاءة استخدام العناصر الغذائية، في الموسم الزراعي 2025/2024 تم اجراء تجربة حقلية في منطقة وادي عتبة في جنوب ليبيا لتقييم تأثير الاسمدة المعدنية والنانوية والشيتوزان على نمو وانتاج الكتلة الحيوية لصنفين من القول (محلّي ومستورد)

صممت التجربة تحت تصميم القطاعات العشوائية التامة بعاملين وثلاث مكررات واحتوت على سبع معاملات تسميدية: الشاهد والتسميد المعدني التقليدي، التسميد النانوي، الشيتوزان، 50%تسميد نانوي+ 50% تسميد معدني، تسميد معدني+ شيتوزان وتسميد نانوي+شيتوزان.

اظهرت النتائج ان معاملات التسميد والتفاعل بينها وبين الاصناف تحت التجربة كان لها تأثير معنوي على جميع الصفات المدروسة وسجلت معاملة التسميد النانوي مع الشيتوزان اعلى القيم بشكل مستمر في كل من ارتفاع النبات، عدد الاوراق، مساحة الورقة، الكتلة الحوية الطازجة والجافة، المحصول البيولوجي ومحصول القش في كل من الصنفين مع تفوق الصنف المستورد على الصنف المحلّي وتلتها المعاملة 50%تسميد نانوي+50% تسميد نانوي.

النتائج تؤكد ان استخدام الاسمدة النانوية مع الشيتوزان تعزز كفاءة استخدام العناصر الغذائية والنمو الخضري وانتاج الكتلة الحيوية للقول في الظروف شبه الجافة ويمثل هذا الاسلوب استراتيجي واعدة لتقليل الاعتماد على الاسمدة المعدنية التقليدية وتحسين انتاجية المحاصيل.

الكلمات المفتاحية: الكتلة الحيوية، محفز حيوي، شيتوزان، القول البلدي، الاسمدة النانوية.

Introduction

Faba bean (*Vicia faba* L.) is considered the backbone of food security in various countries due to the high protein content of the crop, which can be consumed by both humans and animals. The production of faba beans in Libya is still low, although this is important, and thus it cannot meet the local market. The low productivity of the traditional fertilization systems is one of the key factors that restrict productivity since a large percentage of nutrients are lost through leaching and volatilization. This highlights the need for more efficient and sustainable fertilization strategies and sustainable fertilization strategies.

The development of nano-fertilizers is a recent phenomenon that has come to replace the traditional fertilizers because of its efficiency in increasing the use of nutrients. Nanoparticles have the potential to enhance the delivery of nutrients and help the plant tissues to absorb better due to the small particle size. Consequently, the nano-fertilizers will be able to decrease the loss of nutrients, minimize pollution of the environment, and enhance the growth and fertility of plants (Goyal et al., 2025).

El-Shabasy et al. (2025) showed that the maximum concentration of Nano NPK recorded the tallest plants and the maximum number of leaves, a trend that was also observed by Tantawy et al. (2025), who recorded a significant improvement in the number of leaves. Further studies by Sunil et al. (2025) reported that nano-micronutrients improved productivity even under water stress.

Omer et al. (2025) described Nano-fertilizers as an effective means to enhance productivity in saline soils. Goyal et al. (2025) documented that Nano NPK treatment yielded the highest biological and straw yields, the leaf area and both fresh and dry weight increased from Nano NPK sprays. Al-Mayyahi (2024) concluded

Priyadarsini et al. (2024) found that the application of Nano NPK increased plant height, leaf number, leaf area, and biological yield in cowpea. The results are consistent with the findings of Pandao et al. (2024), who found that the application of Nano DAP along with fertilizers increased plant height, dry matter, and straw and biological yield in chickpea.

As a biodegradable bio stimulant and a defense elicitor, chitosan improves photosynthesis, germination, root system development, chlorophyll content, and nutrient uptake and use efficiency, thus promoting yield in various crops. Moreover, as a seed coating material, foliar

spray, and soil treatment, chitosan improves the immunological system and antioxidant system of the plants, thus reducing the severity of diseases and stress caused by drought and salinity (Rojas et al., 2024).

Alencar et al. (2025) reported significant increases in the growth height of peas, lentils, and common beans from the chitosan use, Abdelhameed et al. (2024) documented a significant increase in both plant height and fresh weight following foliar application. Notable increase in leaf number, expanded leaf area, and a consequently higher straw yield, further confirmed these improvements in vegetative growth. Supporting these findings. Abdel Kader (2024)

El-Gazzar et al. (2023) found that there was a significant increase in the end biological yield. These arguments are supported by the entire research of Fouada et al. (2022), who indicated significant growth in the plant height, leaf number and area, fresh weight, and biomass and straw, which in turn provided a strong argument in favor of the use of chitosan as an effective growth promoter in faba beans. Galal et al. (2021) indicate that the increased weight of the seed per plant was attributed to the increased phenolic and antioxidant enzyme activity (Giza 40). In order to increase legume protein systems, priming/spraying and chitosan films/coatings were studied.

The effects of nano-fertilizers and chitosan (as an individual) have been extensively examined; however, there is a lack of studies that address the joint (synergistic) effects of the two on the growth of faba bean and its biomass yield, especially in a semi-arid environment such as southern Libya. Thus, it is necessary to examine the possible interaction of these two methods to enhance crop production in these conditions.

Therefore, this experiment attempted to determine the single and combined impact of nano NPK fertilizer and chitosan on the growth parameters and biomass generation of two faba bean types, the domestic and the imported, under the environmental circumstances of Wadi Atba, Southern Libya.

Material and methods

A field experiment was carried out in the 2024-2025 growing season in Wadi Atba, Southern Libya, to determine the impact of the mineral, nano, and chitosan fertilizers on the growth and biomass productivity of two varieties of faba bean one local and the other a commonly imported cultivar. The experiment was arranged as a two-factor factorial in a randomized complete block design (RCBD) with three replications. The former factor was composed of seven fertilizers, whereas the latter factor was composed of two types of faba beans cultivar. The following were the fertilizers used in this experiment:

- Control
- Recommended Mineral NPK (NPKmin)
- Nano NPK (NPK Nps)
- Chitosan
- %50Nano NPK +50% Mineral NPK
- Mineral NPK + Chitosan
- Nano NPK + Chitosan

The fertilizers were urea, diammonium phosphate and potassium sulfate that contained 46% N, 18% N, 46% P₂O₅ and 50% K₂O respectively. Land preparation fully involved the use of DAP in the soil. Urea and potassium sulfate were divided into two equal applications where one was done during the initial vegetative growth, approximately 2-3 weeks after emergence and the other one when the plants were starting to form pods. Nano NPK fertilizers, on the other hand, were used in the foliar forms whereas chitosan was applied on the plants 10 days following the application of Nano fertilizers. The foliar sprays of the Nano fertilizers were

completed 25, 40 and 55 days and the chitosan sprays were completed 10 days following the Nano fertilizers application. Nano fertilizers and chitosan were sprayed on the leaves of the plants by following the recommended dosage.

The semi-arid conditions of Wadi Atba are represented by the experimental soil that is moderately fertile. (ANOVA) that was used in statistical analysis of the data collected during the study was suitable in a factorial experiment under RCBD.

Table 1. Some soil properties of the experimental site at Wadi Atba, Libya (2024/2025 season)

Mechanical analysis	
Clay (%)	20.2
Silt (%)	18.2
Sand (%)	61.1
Organic matter (%)	0.50
Texture class	Sandy clay loam
Chemical analysis	
pH	8.2
EC (dS/m)	1.7
HCO ₃ ⁻ (%)	11.5
CaCO ₃ (%)	23.5
N (mg/kg)	26.0
P (mg/kg)	6.8
K (mg/kg)	180.0
Fe (mg/kg)	4.5
B (mg/kg)	0.9
Zn (mg/kg)	1.0
Cu (mg/kg)	2.0
Mn (mg/kg)	5.0

Studied characters:

- 1- Plant height(cm): it was determined as the average of three measurements were made on the soil surface up to top of the plant.
- 2- leaf number: three plants were measured and the leaf counted at the middle of the plant-3.
- 3- Leaf area (cm²): it was quantified by averaging the three plants, and the leaves were collected in the middle of the plant. The following equation was used to calculate it:

$$\text{Leaf area} = \text{maximum width of the leaf} \times \text{maximum length} \times 0.7$$
- 4- Fresh weight (g/m²): it was obtained from three randomly selected plants and measured directly using a balance.
- 5- Dry weight (g/m²): the samples of the plants were taken randomly in each sub-plot, dried in an oven at a temperature of 60 degrees Celsius over a duration of 3 days, and then weighed after the sample had attained a constant weight.
- 6- Biological yield (kg/fed.): It was estimated as total yield

$$\text{Biological yield} = (\text{Seed yield} + \text{straw yield}).$$
- 7- Straw yield (kg/fed.): it was estimated as weight of the straw, which harvested from an area of three ridges in kg for each sub- plot after threshing and then recorded in kg/fed.

Results and discussion

The interaction between fertilization treatments and cultivar was significant for all examined parameters, demonstrating varied responses of the two-faba bean cultivars to the treatments administered.

Growth Traits

Figure (1-A) illustrates that the imported cultivar recorded the highest plant height under the NPK Nps + Chitosan treatment, measuring 138.6cm, which was significantly higher than that of the local cultivar (131.6 cm) under identical conditions. The imported cultivar subjected to the 50% NPK Nps + 50% NPKmin treatment had a mean height of 132.6 cm, statistically comparable to that of the highest-performing local cultivar under identical conditions. Nonetheless, these values were significantly higher than those of the other treatments, except for the highest one the lowest values were recorded in the control treatment for both cultivars. A similar trend was observed for leaves number (**Figure 1-B**). The imported cultivar subjected to the NPK Nps + Chitosan treatment recorded the highest number of leaves (91), which was significantly higher than that of the local cultivar (83 leaves). The imported cultivar subjected to the 50% NPK Nps + 50% NPKmin treatment produced 86 leaves, a figure statistically comparable to the corresponding local treatment. All fertilization methods significantly increased leaf number in comparison to the control group.

Concerning leaf area (**Figure 1-C**), the NPK Nps + Chitosan treatment yielded the greatest measurements in both cultivars (2519 and 2379 cm² for imported and local cultivars, respectively), with the imported cultivar exhibiting a significantly superior value. The 50% NPK Nps + 50% NPKmin treatment yielded elevated values, statistically similar to several treatments, although significantly higher than the control group.

Biomass and Yield Parameters

The biomass characteristics, including fresh and dry weight, recorded a consistent pattern. The NPK Nps + Chitosan treatment yielded the highest values in both cultivars, with the imported cultivar surpassing the local cultivar. The imported cultivar's fresh weight attained 567.1 g, compared to 536.1 g for the local cultivar (**Figure 2-A**). The 50% NPK Nps + 50% NPKmin treatment yielded a fresh weight of 537.7 g in the imported cultivar, which was statistically comparable to the highest-performing local treatment.

A comparable trend was noted for dry weight (**Figure 2-B**), with the imported cultivar yielding 146.2 g, in contrast to 135.2 g for the local cultivar under the NPK Nps + Chitosan treatment. The 50% NPK Nps + 50% NPKmin treatment yielded a dry weight of 134.6 g in the imported cultivar, which was statistically similar to the best-performing local treatment.

The interaction between fertilization and cultivar significantly affected biological and straw yields. **Figure (2-C)** and **(2-D)** illustrate that the NPK Nps + Chitosan treatment yielded the maximum biological yield (19.3 kg/fed) and straw yield (12.5 kg/fed) in the imported cultivar, significantly surpassing the local cultivar under the same treatment, which yielded 17.5 kg/fed and 10.0 kg/fed, respectively. The second-best treatment (50% NPK Nps + 50% NPKmin) showed superior performance in the imported cultivar and was significantly higher than all other treatments, except for the best treatment.

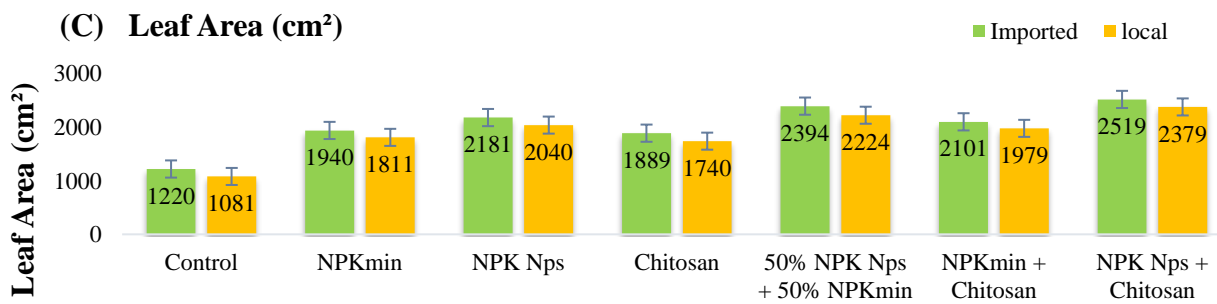
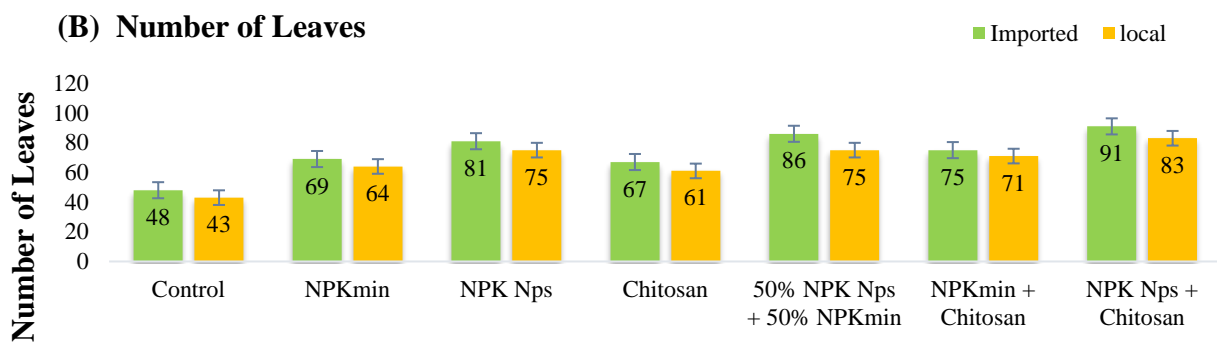
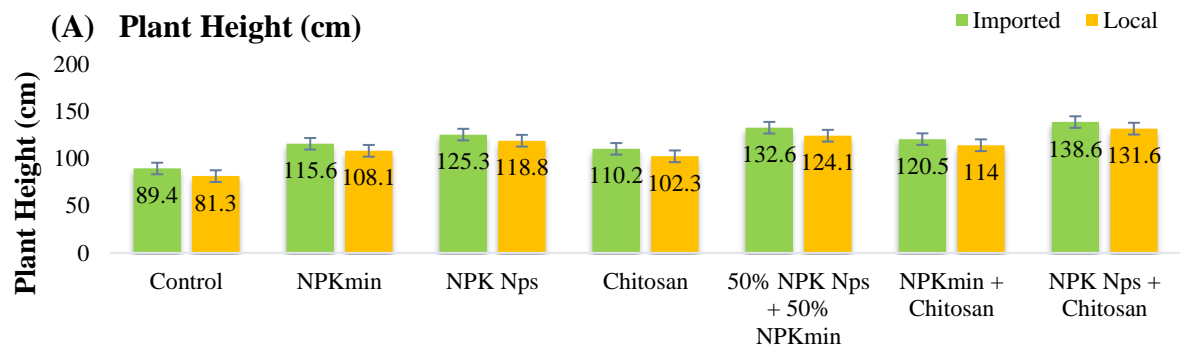


Figure 1. Mean of vegetative growth traits (A: plant height B: number of leaves D: Leaf Area) of local and imported faba bean cultivars under different fertilization treatments.



Figure 2. Mean of Biomass and Yield Parameters (A: Fresh Weight B: Dry Weight, C: Biological Yield D: Straw Yield) of local and imported faba bean cultivars under different fertilization treatments.

Discussion:

The findings indicated that nano NPK and chitosan, especially when used in combination, were highly effective in promoting growth and biomass accumulation. This synergistic action proves the success of the combination of nanotechnology and bio stimulants to enhance the efficiency of nutrient use and crop performance. This represents a sustainable approach towards environmentally friendly agriculture.

Regarding plant height, it was observed that the highest values were recorded with the combined use of NPK Nps and chitosan, compared to the control and the individual treatments. The positive influence of nano NPK on plant height has been largely attributed to enhanced nutrient availability and uptake efficiency, which causes improved vegetative growth (Kamel, 2025; Abou-Yousef et al., 2022; Salama et al., 2022).

Conversely, chitosan and nano-chitosan have been reported to have a tremendous positive effect on plant height in faba bean through improved nutrient uptake, cell division, and physiological performance (Abdel-Kader, 2025, El-Gazzar et al., 2023 and Fouda et al., 2022). The high performance of the combined treatment can be explained by the synergistic effect: nano NPK provides a sustained supply of essential nutrients, while chitosan enhances nutrient absorption, hormonal balance, and enzymatic activity, ultimately promoting cell elongation and vegetative growth.

A substantial increase in leaf number was observed with the nano NPK + chitosan treatment compared to the control. This finding is consistent with the research of nano fertilization, which showed an increase in vegetative growth and leaf development because of the increase in nutrient availability (Abou-Yousef et al., 2022; Salama et al., 2022).

On the same note, chitosan and nano-chitosan had a significant effect in enhancing leaf number in faba bean by promoting meristematic activity and enhancing photosynthetic efficiency (Abdel-Kader, 2025; El-Gazzar et al., 2023 and Fouda et al., 2022).

The additive effect could be described to be due to an improved level of nitrogen assimilation and metabolism whereby nano NPK supplies vital nutrients and chitosan stimulates cell division and differentiation leading to high leaf production and expansion of the canopy.

The combination of nano NPK and chitosan showed a great enhancement in leaf area, which is a sign of better photosynthesis. This observation is consistent with the findings of Kamel (2025), Abou-Yousef et al. (2022), and Salama et al. (2022), who reported that nano fertilization enhances leaf growth and photosynthetic surface area.

In addition, chitosan and nano-chitosan have also been reported to enhance the leaf area by promoting chlorophyll synthesis and cell growth (El-Gazzar et al., 2023, Fouda et al., 2022). This can be explained by the synergistic effect between nano NPK and chitosan, in which better nutrient availability (particularly N and P) enhances chlorophyll content and photosynthetic performance, whereas chitosan induces cell elongation and expansion of leaves, resulting in an increase in leaf surface area.

A significant increase in fresh biomass was observed in the nano NPK + chitosan treatment, indicating enhanced biomass accumulation. This result agrees with Kamel (2025), Abou-Yousef et al. (2022) and Salama et al. (2022), who reported increased biomass under nano fertilization.

Moreover, chitosan and nano-chitosan were effective in enhancing fresh biomass in faba bean, as they increased water uptake, nutrient absorption, and physiological activity (Abdel-Kader, 2025, El-Gazzar et al., 2023 and Fouda et al., 2022).

The joint treatment effect can be explained by the effect of a better metabolic activity and water relations, where nano NPK increases the nutrient availability and chitosan increases the water retention and decreases oxidative stress, which results in an increase in the accumulation of fresh biomass.

Dry weight was also significantly increased under the nano NPK + chitosan treatment compared to the other treatments. This finding is in line with Kamel (2025), Abou-Yosef et al. (2022), and Salama et al. (2022) who have found enhanced accumulation of dry matter with nano fertilization.

Likewise, chitosan and nano-chitosan added to faba bean boosted dry biomass through the increase of photosynthetic activity and nutrient absorption (Abdel-Kader, 2025; El-Gazzar et al., 2023 and Fouda et al., 2022).

This growth can be explained by the better production and storage of carbohydrates, better production of nutrient use, and the presence of more activity of enzymes, so it produces more structural biomass.

The nano NPK + chitosan treatment resulted in a marked increase in biological yield, indicating enhanced total biomass production. This observation is consistent with Kamel (2025), Abou-Yousef et al. (2022) and Salama et al. (2022), who found greater biomass when using nano fertilization.

Similarly, chitosan and nano-chitosan had a significant positive effect on biological yield in faba bean by enhancing vegetative growth and yield components (Abdel-Kader, 2025, El-Gazzar et al., 2023 and Fouda et al., 2022).

This can be explained by the fact that there is enhanced photosynthetic efficiency, nutrient uptake, and translocation of the assimilates due to the combined action of nano fertilizers and chitosan.

Straw yield was higher in the nano NPK + chitosan treatment compared to the control, indicating enhanced vegetative growth. This finding is in line with Kamel (2025) and Abou-Yousef et al. (2022) and, as well as Salama et al. (2022), who reported an increase in vegetative biomass nano fertilization.

In addition, chitosan and nano-chitosan play a significant role in improving straw yield by boosting the biomass accumulation and vegetative growth (Abdel-Kader, 2025, El-Gazzar et al., 2023 and Fouda et al., 2022).

This can be explained by increased uptake of N, P and K, increased stem growth, and increased structural carbohydrate stores leading to increased straw biomass.

Conclusion

Nano NPK and chitosan application in combination produced significant effects on the growth, physiological characteristics, and yield of both local and imported faba bean plants in terms of plant height, number and area of the leaves, biomass, biological yield, and straw yield. The effect of this synergy has been ascribed to better accessibility of nutrients, photosynthesis, cell division, and water and antioxidant management. Hence, the use of nano NPK along with chitosan is proposed to achieve the maximum productivity, enhance the stress resistance, and

decrease the use of chemical fertilizers, which will help to make faba bean production more sustainable.

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