International Science and Technology Journal
المجلة الدولية للعلوم والتقنية
Volume 38 العدد
Part 2 المجلد
المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ

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http://www.doi.org/10.62341/istj-vol38-2-sm25

Received	**2026/05/01**	**تم استلام الورقة العلمية في**
Accepted	**2026/05/23**	**تم قبول الورقة العلمية في**
Published	**2026/05/24**	**تم نشر الورقة العلمية في**

Effect of Nano and Mineral Fertilizer Combinations on Growth and Yield of Pea in Al- Ruqaybah, Libya

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Abstract:
Pea (*Pisum sativum* L.) is an important legume crop due to its high nutritional value and its role in improving soil fertility through biological nitrogen fixation. This experiment was conducted to evaluate the effect of different combinations of nano and mineral NPK fertilizers on growth and yield of pea under dry conditions in Al-Ruqaybah, Libya, during the 2025–2026 growing season. The experiment was arranged in a Randomized Complete Block Design with three replicates and included six treatments, control, 100% nano NPK, 100% mineral NPK, 50% nano NPK + 50% mineral NPK, 25% nano NPK + 75% mineral NPK and 75% nano NPK + 25% mineral NPK.
The results showed that the highest seed yield (3.72 kg/plot), biological yield (24.42 kg/plot), and straw yield (20.70 kg/plot) were obtained with the 75% nano NPK + 25% mineral NPK treatment. It also produced the highest 100-seed weight (35 g), lowest values occurred in the control. Although the harvest index was higher in the control, fertilization significantly increased overall biomass and yield components.
These findings suggest that partial substitution of mineral NPK fertilizers with nano NPK is recommended to improve nutrient use efficiency and enhance pea productivity under arid conditions. Moreover, optimizing the ratio between nano and mineral fertilizers

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is strongly recommended to achieve maximum yield performance in pea cultivation under dry environmental conditions.
Keywords: Pea, Nano NPK, Mineral NPK, Yield, Arid conditions.

تأثير تراكيب الأسمدة النانوية والمعدنية على نمو وإنتاجية البازلاء في الرقيبة، ليبيا

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الملخص

تعد البازلاء (*Pisum sativum* L.) من المحاصيل البقولية المهمة نظرًا لقيمتها الغذائية العالية ودوره في تحسين خصوبة التربة من خلال التثبيت الحيوي للنيتروجين. أُجريت هذه التجربة لتقييم تأثير تراكيب مختلفة من أسمدة NPK النانوية والمعدنية على نمو وإنتاجية البازلاء تحت الظروف الجافة في منطقة الرقيبة، ليبيا، خلال الموسم الزراعي 2025–2026. نُفذت التجربة وفق تصميم القطاعات العشوائية الكاملة (RCBD)بثلاث مكررات، وتضمنت ست معاملات هي: معاملة المقارنة،100 % NPKنانوي، 100% NPK معدني، 50 % NPKنانوي + 50 % NPK معدني، 25% NPK نانوي + 75%NPK معدني، 75 % NPK نانوي + 25 % NPK معدني.

أظهرت النتائج أن أعلى محصول للبذور (3.72 كجم/ القطعة التجريبية)، والمحصول البيولوجي (24.42 كجم/ القطعة التجريبية)، ومحصول القش (20.70 كجم/ القطعة التجريبية) قد تحقق عند معاملة 75 NPK %نانوي + 25 NPK %معدني. كما سجلت هذه المعاملة أعلى وزن لـــ 100 بذرة (35 جم)، في حين سُجلت أقل القيم في

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معاملة المقارنة. وعلى الرغم من أن دليل الحصـــاد كان أعلى في معاملة المقارنة، فإن المعاملات المسمدة أدت إلى زيادة الكتلة الحيوية ومكونات المحصول.

تشـير هذه النتائج إلى أن الاسـتبدال الجزئي للأسـمدة المعدنية NPK بالأسـمدة النانوية NPK يُوصـى به لتحسين كفاءة استخدام العناصـر الغذائية وزيادة إنتاجية البازلاء تحت الظروف الجافة. علاوة على ذلك، يُوصـــى بشـدة بتحسـين نسـبة الخلط بين الأسـمدة النانوية والمعدنية لتحقيق أقصى إنتاجية في زراعة البازلاء تحت الظروف البيئية الجافة.

الكلمات المفتاحية: البازلاء، NPK النانوي، NPK المعدني، المحصـــول، الظروف الجافة.

Introduction

The problem of lack of plant proteins for feed and good quality food and the "hidden hunger" from insufficient micronutrients in the food of humans and animals is getting worse. The use of peas, which performs a significant role in the production of legumes, which is a way to address this challenge (Yeremko *et al*., 2024).

Nano fertilizers are considered as a promising technology for sustainable agriculture, due to their increased use efficiency, and lower losses into the environment, in addition to increasing crop productivity in comparison with conventional fertilizers. They also ensure a controlled and targeted release of nutrients, preventing leaching and pollution of the soil. The nano-fertilizers are a beneficial alternative to conventional fertilizing techniques. The application of nano-fertilizers at low concentrations has shown several positive effects on plant growth and nutrient utilization under different agricultural conditions. Nano-fertilizers can improve nutrient stability and reduce nutrient losses, thereby enhancing fertilizer efficiency and supporting sustainable agricultural production. The use of nano-fertilizers as supplements to conventional mineral fertilizers can enhance crop productivity and nutrient use efficiency (Semenova *et al*., 2024; Bernela *et al*., 2021) El-Shabasy *et al*. (2025) demonstrated that application of biochar together with nano phosphorus fertilizer showed a significant positive effect on nutrient availability, nutrient uptake efficiency

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and yield of common bean in high pH soil that enabled using lower concentration of nano-P fertilizer. Similarly, Kamel (2025) reported that application of nano-fertilizers along with composts resulted in better soil properties and yield of faba bean than conventional fertilization treatments. Furthermore, the combined application of compost, nano-fertilizers and mineral NPK improved soil chemical properties and cowpea production substantially under the saline soil environment as reported by (Shaban *et al*. 2025).

Choudhary *et al*. (2024) reported that nano-fertilizers significantly improved growth, yield, and economic returns in legume crops when applied alone or in combination with conventional fertilizers. Optimized application of nitrogen and phosphorus fertilizers significantly improved growth parameters, yield components, and economic profitability of pea cultivation under Indian agro-climatic conditions. Similarly, foliar application of Nano-NPK at 5 mL L^{-1} significantly enhanced growth, yield, and quality attributes of French bean plants. Moreover, application of Nano-DAP and Zn-EDTA in cowpea had statistically significant positive effect on growth and yield (Maurya *et al*. 2024 and Balachandrakumar *et al*. 2024).

Alsamak and Noori (2025) stated that nano-form potassium (N-Pok) enhanced nutrient use efficiency by increasing potassium uptake and reducing nutrient losses in soil (NUE) by increasing the uptake of potassium and decreasing its losses in soil, Foliar application of nano-potassium improved physiological efficiency, nutrient balance, plant height, leaf area, and biomass production in faba bean plants under both normal and stress conditions. The improvement is mainly due to better nutrient absorption efficiency and enhanced physiological activity. Shaaban *et al*. (2026). Nano-potassium enhances chlorophyll stability, antioxidant defense systems and helps in maintaining the osmotic balance, thereby improving the tolerance of plants under drought and salt stress. Consequently, plants exhibited improved physiological performance and greater tolerance to stress conditions (Gupta *et al*., 2024).

Salama *et al*. (2022) indicated that the use of Nano-potassium enhanced the yield attributes like number of pods per plant, weight of seeds and total grain yield in legumes. This is related to increased

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translocation of photosynthetic and increased sink strength during filling. Nano potassium has been shown to have a significant effect on vegetative growth of legumes like faba bean, in terms of plant height, leaf area, chlorophyll content and total biomass production following foliar application. This improvement is mainly attributed to enhanced nutrient availability, greater absorption efficiency, and improved physiological activity at the cellular level. Within the cellular level according to Al-Falahi and Abdul Kafoor (2021). Nano potassium enhances yield related traits in legumes such as number of pods per plant, seed weight and total grain yield. This effect is related to the increased translocation of photosynthesis and increased sink strength during the reproductive phase, which leads to better seed filling and higher productivity as mentioned by Huthily *et al* (2021).

Significance of the Study:

1. Helps develop sustainable fertilizer management plans for arid and semi-arid situations.
2. Supports better NSE (nutrient use efficiency) and minimizes losses due to conventional mineral fertilizers.
3. Promotes the use of nanotechnologies in agriculture as alternatives and/or complementary to mineral fertilizers.
4. Supplies scientific information with regard to pea response to desert environment in southern Libya.
5. Helps to boost legume productivity and local food security.

Objectives of the Study:

1. To investigate the effect of various combinations of nano–mineral NPK fertilizers on pea growth.
2. The effect of these treatments on yield components (number of seeds, 100 seed weight and total yield) was studied.
3. To establish the best mix of nano and mineral fertilizers to achieve higher productivity.
4. To analyze the effect of treatments on harvest index.
5. Evaluation of fertilizer utilization in arid environmental conditions in Al-Ruqaybah region.

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Material and methods:

A field experiment was conducted during the 2025–2026 growing season in Al-Ruqaybah, Libya, to evaluate the effects of different combinations of nano and mineral NPK fertilizers on the growth and yield of pea. The experimental soil was sandy in texture, and its physicochemical properties are presented in Table 1.

The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replicates. Each experimental plot had an area of 3 m^2. Plants were spaced at 25 cm within rows and 20 cm between rows. Irrigation was carried out using a sprinkler system according to crop requirements.

Six fertilization treatments were applied:

- Control
- 100% nano NPK
- 100% mineral NPK
- 50% nano NPK + 50% mineral NPK
- 25% nano NPK + 75% mineral NPK
- 75% nano NPK + 25% mineral NPK

Nano NPK fertilizer was applied as a foliar spray at a concentration of 2 g L^{-1} at 15, 30, and 45 days after planting. Standard agronomic practices were followed throughout the experiment.

For data collection, three plants were randomly selected from each replicate, and their values were averaged.

The following parameters were measured:

100-seed weight (g): A random sample of 100 seeds was taken from each treatment and replicate and weighed at standard moisture content.

Harvest index (%): Calculated as the ratio of seed yield to biological yield using the formula:

$$Harvest\ Index\ (\%) = (Seed\ Yield\ /\ Biological\ Yield) \times 100$$

Seed yield (kg/plot): Seeds were separated from pods at physiological maturity, dried, and weighed.

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Straw yield (kg/plot): Vegetative parts (stems, leaves, and empty pods) were oven-dried at 70 ± 2°C until constant weight and recorded as straw yield.
Biological yield (kg/plot): Calculated as the sum of seed yield and straw yield on a dry weight basis.
All data were subjected to analysis of variance (ANOVA) using COSTAT software. Treatment means were compared using the least significant difference (LSD) test at the 0.05 probability level.

Table 1 the physicochemical characterization of the field soil.

Soil Properties	
A) Mechanical Analysis	
Clay %	15.00
Sand %	65.00
Silt %	20.00
Soil Texture	
B) Chemical Properties	
Ph (1: 1)	7.0
Ec (dS m^{-1})	0.5
1) Soluble Cations (1:2) (Cmol/Kg Soil)	
K+	0.2
Ca++	3.0
Mg++	0.5
Na+	0.1
2) Soluble Anions (1 : 2) (Cmol/Kg Soil)	
Co3--+ Hco3-	1.0
Cl-	03
So4—	0.5
Calcium Carbonate (%)	5.0
Total Nitrogen %	0.1
Available Phosphate(mg kg^{-1})	15.0
Organic Matter (%)	2.0

Results

100 seed weight

The results showed that nano–mineral NPK combinations significantly affected the 100-seed weight of pea plants (**Fig**. 1). The

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highest value (35.0 g) was recorded in the treatment of 75% nano NPK + 25% mineral NPK, followed by 25% nano NPK + 75% mineral NPK (34.0 g) and 50% nano NPK + 50% mineral NPK (33.0 g). In contrast, the lowest value (24.0 g) was observed in the control treatment.

Harvest index %

The harvest index (%) was significantly influenced by fertilization treatments (**Fig**. 2). The highest value (45%) was recorded in the control treatment, while the lowest value (15%) was observed under 75% nano NPK + 25% mineral NPK. Fertilized treatments generally showed lower harvest index values due to increased biomass production.

The various fertilization treatments significantly affected the **seed yield, biological yield and straw yield** of the pea plants as shown in Table 2.

The treatment of 75% nano NPK + 25% mineral NPK gave the highest seed production (3.72 kg/plot) which was significantly higher than all the other treatments. This is significantly higher than the two mineral NPK (1.42 kg/plot) and nano NPK (1.76 kg/plot) and suggests a high synergy from using both types of fertilizer. The second best performance was recorded for 25% nano NPK + 75% mineral NPK (2.36 kg/plot) and the lowest yield was recorded for the control (0.95 kg/plot).

The same trend was noticed for biological yield (24.42 kg/plot) of the 75% nano NPK + 25% mineral NPK treatment compared to other treatments. This finding shows a significant increase in total biomass production with integrated fertilization. The control treatment, on the other hand, and without fertilization, the lowest biological yield (1.38 kg/plot) was obtained, which highlights the importance of fertilization for the accumulation of biomass.

Similarly, in the case of straw yield, the same treatment (75% nano NPK + 25% mineral NPK) had the highest straw yield (20.70 kg/plot) followed by (25% nano NPK + 75% mineral NPK) with straw yield of (8.40 kg/plot) Again, the lowest value was for the control treatment (0.43 kg/plot) The significant improvement in straw yield in treatments with nanotechnology was an indicator of dry matter accumulation and vegetative growth

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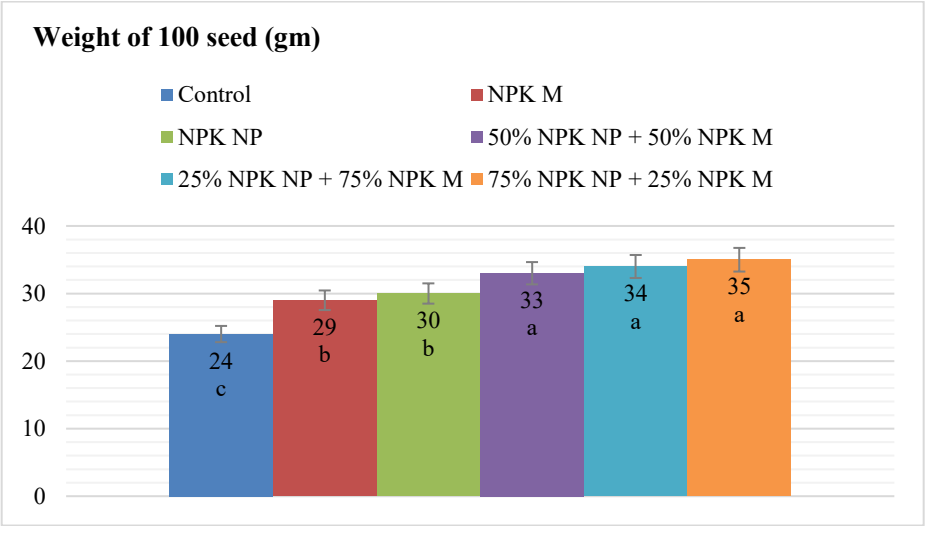

Fig. 1. The mean value of the weight of 100 seed (g) for pea plants for the 2025/2026 season under the fertilization treatments.

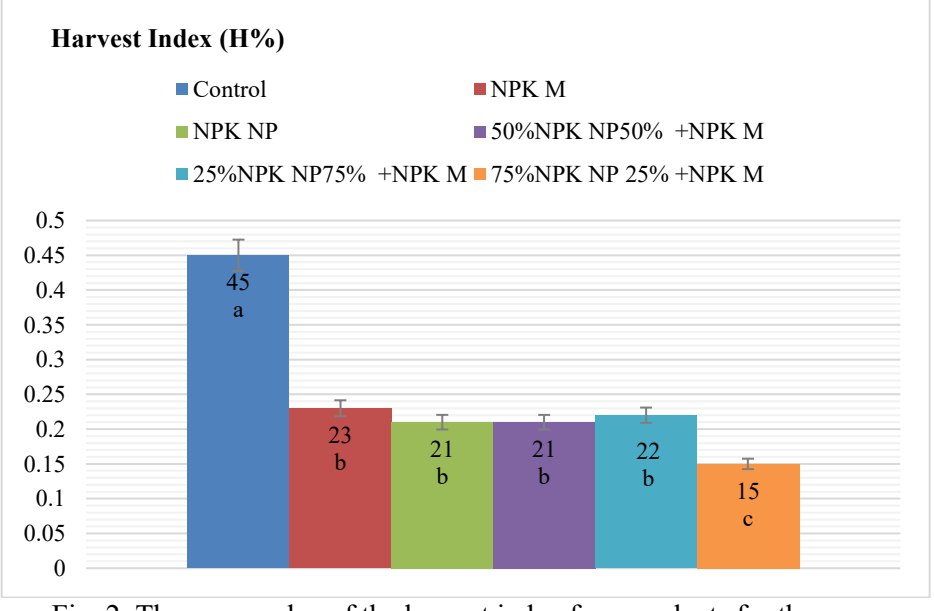

Fig. 2. The mean value of the harvest index for pea plants for the 2025/2026season under the fertilization treatments.

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Table (2): The mean value of seed yield, biological yield, and straw yield for pea plants for the 2025/2026 season under the fertilization treatment

Treatment	Seed yield (kg/plot)	Biological yield (kg/plot)	Straw yield (kg/plot))
Control	0.95 e	1.38 d	0.43 d
NPK Np	1.76 cd	8.42 bc	6.66 bc
NPK M	1.42 d	6.05 c	4.63 c
50% NPK Np + 50% NPK M	2.07 bc	9.94 b	7.87 bc
25% NPK Np + 75% NPK M	2.36 b	10.76 b	8.40 b
75% NPK Np+ 25% NPK M	3.72 a	24.42 a	20.70 a
LSD (0.05)	0.41	2.85	2.30

NPK M = Mineral NPK fertilizer, NPK Np= Nano NPK fertilizer

Discussion:

The study optimized the replacement of mineral and nano NPK fertilizers in order to improve pea productivity under the dry conditions of Al-Ruqaybah, Libya. The treatment consisting of 75% nano NPK + 25% mineral NPK exhibited the best overall performance; showing significant improvements in major yield-related traits. The findings suggest that partial substitution of mineral fertilizers with nano NPK enhances yield efficiency over mineral fertilizers and organic fertilizers used individually.

The use of nano-mineral NPK combinations significantly increased 100-seed weight of pea than the control and sole mineral fertilization, indicating enhanced seed filling and seed development. The results are consistent with Hassan and Nasser (2023) for broad bean Harshitha (2022) for rice bean and Alhasany *et al*. (2024) who found that integrated nano-mineral fertilization might affect the yield traits of legumes. The increased 100-seed weight reflects improved assimilate accumulation and nutrient translocation toward seed development, suggesting that optimized nutrient management enhances assimilate partitioning and sink strength, thereby improving seed development and overall yield performance, but

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also enhances sink capacity, which would be crucial for yield improvement.

These findings were inconsistent with those reported by Balachandrakumar *et al*. (2024) and Gomaa *et al*., (2016) who reported that nanotechnology has a positive effect on the harvest index. This indicates that a greater proportion of assimilates may have been partitioned toward seed production in the control treatment, resulting in a relatively higher harvest index. On the other hand, the total biomass was higher but the harvest index lower with nano-mineral NPK mixtures, suggesting greater vegetative growth compared to seed production in these treatments. However, absolute grain production was still higher than the check due to the substantial increase in total biological yield.

Pea seed yield was significantly higher in the two combinations of NPK with nano-mineral (75% nano NPK + 25% NPK M; 25% nano NPK + 75% NPK M) as compared to all other treatments. These findings are consistent with El-Azizy and Habib (2021), Choudhary *et al*. (2024), and Shaban *et al*. (2025) who reported better grain yield when legumes are fertilized with nano or integrated nano-mineral. The improvement is believed to be due to better nutrient uptake, use efficiency, enhanced source activity (photosynthesis) and sink development (pod and seed formation) under integrated treatments.

Under the dry soil environment of Al-Ruqaybah, the nano-mineral NPK blends improved pea biological yield over the unfertilized control and single mineral applications, indicating increased total biomass under arid soil conditions. These results are consistent with the results of El-Azizy and Habib (2021), Hassan and Nasser (2023) and Hosseini *et al*. (2023) which showed that the use of nano P, nano K and integrated nano mineral fertilizer improved straw yield, seed yield, and total biological productivity in legumes. The synergistic effect of conventional NPK fertilizers, which provide rapid nutrient availability, and nano formulations, which ensure controlled nutrient release and improved retention, has been credited for the improvement as they keep the photosynthetic activity and dry matter accumulation during the growth.

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Nano-mineral NPK combinations resulted in the highest pea straw production than the unfertilized control and single mineral treatments, showing a better vegetative biomass under the dry conditions of Al- Ruqaybah. The results obtained are in agreement with El-Azizy and Habib (2021) with broad bean and Raut (2023) and El- Shabasy *et al*. (2025) in other crops. The higher straw yield is attributed to the controlled release of nutrients and their enhanced availability in the nano fraction and to the nitrogen-induced leaf growth, phosphorus-induced root growth and potassium-mediated osmotic regulation and metabolic activities.

Conclusion

The outcomes of this study suggests that its application of nano and mineral NPK fertilizer has shown a significant improvement in the growth and productivity of pea under arid conditions. The treatment of 75% nano NPK + 25% mineral NPK showed maximum improvement in seed yield, biological yield and straw yield.

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