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IMPACT OF SHRIMP SHELL POWDER WITH PHOSPHORENE ON THE VEGETATIVE CHARACTERISTICS OF FABA BEAN (*Vicia faba* L.) IN A SANDY SOIL

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ABSTRACT

In order to improve soil fertility and plant nutrients, agricultural growth will optimize agricultural waste resources, such as shrimp waste. More than half of the yearly global output weight is made up of shrimp waste. Pots experiment was conducted to assess the impact of these wastes on faba bean production by incorporating phosphorene (phosphorus-dissolving bacteria) and using them as a total or partial substitute for mineral fertilization. The design used was completely randomized blocks (CRD), consisting of nine treatments: control, NPK, Phosphorene, Shrimp shell powder, Shrimp + ½ NPK, Phosphorene + ½ NPK, Shrimp + Phosphorene, Shrimp + Phosphorene + ½ NPK, and Shrimp + Phosphorene + NPK. Results showed that adding shrimp shells with phosphorene and half of the recommended dose of the chemical fertilizer for beans recorded the highest germination rate, germination velocity index (GVI), plant weight and length, and root weight. The addition of phosphorene improved the nutritional state of the plant and soil by increasing phosphorus and potassium levels. Nitrogen recorded the highest value with the addition of shrimp shells with phosphorene. Shrimp shells and phosphorene are eco-friendly fertilizers, emphasizing their combined benefits for soil health and plant growth. Therefore, reducing chemical additives by adding shrimp shells and phosphorene is recommended.

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Keywords: Biofertilizers, Biomass, Germination Velocity Index, Nutrient content.

INTRODUCTION

Large volumes of shrimp trash were created by restaurants and seafood processing facilities and were carelessly dumped, causing a horrible odor and significantly contaminating the environment. **(Nargis *et al.,* 2006)**. It is believed that for every ton of seafood consumed, nearly equal amounts are thrown as waste **(Venugopal, 2022).** Shrimp is one of Egypt's most popular crustaceans and favored species. Egypt produced 23,748 tons of shrimp in 2021. Egypt produces roughly 12 thousand tons of shrimp waste each year. Large amounts of this byproduct are discarded, resulting in a loss of essential bioactive components and increasing environmental pollution **(Nirmal *et al.,* 2020).** Shrimp and shrimp products are widely consumed all over the world, and their demand is increasing yearly **(N'Souvi *et al.,* 2024).** Shrimp waste study findings centered on the usage of shrimp waste as a source of chitin and chitosan for the production of natural polymers and slow-release fertilizers **(Mansyur *et al.,* 2021).** Shrimp waste can be used as fish meal **(Nargis *et al.,* 2006).** Shrimp waste contains a high total nitrogen concentration, making it an excellent source of organic nitrogen fertilizer **(Wani *et al.,* 2024).**

Biofertilizers are a sustainable and inexpensive source of plant nutrition. Biofertilizers contain various kinds of bacteria that help crops get the nutrition they need from the environment **(Areeshi, 2022).** It could be in the form of pellets, liquids, or powders that were added directly to the soil **(Alengebawy *et al.,* 2022).** It includes several microbes such as phosphate-solubilizing bacteria, bacteria responsible for nitrogen fixation, fungi, and nitrogen-fixing cyanobacteria **(Areeshi, 2022).** Faba bean (*Vicia faba* L.) is a major food and feed legume because of the high nutritional value of its rich protein and starch seeds. Seeds are consumed dry, fresh, frozen or, canned **(Duc *et al.,* 2010).** It is one of the most main legume crops grown in Egypt, and it is considered one of the main dishes on the Egyptian Table **(Youseif *et al.,* 2014;**

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Boukraa *et al.,* 2025). Around the world, faba beans are grown in a variety of agricultural systems as a green manure crop and grain legume. In the Middle East and Europe, it is very popular as a vegetable and is the fourth most important pulse crop in the world. Global faba bean production reached 5.67 million metric tons in 2020, a significant increase from the 4.35 million metric tons reported in 1990 **(Torabian *et al.,* 2024).**

In order to boost crop productivity, particularly for beans, and improve soil fertility, the study sought to decrease the usage of artificial fertilizers in agriculture and employ shrimp waste as well as phosphorus-dissolving bacteria.

MATERIALS AND METHODS

Soil sampling and characterization

Sandy soils were collected from Damanhour agriculture faculty's farm in Al-Bustan region, Al-Dalangat, El-Beheira governorate, Egypt. Soil samples were collected from 0 cm to 20 cm depth, air-dried, and sieved to 2 mm. Table 1 illustrates Soil chemical properties, which were measured according to **Page *et al.* (1982)** and **Burt (2004).**

Table 1: Chemical characteristics of the sandy soil under consideration before bean planting.

pH	7.82	O.M (%)	0.25
Soluble Anions (mg/kg)			
Cl^- 284	CO_3^{-2} ----	HCO_3^{-2} 61	SO_4^{-2} 432.2
Soluble Cations (mg/kg)			
Na^+ 251.6	K^+ 37.2	Ca^{+2} 180	Mg^{+2} 300
Macro nutrients (mg/kg)		**EC (1:2.5) dS/m**	
N 560	P 1.37	1.24	

Experimental design

Pots experiment was conducted in the faculty of agriculture, Damanhour University, El-Beheira Governorate, Egypt. The experimental design is factorial in a completely randomized design (CRD). The experiment consisted of nine treatments; each treatment had three replicates. Treatments included; control (soil without any additives), NPK (recommended does were 20 Kg N , 150 Kg P_2O_5 and 50Kg K_2O/ feddan), Phosphorene (Ph= 6 g/pots), shrimp waste (Sh=15 g/pots from shrimp shell powder), shrimp + ½ NPK (Sh+ ½ NPK), phosphorene + ½ NPK (Ph+ ½ NPK), shrimp + phosphorene (Sh+Ph), shrimp + phosphorene + ½ NPK (Sh+ Ph + ½ NPK), and shrimp + phosphorene + NPK(Sh+ Ph + NPK). Then, the bean plant was planted in black plastic pots. Each pot has four holes at the bottom, and a layer of gravel is placed at the bottom of the pots to improve the drainage process. Posts were filled with three kg of soil.

Table 2: Analysis of shrimp shell powder.

pH (1:2.5)	EC(dS/m) (1:2.5)	N (%)	P (%)	K (%)
8.32	**7**	**10%**	**1.60%**	**0.75%**

The germination rate was monitored daily through observation and counting. After two weeks, the germination percentage and germination velocity index (GVI) were calculated in accordance with **Maguire (1962).**

$$\textbf{GVI} = \frac{G1}{N1} + \frac{G2}{N2} + \cdots + \frac{Gn}{Nn} \ldots\ldots\ldots\ldots\ldots \textbf{Eq1}$$

Where: G1, G2 and Gn were the number of germinated seeds in first, second and last count. N1, N2 and Nn were the number of sowing days at the first, second….and last count.

After about two months of planting, growth parameters were measured, such as fresh weight, shoot and root length, and root volume by fresh washed roots, which have been carefully dried and the overflow water volume is measured in a graduated cylinder. Plant nutritional status can be assessed through the analysis of nitrogen (N) **(Bremner, 1965),** phosphorus (P) **(Olsen and Sommers, 1982),** and potassium (K) **(Chapman and Pratt, 1961).** Soil samples were collected to measure EC, pH, total N, P, and K concentrations in the soil **(Chapman and Pratt, 1961).** Soil biomass was measured according to the approach by **Shen *et al.* (1984)** and calculated as the following equation:

$$\textbf{Microbial biomass C} = \frac{(Fc - UFc)}{Kc} \quad \ldots\ldots\ldots\ldots\ \textbf{Eq2}$$

Where: Fc = CO_2 released from the fumigated sample (mg CO_2 – C/Kg). UFc = CO_2 released from the unfumigated sample (mg CO_2 – C/Kg). Kc = fraction biomass C mineralized to CO_2 or extracted, Kc = 0.41.

Statistical analysis

The results were statistically analyzed using R software (R version x64 4.1.2). An analysis of variance (ANOVA) Table was analyzed and calculated for each measured trait for all treatments, and a Tukey test (HSD at 0.05) was conducted to calculate the significance between the treatments.

RESULTS AND DISCUSSIONS

In Figure 1 a significant increase in germination percentage was observed in (Sh + Ph + 1/2 NPK) treatment, reaching 91.6%, an improvement over the control by 451.8%. The germination percentage at 7 days after sowing ranged between 16.6% and 91.6% in all treatments. The control and (Ph + ½ NPK) treatments were the lowest and (Sh + Ph + ½ NPK) treatment was the highest. NPK is a valuable source of nutrients for seed germination and plant growth **(Marschner, 2012).** Shrimp waste and phosphorene have moderate impacts **(Adesemoye and Kloepper, 2009; Wang *et al.*, 2023),** but when combined or in conjunction with lowered NPK, they exhibit notable improvements. Shrimp waste, phosphorene, and half NPK produce the highest results

(91.67%), emphasizing the need to maintain a balance between organic and inorganic inputs **(Agegnehu *et al.,* 2017).** Shrimp waste + phosphorene + 1/2 NPK is the greatest effective treatment for promoting bean seed germination. This underlines the importance of combining organic and lower doses of mineral fertilizers to maximize seed germination. **Vessey (2003)** offers an overview of phosphorus biofertilizers and their effects on plant germination. **Agegnehu (2017)** covers the combined impacts of inorganic and organic inputs on plant growth and soil health.

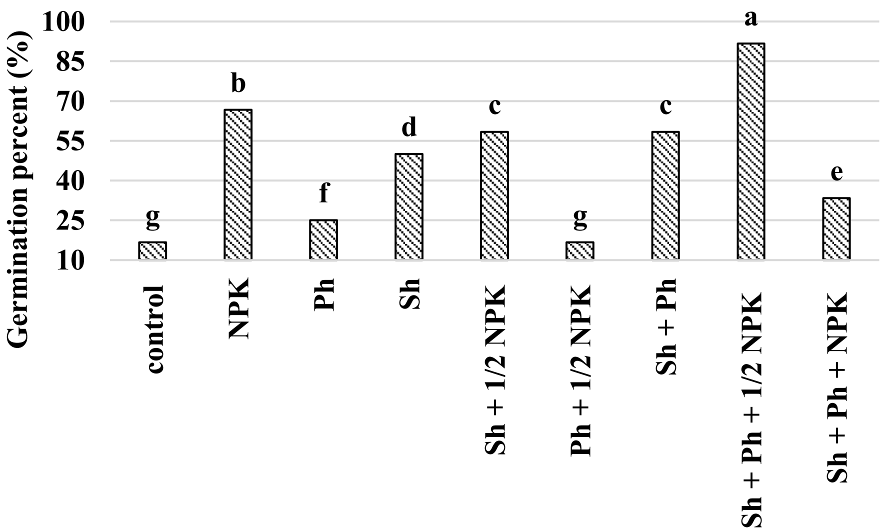

Figure 1: Germination percent (%) of bean seeds at 7 days after sowing. Within columns, values followed by different lowercase letters are significantly different at α = 0.05.

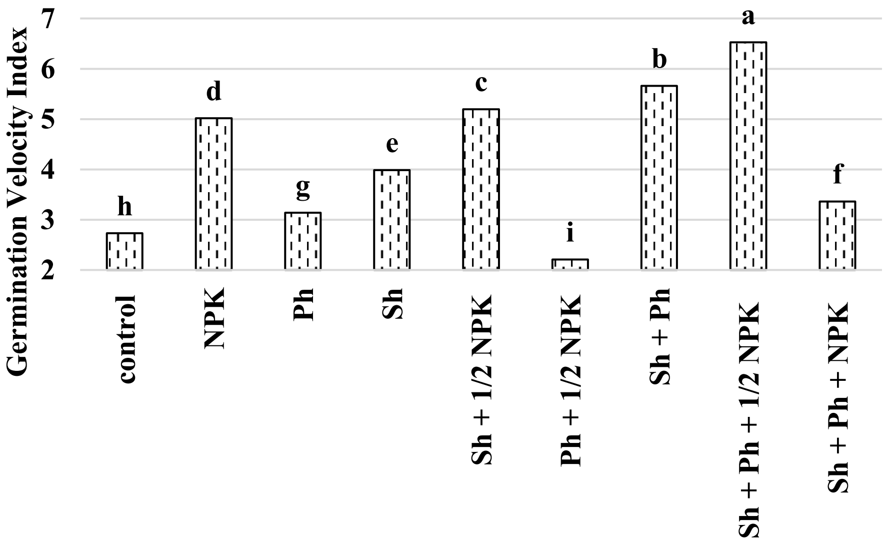

Figure 2: Germination velocity index of bean seeds. Within columns, values followed by different lowercase letters are significantly different at α = 0.05.

The Germination Velocity Index (GVI) gauges the rate at which seeds sprout under various conditions. Faster germination, which can result in more consistent crop establishment and better use of resources like water and nutrients, is indicated by a higher GVI. Figure 2 showed the GVI of bean seeds. When NPK is applied, the GVI rises noticeably above the control. This shows that NPK contains essential nutrients that promote faster seed germination. Although it is significantly less effective than NPK, phosphorene biofertilizers have a slight positive impact when compared to the control. This suggests that phosphorene has a limited effect when administered alone, even though it might provide some nutrients or chemicals that promote growth. Shrimp waste is not as effective as NPK, but it does improve the GVI when compared to the control. This suggests that the organic content and nutrients found in shrimp excrement probably promote quicker germination.

The GVI is somewhat higher when shrimp waste and half the dose of NPK are combined than when either treatment is used alone. According to this, shrimp waste enhances NPK but cannot completely replace it. Phosphorene biofertilizer and lowered NPK interact antagonistically, as evidenced by the fact that phosphorene biofertilizer + 1/2 NPK performs worse than the control. Competition or nutritional imbalances may be the cause of this. When shrimp waste and phosphorene biofertilizers are mixed, the results are significantly better than when either treatment is applied alone. This implies synergistic effect. shrimp waste + phosphorene biofertilizer + 1/2 NPK yields the highest GVI, suggesting a strong synergistic impact. While the lowered NPK supplies necessary minerals without producing nutrient toxicity, the shrimp waste and phosphorene probably improve soil conditions and nutrient availability. Half NPK works better than the combination of Shrimp waste, Phosphorene biofertilizer, and NPK. This implies that the full dosage of NPK can be harmful or excessive when mixed with phosphorene and shrimp waste, perhaps as a result of osmotic stress or nutritional imbalances **(Kirkby, 2001; Marschner, 2012).** Germination is crucial for nutrition as well as product cultivation **(Bozoğlu and Aybey, 2024).** Under optimal growing conditions, faba bean seeds germinate about 10 to 14 days. However, in dry or extremely cold situations, it may take longer **(Damalas *et al.*, 2019).**

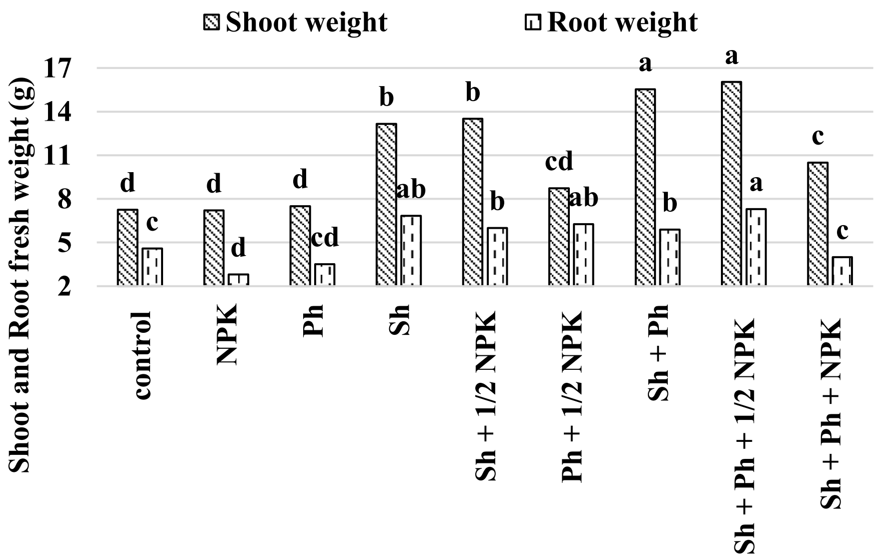

Figure 3: Effect of different treatments of shrimp shell, phosphorene and NPK on bean plant shoot and root fresh weight (g). Within columns, values followed by different lowercase letters are significantly different at α = 0.05.

Figure 3 showed that there was no significant difference between the following treatments, namely control, NPK, and Ph, in terms of fresh shoot weight of the bean plant, but there was a significant difference in terms of fresh root weight between the control and NPK treatments, whereas the Ph treatment differed from them. Shoot weight is considerably increased by shrimp waste (sh) in comparison to the control. Mixing phosphorene with shrimp increases the weight of the shoots. The shrimp + phosphorene combination produces the highest shoot weight (16.03) when 1/2 NPK is added. Shoot weight is decreased when full NPK is added to shrimp waste + phosphorene as opposed to 1/2 NPK. In addition, shrimp waste considerably raises root weight in comparison to the control. The highest treatment in fresh weight, whether shoot or root, was Sh + Ph + ½ NPK, which improved over the control by 121.1% and 59.38%, respectively. This is consistent with the results of **(Widnyana *et al.,* 2023),** where liquid organic fertilizer of fish waste was used, the fresh weight of the shoot and root increased. In addition, in the study of **(Indratmi *et al.,* 2024),** different quantities of shrimp shell fertilizer were utilized, which yielded positive results in terms of fresh weight of shallot tubers, with percentage increases ranging from 106% to 164.2% over the control. The results for the fresh weight of the shoot align with **Hu *et al.* (2023),** who found that using shrimp increased pakchoi shoot fresh weight. However, there is a difference in findings regarding root fresh weight, as their study showed no significant difference between shrimp shell fertilizer and the control. Chitin derived from crab shells was employed, as it was applied at a rate of 2% to the potting soil (1.5 liters), and lettuce seedlings were planted. At the end of the experiment, lettuce heads were picked, and an increase of roughly 20% was noticed in the fresh weight of the lettuce leaves **(Debode *et al.,* 2016).** The highest root weight (7.3) was achieved by combining shrimp waste, phosphorene, and half NPK.

When phosphorene and shrimp waste are combined, complete NPK results in much lower root weight. Shrimp waste improves nitrogen uptake and promotes plant growth, especially in terms of shoot biomass **(Suresh *et al.*, 2019; Abirami *et al.,* 2022).** Phosphorene promotes root elongation and shoot biomass by increasing the amount of phosphorus in the soil **(Chaurasia *et al.,* 2021).** Overuse of NPK fertilizers lowers soil organic matter and adversely affects root development **(Tripathi *et al.,* 2020).** It has been demonstrated that combining organic fertilizers (such as phosphorene and shrimp waste) with lower concentrations of inorganic fertilizers (such as 1/2 NPK) improves plant development more than applying either fertilizer type alone. Half-dose NPK combined with organic amendments increases shoot and root biomass and enhances nutrient usage efficiency **(Sagar *et al.,* 2022).** Even when paired with organic amendments, high levels of synthetic fertilizers disturb soil microbial populations and inhibit plant growth **(Yu *et al.,* 2024).**

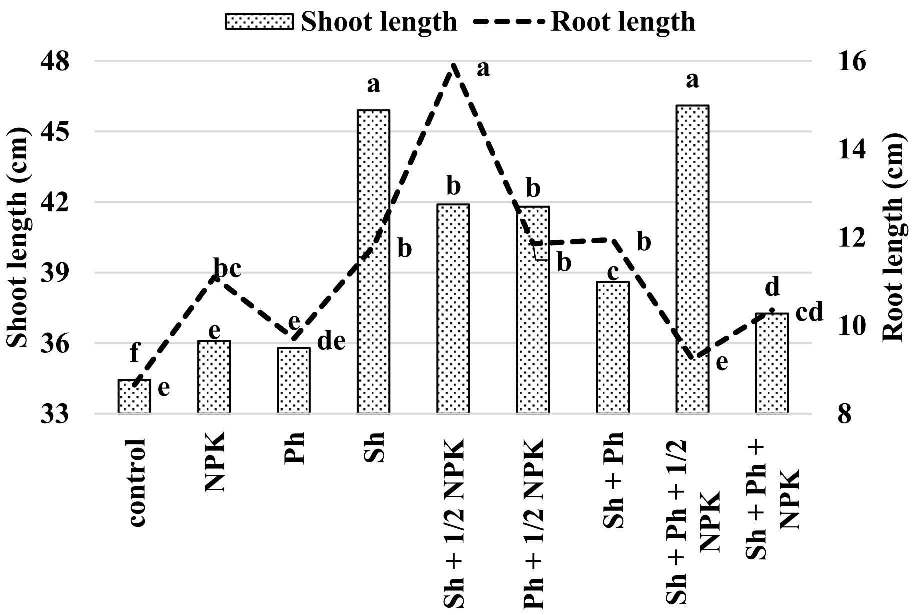

Figure 4: Effect of different treatments shrimp shell, phosphorene and NPK on bean plant shoot and root length (cm). Within columns, values followed by different lowercase letters are significantly different at α = 0.05.

It is noticed that shrimp shells aid to enhance the length of the bean plant's shoot, as any treatment to which shrimp shells were added, whether alone or in combination with other factors such as NPK fertilizer or phosphorene, resulted in an increase in the length of the bean plant's shoot (Figure 4). There was no significant difference between the treatment in which only shrimp shells were added (Sh) and the treatment in which half the amount of NPK fertilizer and phosphorus was added to the same amount of shrimp shells (Sh + Ph + ½ NPK), as they represented the two highest treatments in the length of the shoot, with an improvement over the control by a 33.4% and 33%, respectively. The increase in shoot length is owing to the high nutrient content of shrimp shells, particularly nitrogen **(Indratmi *et al.,* 2024),** which is consistent with the findings of **(Mansyur *et al.,* 2021),** who found that using shrimp waste with biochar increased the height of the corn plant. A study in Egypt on faba beans (Sh + Ph + ½ NPK) found that spraying plants with amino acids from shrimp peels at different concentrations, under varying irrigation water salinity levels and plant ages, resulted in the greatest plant height when using a 2000 mg/L amino acid solution with tap water for irrigation **(Abdeen and Hefni, 2023).**

The presence of amino acids already in shrimp shells plays a role and positive effect on increasing the height of faba bean plant. This is also consistent with the study of **(Rusmini *et al.,* 2017)** where shrimp shells-based composts were used with kenaf plants and this resulted in an increase in plant height. **Indratmi *et al.* (2024)** found that employing shrimp shell at various doses increased the height of the shallot plant. It also agrees with the findings of **Hu *et al.* (2023),** who found that fertilizer containing shrimp waste boosted shoot length. It was discovered that phosphorene was ineffective in improving and increasing plant height, as the control treatment (without any additives) was the lowest with a value of 34.4 cm, and the highest with a slight difference was the phosphorene treatment with a value of 35.8 cm, representing a 4% improvement over the control. As for the root length in the bean plant, there is no significant difference between these three treatments, which are when shrimp shells were added (Sh), or when phosphorene was added with half the amount of NPK fertilizer (Ph + ½ NPK), or when shrimp shells were added with phosphorene (Sh + Ph). However, when shrimp shells were added with half the amount of NPK fertilizer (Sh + ½ NPK), the maximum possible root length was reached through the different treatments, with an increase over the control treatment by 83.8%, as the root length during the treatments ranged from 8.65 cm for the control treatment to 15.9 cm for the shrimp shells+ 1/2 NPK (Sh+1/2NPK) treatment. Root length improved by 86% when using liquid organic fertilizer of fish waste compared to the control **(Widnyana *et al.,* 2023)** and it increased by fertilizer containing shrimp waste **(Hu *et al.,* 2023).**

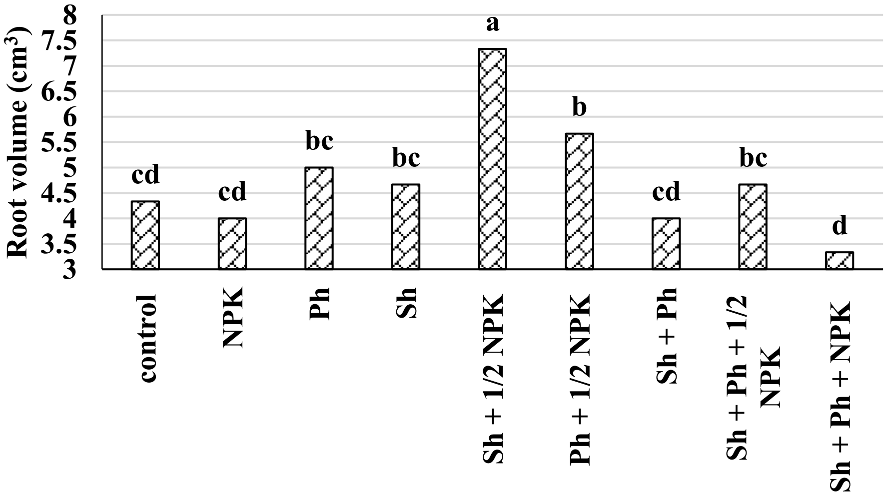

Figure 5: Effect of different treatments shrimp shell, phosphorene and NPK on bean plant root volume (cm^3). Within columns, values followed by different lowercase letters are significantly different at $\alpha = 0.05$.

Shrimp waste and reduced NPK (shrimp waste plus 1/2 NPK) appear to operate together to improve root volume more than either treatment alone. This highlights the potential benefits of combining inorganic and organic fertilizers in optimal ratios. In contrast to their individual uses, the combination of phosphorene and shrimp waste had an antagonistic impact, reducing root volume. This demonstrates how different biofertilizers interact with one another before mixing them. The disappointing findings of the total NPK combination with phosphorene and shrimp waste underscore the importance of balanced fertilization approaches and suggest that excessive nutrient intake may have a negative impact on root development. According to these findings, mixing organic biofertilizers with lower quantities of mineral fertilizers (such as 1/2 NPK) can improve root growth and potentially increase total crop production. However, when combining different biofertilizers, exercise caution because they may interact negatively and reduce their effectiveness. This is consistent with the findings of **Ji *et al.* (2017),** who employed NPK fertilizer as well as other liquid organic fertilizers.

Shrimp extracts were the liquid organic fertilizer that improved Chrysanthemum root size the most. **Adesemoye *et al.* (2009)** discuss how biofertilizers combine with mineral fertilizers to improve plant development and nutrient utilization efficiency. **Bhardwaj *et al.* (2014)** highlight the benefits of biofertilizers in boosting soil fertility and plant growth, emphasizing their varied ways of action. **Gopalakrishnan *et al.* (2015)** explore the impact of organic amendments, such as shrimp waste, on plant growth-promoting Rhizobacteria (PGPR) and root development. **Nawaz *et al.* (2025)** look into how phosphorene and other bacterial biofertilizers promote plant growth and nutrient uptake in nutrient-limited conditions.

Table 3: Nutrient content of beans under the effect different treatments of shrimp shell, phosphorene, and NPK.

treatments	Nutrient content of beans (%)		
	N	P	K
control	3.15^{e}	0.675^{g}	0.5^{e}
NPK	6.3^{a}	1.065^{ef}	0.725^{c}
Ph	2.38^{f}	1.02^{f}	0.71^{c}
Sh	4.375^{d}	1.2^{cd}	0.57^{de}
Sh + 1/2 NPK	5.075^{c}	1.32^{b}	1.06^{b}
ph + 1/2 NPK	4.9^{c}	1.41^{a}	1.7^{a}
Sh + Ph	5.35^{b}	1.12^{de}	0.68^{cd}
Sh + Ph + 1/2NPK	6.35^{a}	1.275^{bc}	0.65^{cd}
Sh + Ph + NPK	4.2^{d}	1.085^{ef}	0.95^{b}

Values followed by different lowercase letters were significantly different at $\alpha = 0.05$.

Shrimp shells contain huge amounts of chitin **(Zhu *et al.,* 2025).** Chitin has the potential to serve as an effective growth enhancer in plants by boosting nutrient absorption and increasing the activity of growth hormones **(Ngasotter *et al.,* 2023).** When adding chitin to crops, it can be rapidly used as a source of energy and nitrogen by plants and microorganisms **(Sharp, 2013). Table 3** shows that the highest N, P, and

K uptake is observed in the NPK treatment (6.3; 1.41; and 1.7) and the (Sh+Ph+1/2NPK) treatment (6.35). While the lowest N, P, and K uptake is in control (3.15; 0.675 g; and 0.5). Full NPK fertilization or the combination of half NPK with phosphorene and shrimp waste (Sh + Ph + 1/2NPK), results in the highest N uptake. Phosphorene and shrimp waste alone increase N, P, and K uptake in contrast to the control, although not as much as when combined with NPK. It may not be a significant source of nitrogen because phosphorene has little effect on N uptake on its own. Shrimp waste also improves P uptake, either alone or in combination with other therapies, though not as effectively as NPK. Phosphorene and shrimp waste do not influence K uptake, but when mixed with NPK, they significantly increase K levels.

Mansyur ***et al.*** **(2021)** showed that shrimp waste was used to fertilize corn plants, either alone or mixed with biochar, whereas the efficiency of plant uptake of nitrogen was higher compared to control by 24.9% and 35%, respectively. This confirms the role of shrimp waste as a source of organic nitrogen fertilizer. The concentration of phosphorus in the bean leaves ranged from 0.675% to 1.41%, with the highest value representing (Ph + ½ NPK) treatment and the lowest value representing control treatment (Table 3). The superiority of (Ph + ½ NPK) treatment indicates the efficiency of microbes in solubilizing phosphorus and potassium and delivering them to the bean plant. This occurs in the presence of half the suggested amount of NPK mineral fertilizer. Phosphorus-solubilizing bacteria enhance plant uptake of phosphorus in an environmentally friendly manner, furthermore, they have the potential to remediate soil environments contaminated by conventional commercial fertilizers and improve soil structure **(Chen *et al.,* 2021).** The microbes work to transfer the solubilized form of potassium in the soil to the plant **(Suyal *et al.,* 2022).**

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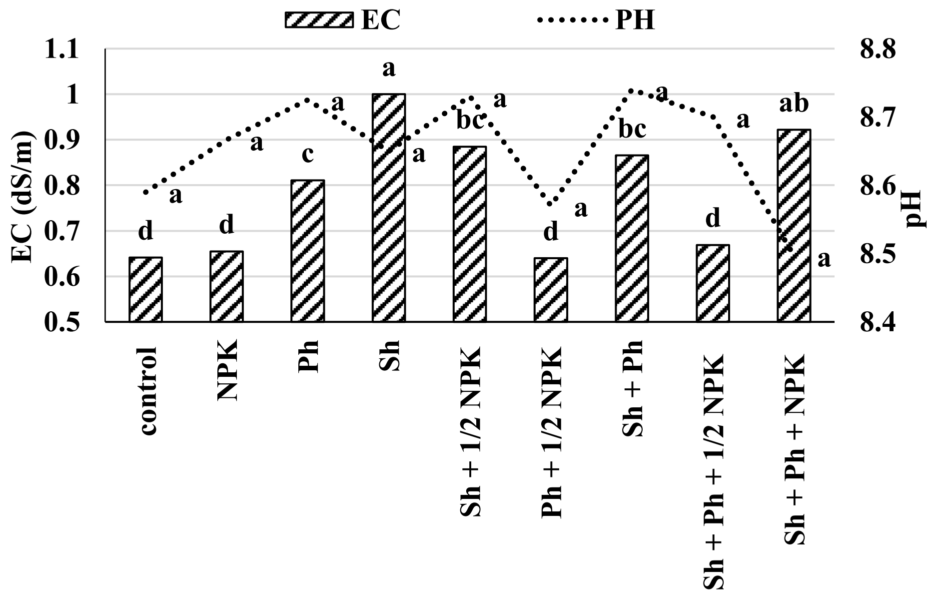

Figure 6: Effect of shrimp shell, phosphorene and NPK on EC (dS/m) and pH of soil. Within columns, values followed by different lowercase letters are significantly different at α = 0.05.

The electrical conductivity of the soil ranged between 0.64 and 1 dS/m. Figure 6 shows that using phosphorene with half the amount of NPK (Ph + ½ NPK) or adding shrimp shells (Sh + Ph + ½ NPK) did not significantly differ from the control treatment. The values for (Ph + ½ NPK), (Sh + Ph + ½ NPK), and (control) were equal to 0.64 dS/m, 0.669 dS/m, and 0.641 dS/m, respectively. The treatment containing solely shrimp shells (Sh) exhibited the greatest electrical conductivity value, measuring 1 dS/m, a 56% increase over the control. The addition of shrimp shells to all treatments increased the EC value significantly compared to the control, except for the (Sh + Ph + ½ NPK) treatment. This may be due to the inherent high EC of shrimp shells (0.7 dS/m). Regarding pH, no significant differences were observed among treatments, with values ranging from 8.49 to 8.74 (Figure 6). However, most treatments with shrimp shells showed higher pH than the control, confirming their alkaline nature (pH 8.32), except for the Sh + Ph + NPK treatment. Shrimp shells also included calcite minerals ($CaCO_3$), which provided OH^- and increased soil pH **(Mansyur *et al.,* 2021).**

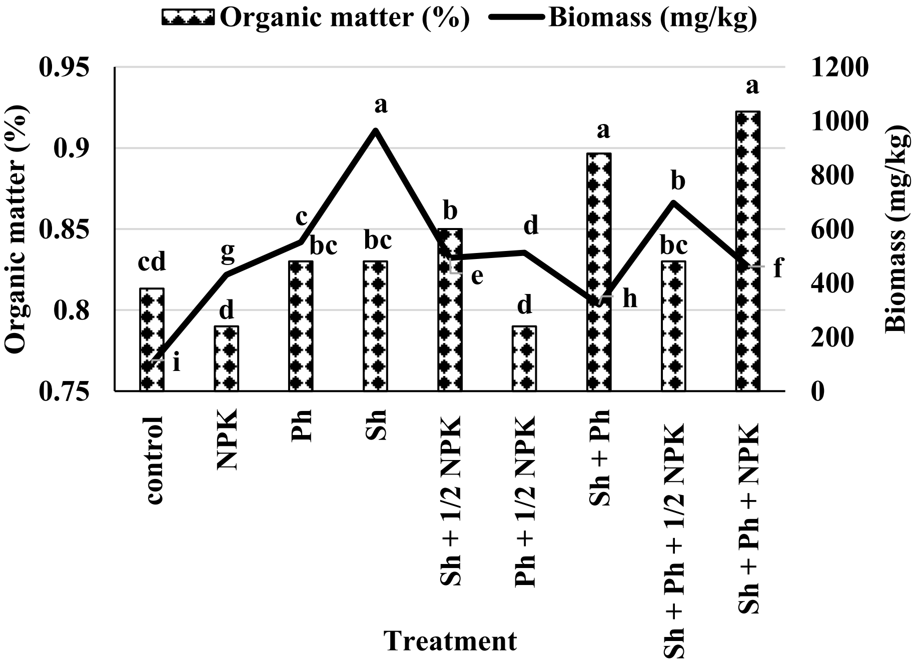

Figure 7: Effect of shrimp shell, phosphorene and NPK on soil organic matter (%) and Biomass (mg/kg). Within columns, values followed by different lowercase letters are significantly different at α = 0.05.

The addition of shrimp shells and phosphorene improved the proportion of organic matter in the soil (Figure7). This is especially noticeable in two treatments, (Sh + Ph) and (Sh + Ph + NPK), where the values are 0.90% and 0.92%, respectively, representing an 11.1% and 13.58% improvement over the control, with the control value being 0.81%. The increase in soil organic matter is attributed to shrimp shells, which are rich in chitin—a carbon source for soil microbes that enhances nutrient cycling and fertility **(Hui *et al.,* 2020).** This finding aligns with **Hu *et al.* (2023),** where shrimp waste combined with *Bacillus* bacteria increased soil organic matter by 8.8% to 10.16% compared to the control. Adding shrimp shells alone (Sh treatment) significantly increased soil microbial biomass, reaching up to 9.4 times higher than the control, due to the provision of organic matter and nitrogen through decomposition, despite a high C/N ratio of 43:1. This suggests the presence of microbes capable of thriving in high-carbon environments and breaking down complex materials like chitin found in shrimp shells. The chitin soil addition increased the relative and absolute populations of numerous fungal and bacterial groups that contribute to plant growth and biological control **(Debode *et al.,* 2016).** Incorporating chitin into soil changes the environmental dynamics within the rhizosphere, as it alters the microbial equilibrium to support advantageous organisms while negatively impacting plant pathogens **(Sharp, 2013).** Adding phosphorene, either alone or combined with shrimp shell powder, NPK fertilizer, or both, enhances biomass value. Phosphorus-solubilizing *Bacillus* bacteria also improve microbial biodiversity and biomass **(Xi *et al.,* 2015; Zhang *et al.,* 2021).**

Table 4: Nitrogen, Phosphorus and Potassium concentrations in the soil after the end of the cultivation period.

Treatments	The nutrient content of the soil (mg/Kg)		
	N	P	K
Control	70.00 g	10.92 f	34.70 f
NPK	105.00 e	12.72 de	39.75 d
Ph	70.00 g	17.57 a	58.05 a
Sh	112.00 d	15.85 b	47.60 b
Sh + 1/2 NPK	105.00 e	13.95 cd	47.45 b
Ph + 1/2 NPK	91.00 f	12.17 ef	39.70 d
Sh + Ph	129.50 b	14.55 bc	46.20 c
Sh + Ph + 1/2NPK	147.00 a	14.90 bc	37.20 e
Sh + Ph + NPK	126.00 c	14.55 bc	46.05 c

Values followed by different lowercase letters are significantly different at α = 0.05.

The study found that the lowest soil nitrogen concentration (70 mg/Kg) was in the control and Ph treatments, while the highest (147 mg/Kg) was in the Sh + Ph + ½ NPK treatment, which was 2.1 times higher than the control. This increase is attributed to the nitrogen-rich shrimp shells (containing about 10% nitrogen) and the added mineral fertilizer NPK. Shrimp waste is a valuable source of essential nutrients (nitrogen and phosphorus) **(Kazemi *et al.,* 2019).** The highest phosphorus concentration was found in (Ph) treatment, with a value equal to 17.58 mg/Kg, an improvement of 60% over the control. Phosphorus-solubilizing microorganisms (PSMs) release phosphorus from either organic or inorganic materials **(Li *et al.,* 2019).** PSMs solubilize inorganic phosphorus by secreting acids and lowering the pH value, this can be done at a variety of temperatures, such as 4 or 28 degrees Celsius **(Hayat *et al.,* 2017).** The treatment with the highest potassium concentration (58.05 mg/Kg), showing a 67.29% increase over the control (34.7 mg/Kg), was achieved using phosphorene **(***Bacillus megaterium***).** This is due to the bacteria's ability to solubilize phosphorus and enhance potassium availability in the soil for plant uptake. Different strains of Bacillus bacteria can solubilize either phosphorus or potassium, enhancing soil fertility **(Negi *et al.,* 2023).** This aligns with findings that shrimp shell fertilizer increases N, P, and K levels in soil **(Murtilaksono *et al.,* 2022).** Phosphorus-solubilizing bacteria, often found in plant tissues or rhizosphere soils, boost soil health by releasing beneficial substances like organic acids, siderophores, protons, auxin, and extracellular polysaccharides (EPS), with minimal ecological impact **(Yang *et al.,* 2022).**

CONCLUSION

From the results of this study, it is suggested to use shrimp waste as an organic fertilizer and improve this fertilizer by adding phosphate-solubilizing bacteria to facilitate phosphorus and reduce soil alkalinity. This research could provide valuable insights into enhancing nutrient availability for plants in calcareous soils. Additionally, discovering the synergistic effects of these combinations may lead to more sustainable agricultural practices that increase soil health and crop yields, so future studies are recommended as follows: (i) the effect of adding shrimp shells with phosphorus-solubilizing bacteria in calcareous soils, (ii) its effect with Rhizobium bacteria with leguminous plants in calcareous soils, and (iii) its combined effect with phosphorus-solubilizing bacteria and Rhizobium.

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الملخص العربي

تأثير مسحوق قشور الجمبري مع الفسفورين على الخصائص الخضرية لنبات الفول البلدي (*Vicia faba* L.) في التربة الرملية

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ينتج نصف وزن الإنتاج العالمى السنوي من الجمبري مخلفات ، لذلك تهدف هذه الدراسة الى تقييم دور هذه المخلفات في إنتاج الفول مع إضافة الفسفورين (بكتيريا مذيبة للفسفور) واستخدامهم كبديل كلى أوجزئي للتسميد المعدني . أجريت هذه الدراسة بأستخدام تصميم القطاعات كاملة العشوائية ومكونه من ٩ معاملات مع ٣ مكررات وهي الكنترول (بدون اضافات) ، NPK (إضافة الأسمدة المعدنية الموصى بها) ، الفسفورين (Ph) ، بودرة قشور الجمبري (Sh) ، قشور الجمبري + نصف التسميد المعدني (Sh+1/2NPK) ، فوسفورين + نصف التسميد المعدني (Ph+1/2 NPK) ، الفسفورين + قشور الجمبري (Sh+Ph) ، الفسفورين + قشور الجمبري + نصف التسميد المعدني (Sh+Ph+1/2 NPK) و الفسفورين + قشور الجمبري + التسميد المعدني (Sh+Ph+NPK) . وقد وجد إن إضافة قشور الجمبري مع الفسفورين مع نصف السماد المعدني الموصى به سجل أعلى نسبة إنبات ووزن النبات والجذر وطول النبات. بينما الحالة التغذوية للنبات سجلت أعلى قيم للفسفور والبوتاسيوم بإضافة الفسفورين ولكن تركيز النتروجين سجل أعلى قيم بإضافة قشور الجمبري مع الفسفورين . وتعد قشور الجمبري كسماد عضوي والفوسفورين من الأسمدة الحيوية الصديقة للبيئة، مع التأكيد على فوائدهما المشتركة لصحة التربة ونمو النبات. لذلك يوصى بتقليل إضافات الأسمدة المعدنية الى النصف مع إضافة قشور الجمبري والفسفورين .

الكلمات الدالة : الأسمدة الحيوية، الكتلة الحيوية، محتوى العناصر الغذائية، مؤشر سرعة الإنبات.