



Asian Journal of Plant Sciences

ISSN 1682-3974

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Research Article

Preparation, Characterization and Evaluation of Nano Phosphorus Foliar Application on Peanut Production under Sandy Soil

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Abstract

Background and Objective: Nanotechnology is a new multidisciplinary division that can have an extensive possible effect on agriculture via orchestrating the slow and stable release of nutrients and consequently reducing the lack of nutrients and improving the nutrient use efficiency. So, this study aimed to measure the effect of nano fertilizers especially Phosphorus nano-fertilizer on peanut productivity.

Materials and Methods: Incomplete randomized block design, two field experiments were set up at the experimental farm of National Research Centre, Al-Nubaria district, Al-Behaira Governorate, Egypt, in two summer seasons of 2019 and 2020. The treatments were (control, one dose of 100 ppm, one dose of 200 ppm, two doses of 100 ppm and two doses of 200 ppm). **Results:** The results indicated that the full recommended rate of conventional fertilizer and Phosphorus nano-fertilizer enhanced all the studied growth parameters measured at mid-season except for root length. Regarding the chemical composition of leaves and seeds, the addition of Phosphorus nano-fertilizer tended to increase N, P, Na, Ca, Mn and Zn in peanut leaves. However, K, Mg, Fe and Cu were not affected by the treatments. In seeds, only P and Mn were increased by Phosphorus nano-fertilizer. **Conclusion:** At the end of the experiment, all the studied parameters were enhanced by the full recommended rate of conventional fertilizer and Phosphorus nano-fertilizer. Application of Phosphorus nano-fertilizer at 200 ppm either once at 30 Days After Sowing (DAS) or twice at 30 and 60 DAS resulted in a significant increase in pod yield, seed yield and oil yield compared to the control treatment.

Key words: Peanut, Phosphorus nano-fertilizer, seed yield, quality, sandy soil, leguminous crops, days after sowing

Citation: Bakry, B.A., S.S. El-Nwehy, R.R. Afify, O.M. Ibrahim and M.E. Abd El-Aziz, 2022. Preparation, characterization and evaluation of nano Phosphorus foliar application on peanut production under sandy soil. Asian J. Plant Sci., 21: 423-431.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Nanotechnology is a modern scientific way that aims at the use of nanometer-scale materials in different fields such as medicine and agriculture^{1,2}. Also, nanotechnology is considered a progressive field of science being applied widely in a lot of scientific fields and playing a vital role in agriculture^{3,4}. As about 40-60% of the total production of world food relies on fertilizers⁵, plant nutrition is important for agricultural production as well as crop quality. So, enhancing plant nutrition could lead to more productivity and more quality crops. Concerning the importance of the element Phosphorus to crop growth, Phosphorus plays an important role in promoting nodulation of roots in leguminous crops, enhancing nitrogen fixation operation, as well as increasing nutrient-use efficiency^{6,7}. It is the least available macronutrient for plant uptake in many types of soils, especially in alkaline soils with high contents of Ca^{2+} where Phosphorus fixation takes place where low soil available Phosphorus is a great obstacle to the growth and development of leguminous crops⁸. Also, its release from Phosphorus fertilizers is slow⁹, as well as its global reserves, are being diminished at a high rate and it is expected that, by the year 2050, soil Phosphorus reserve will fade away¹⁰.

To avoid such problems, the foliar application is an alternative way^{11,12} and is considered one of the most suitable ways for sustainable agriculture to increase production and decrease pollution in groundwater, dealing with the problems of soil effects and interactions on fertilizers such as fixation and leaching because it uses tiny amounts of the fertilizers as well as reduces the risk of eutrophication¹³ and consequently improve plant growth^{14,15}.

Phosphorus nano-fertilizer could play a vital role to make Phosphorus and other nutrients more available to the crops and consequently reduce the misusing of chemical fertilizers¹⁶. Also, improving the efficiency of nutrient could be achieved by increasing the contact of fertilizer with plant surfaces leading to an increase in uptake via increasing the contact of fertilizer with plant surfaces that could be accomplished by minimizing particle size, which increase the number of particles per unit weight and specific surface area¹⁷.

From the above-mentioned benefits of Phosphorus, the main objective of this study was to investigate the effect of foliar application of nano-Phosphorus fertilizer on the productivity and the quality of peanut crops under conditions of newly reclaimed sandy soil.

MATERIALS AND METHODS

Study area of the experiment: Two Field experiments were set up at the experimental farm of National Research Centre, (latitude 30°30'1.4"N, longitude 30°19'10.9"E), Al-Nubaria district, Al-Behaira Governorate, Egypt during the first of May, in the two summer seasons of 2019 and 2020 to investigate the role of foliar application of Phosphorus nano-fertilizer in growth and seed yield as well as seed quality of groundnut grown in sandy soil.

Materials: All the chemicals used for synthesis were of analytical grade. Ammonium molybdate and citric acid were obtained from Sigma-Aldrich Chemical Company. Ammonium hydroxide was supplied from El-Naser Company.

Preparation of hydroxyapatite¹⁸: $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ (5.8 g) was dissolved in 100 mL of Double-Distilled Water (dd- H_2O) to form solution A. 9.12 g of $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$ and 0.36 g of NaOH were dissolved in another 100 mL of dd H_2O to form solution B. solution A was then added into solution B drop by drop under constant stirring at room temperature until a white precipitate is obtained. The white precipitate was collected using a centrifuge at 5000 rpm and the supernatant was accordingly discarded. The washing and centrifugation steps were repeated at least 3 times to ensure the complete removal of a byproduct. The white precipitate was dried in an oven at 70°C for 72 hrs and ground to a fine powder.

Characterizations: The morphological of nanomaterials were demonstrated by using TEM model JEM-1230, Japan, operated at 120 kV, with a maximum magnification of 600×103 and a resolution until 0.2 nm. A drop of an aqueous dispersion of the nanomaterials was placed on a carbon-coated copper grid and allowed to dry in the air before characterization. The XRD patterns were carried out on a Diano X-ray diffractometer using $\text{CuK}\alpha$ radiation source energized at 45 kV and a Philips X-ray diffractometer (PW 1930 generator, PW 1820 goniometer) with $\text{CuK}\alpha$ radiation source ($\lambda = 0.15418$ nm). The basal spacing (dL) was calculated from the (001) reflection via Bragg's equation.

The soil samples (0-30 depth) were analyzed according to the method described by Cottenie *et al.*¹⁹ (Table 1).

In both seasons, seeds of peanut (*Arachis hypogaea* L.) variety c.v. Gize 6 were inoculated with unique rhizobium bacteria inoculants and sown in 1st May, in both seasons. The nitrogen fertilizer was applied at a rate of 30 kg N/fad as ammonium sulfate (20.6 percent N) in 2 equivalent

Table 1: Some physical and chemical properties of the soil

pH	EC	OM	CaCO ₃	Particle size distribution			Texture
				Sand%	Silt%	Clay%	
1:2.5	dS m ⁻¹	%	%	75.7	5.3	18.28	Class
7.76	1.26	0.84	2.98				Sandyloam
Cations (meq L ⁻¹)				Anions (meq L ⁻¹)			
Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	CO ₃ ⁻⁻⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻⁻⁻
3.62	1.41	3.52	1.48	0.38	3.81	1.82	3.44
Available macronutrients (mg/100 g soil)				Available micronutrients (mg kg ⁻¹)			
N	P	K	Fe	Zn	Mn	Cu	
15.33	3.98	16.52	11.61	0.09	5.89	0.011	

EC: Electrical conductivity and OM: Organic matter

parts, the 1st at sowing and the 2nd 30 days later. In the 1st and 2nd seasons, groundnut was harvested on September, 15th and 25th September, respectively. The plot area was 10.5 m², with 5 rows (3.5×3 m, 60 cm between rows and 20 cm inside rows) and a complete randomized block pattern with three replications.

Phosphorus nano-fertilizer foliar application treatments were (control, one dose of 100 ppm, one dose of 200 ppm, two doses of 100 ppm and two doses of 200 ppm), where the 1st dose at the vegetative stage (30 days after sowing) and the 2nd dose at pod development period (60 days after sowing). Control treatment foliar with water. Plant samples were taken randomly at vegetative growth, 75 days after sowing, to measure plant height, plant fresh weight, root length, root circumference and total chlorophyll.

At harvest, ten guarded plants were sampled to determine yield and its components, including the number of pods per plant, the number of seeds per plant, the pod yield per plant (g), the seed yield per plant (g) and the weight of 100 seeds per plant (g). To measure seed yield ha⁻¹, the whole plot was harvested and the pods were air-dried. The yields of oil and protein per hectare were estimated.

Chemical analysis: Chemical analysis of seed and leaves was carried out using Chapman and Pratt's methods²⁰. N percent was multiplied by 6.25 to get the protein content. AOAC²¹ was used to assess seed oil content.

Statistical analysis: Data were statistically analyzed according to Lawal²² using R version 4.0.2²³.

RESULTS

Phosphorus nano-fertilizer characterization: The result of Fig. 1a illustrated the morphological structure of the prepared nanoparticles. It can be demonstrated that the prepared

nanomaterials with particles size less than 50 nm. While Fig. 1b represented the XRD diffraction pattern of hydroxyapatite Ca₅(PO₄)₃(OH) = 42% (P₂O₅). It has shown the sharp peak at 2θ = 25.9° which indicates the formation of hydroxyapatite in pure form with a good crystallization and growth preference on the (002) crystal plane. Also, it exposed plans at (112), (300) and (202) corresponding to 2θ at 32.07°, 33.1° and 34°, respectively.

Effect of Phosphorus nano-fertilizer on growth parameters of peanut: Table 2, the addition of Phosphorus nano-fertilizer as foliar application caused a significant increase in plant height, shoot fresh weight, shoot dry weight, root circumference, total chlorophyll and P uptake while root length was not affected by these treatments.

Table 2 is the treatment of (one dose of 200 ppm) Phosphorus nano-fertilizer surpassed the other treatments in shoot fresh weight (162.0 g), total chlorophyll content in leaves (67.3 SPAD) and Phosphorus uptake (17.98 mg/plant), while, the treatment of (one dose of 100 ppm) gave the highest values of plant height (55.0 cm), shoot dry weight (105.3 g), then the others treatments, except for root circumference where the maximum increase (28.3 cm) was at the treatment of 2 doses of 200 ppm than others treatments. There were no significant differences between the 2 treatments of (one dose of 100 ppm and one dose of 200 ppm) in plant height, shoot fresh weight (g), shoot dry weight (g) and root length (cm) traits, as well as, non-significant differences between the 2 treatments of (two doses of 100 ppm and two doses of 200 ppm) in plant height (cm), shoot fresh weight (g), shoot dry weight (g), root length (cm), total chlorophyll content in leaves and P uptake (mg/plant), as the same trend. There were non-significant differences between the 2 treatments of (one dose of 100 ppm and the control treatments) in root length and root circumference and non-significant effect between (one dose of 100 ppm, one dose of 200 ppm and two doses of 200 ppm)

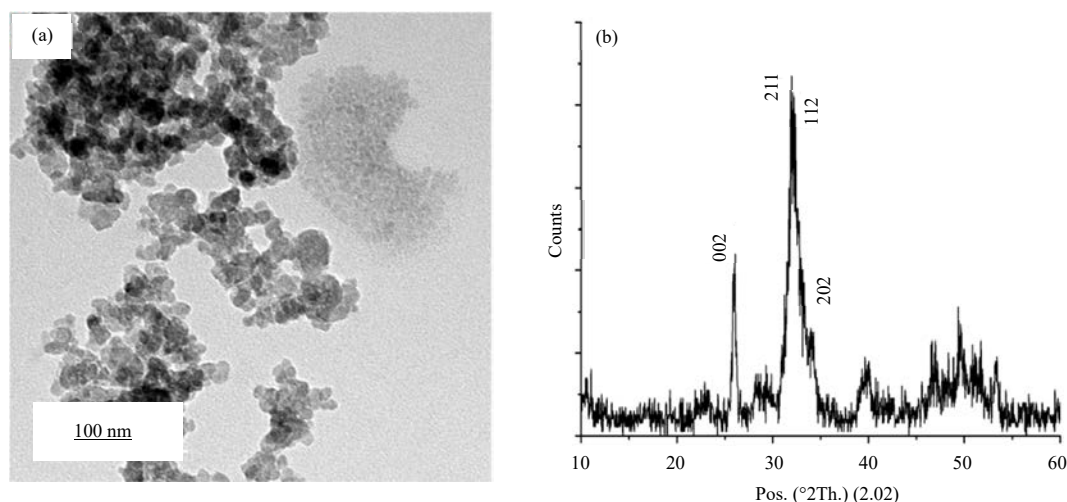


Fig. 1(a-b): (a) TEM and (b) XRD pattern of phosphorus nano-fertilizer

Table 2: Effect of phosphorus nano-fertilizer application on growth parameters of peanut under sandy soil conditions

Phosphorus nano-fertilizer	Plant height (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root circumference (cm)	Root length (cm)	Total chlorophyll SPAD	P uptake mg/plant
Control	48.0 ^c	132.7 ^c	88.3 ^b	25.0 ^c	18.3 ^a	45.0 ^d	4.81 ^c
One dose 100 ppm	55.0 ^a	160.0 ^a	105.3 ^a	25.0 ^c	18.0 ^a	54.7 ^b	9.21 ^b
One dose 200 ppm	52.7 ^{ab}	162.0 ^a	101.3 ^a	26.7 ^b	17.3 ^a	67.3 ^a	17.98 ^a
Two doses 100 ppm	48.0 ^c	145.3 ^b	87.0 ^b	26.0 ^{bc}	18.7 ^a	50.0 ^c	16.92 ^a
Two doses 200 ppm	49.7 ^{bc}	145.3 ^b	87.3 ^b	28.3 ^a	17.0 ^a	50.0 ^c	19.10 ^a

Combined analysis of two seasons of 2019 and 2020, means with super scripted same letters are non significantly different and SPAD: Soil plant analysis development

Table 3: Effect of phosphorus nano-fertilizer application on seed yield and its components of peanut grown on sandy soil

Phosphorus nano-fertilizer	Number of pods/plant	Number of seeds/plant	Shilling (%)	Pod yield (t ha ⁻¹)	Seed yield (t ha ⁻¹)	Oil (%)	Oil yield (t ha ⁻¹)	Protein yield (t ha ⁻¹)
Control	26.0 ^c	37.0 ^d	22.6 ^d	2.45 ^c	1.89 ^c	53.2 ^b	1.22 ^b	0.39 ^c
One dose 100 ppm	28.7 ^c	53.3 ^c	39.6 ^a	4.32 ^b	2.61 ^b	50.7 ^c	1.32 ^b	0.52 ^b
One dose 200 ppm	39.7 ^b	60.0 ^b	30.8 ^b	4.79 ^a	3.32 ^a	55.3 ^{ab}	1.84 ^a	0.72 ^a
Two doses 100 ppm	42.3 ^{ab}	68.3 ^a	25.7 ^{cd}	4.61 ^a	3.42 ^a	54.7 ^{ab}	1.87 ^a	0.73 ^a
Two doses 200 ppm	44.0 ^a	68.3 ^a	26.3 ^c	3.90 ^a	3.40 ^a	56.5 ^a	1.92 ^a	0.78 ^a

Combined analysis of two seasons of 2019 and 2020, means with super scripted same letters are non significantly different

of Phosphorus nano-fertilizer treatments on Phosphorus uptake (mg/plant). This may be due to that the 2nd dose of Phosphorus nano-fertilizer was applied 15 days before sample taking and maybe its effect did not take place.

Effect of Phosphorus nano-fertilizer on seed yield and its components of Peanut: Table 3 revealed that foliar application of Phosphorus nano-fertilizer significantly enhanced the number of pods/plant, number of seeds/plant, pod yield ha⁻¹, seed yield ha⁻¹, seed oil content, oil yield ha⁻¹ and protein yield ha⁻¹. The increase in the above-mentioned parameters was gradual with the treatments. Shilling percent tended to significantly decrease after the treatment of one dose of 100 ppm, meaning that empty pods were decreased due to the application of Phosphorus nano-

fertilizer. The maximum number of pods/plant (44.0), number of seeds/plant (68.3), pod yield (4.79 t ha⁻¹), seed yield (3.42 t ha⁻¹), seed oil content (56.5 %), oil yield (1.92 t ha⁻¹) and protein yield (0.78 t ha⁻¹) were produced by the treatment of 2 doses of 200 ppm with no significant difference with the treatment 2 doses of 100 ppm.

There were no significant differences among the treatments (One dose of 200 ppm, two doses of 100 ppm and two doses of 200 ppm) concerning pod yield ha⁻¹, seed yield ha⁻¹, oil percentage, oil yield ha⁻¹ and protein yield ha⁻¹ as depicted in Fig. 2-3.

The improvement of seed yield was almost 37 and 77% as compared to the control treatment when applying one dose of 100 ppm or any treatment of the other 3 treatments (One dose of 200 ppm, two doses of 100 ppm and two doses of 200 ppm).

Effect of Phosphorus nano-fertilizer on the chemical composition of peanut leaves and seeds:

Foliar application of Phosphorus nano-fertilizer has a significant effect on N, P, Na, Ca, Mn and Zn in leaves while K, Fe and Cu were not significantly affected (Table 4). The treatment (two-dose of 200 ppm) of Phosphorus nano-fertilizer gave the highest values of N (4.01%), P (0.42%), K (2.3%), Na (2.7%), Fe (120.7 ppm), Mn (154.3 ppm) and Cu (6.3 ppm) in leaves with non-significant with the other treatments compared to control.

It was clear that Phosphorus nano-fertilizer foliar application enhanced the chemical composition of leaves and this may be due to the synergistic effect of Phosphorus nano-fertilizer on the conventional fertilizer for better nutrient absorption by the crop which leads to optimal peanut growth. In seeds, all the above-mentioned elements were not significantly affected except for P and Mn. The treatment

(two-dose of 200 ppm) of Phosphorus nano-fertilizer gave the highest values of N (4.20%), P (0.047%), K (0.52%), Mn (10.0 ppm) and Cu (18.7 ppm) in seeds with non-significant with the other treatments compared to control.

Both P (0.047%) and Mn (10.0 ppm) were significantly increased due to the foliar application of (two doses of 200 ppm) Phosphorus nano-fertilizer. As P increased in leaves, re translocation takes place and P in seeds was improved (Table 5).

As depicted from Fig. 4 seed yield was significantly correlated to Phosphorus in seeds (0.89) whereas nitrogen in seeds was not strongly correlated to seed yield (0.52). The high correlation between P and seed yield reflects the important role of Phosphorus nano-fertilizer in improving seed yield as Phosphorus is the store of energy in plants. However, nitrogen in seeds was less important to seed yield since nitrogen is more related to protein content (quality) than yield (quantity).

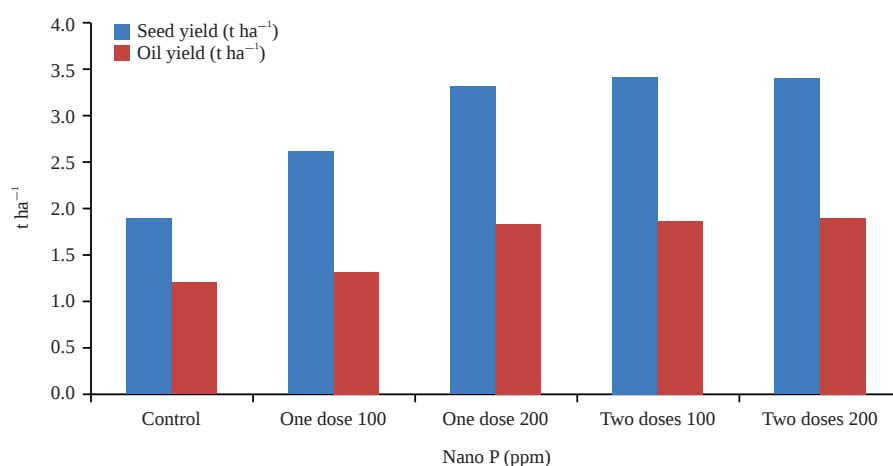


Fig. 2: Response of peanut seed yield and oil yield to phosphorus nano-fertilizer

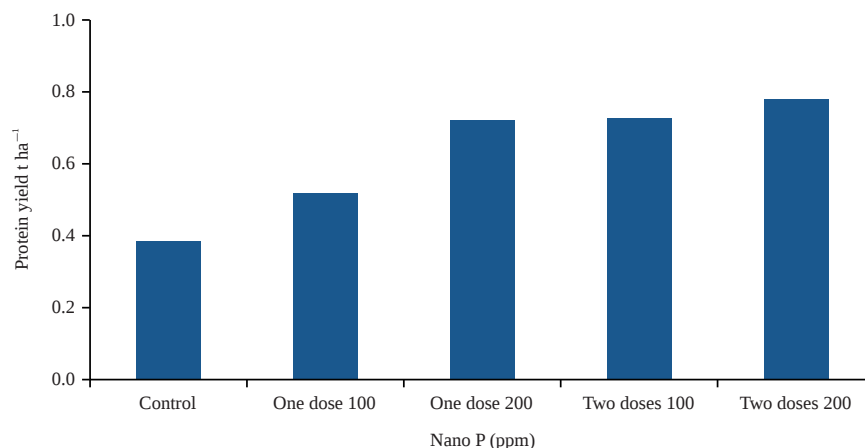


Fig. 3: Response of peanut protein yield to phosphorus nano-fertilizer

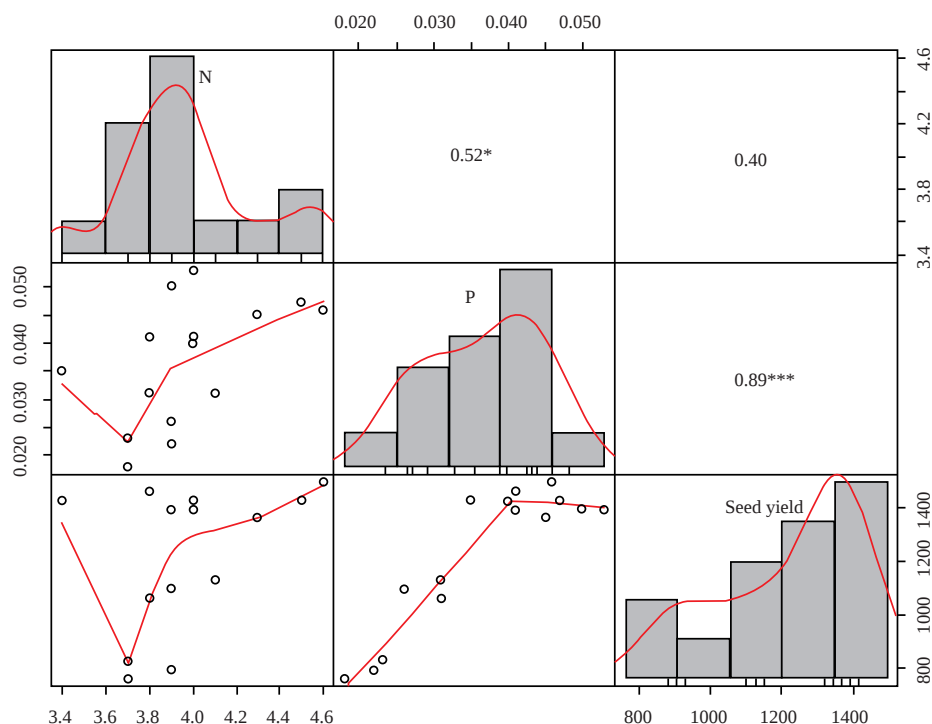


Fig. 4: Relationship between phosphorus and nitrogen in seeds and seed yield

*Significant at 0.05, ***Significant at 0.001

Tables 4: Effect of phosphorus nano-fertilizer application on some macro (%) and micro (ppm) nutrients content in peanut shoot grown on sandy soil

Phosphorus nano-fertilizer	N (%)	P (%)	K ⁺ (%)	Na ⁺ (%)	Ca ²⁺ (%)	Mg ²⁺ (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Control	3.55 ^b	0.24 ^b	1.97 ^a	1.93 ^b	1.67 ^b	0.70 ^a	74.0 ^a	66.0 ^c	39.7 ^a	5.0 ^a
One dose of 100 ppm	3.5 ^b	0.41 ^a	1.90 ^a	2.3 ^{ab}	2.1 ^a	0.72 ^a	96.3 ^a	170.7 ^a	30.3 ^{ab}	4.7 ^a
One dose of 200 ppm	3.8 ^{ab}	0.34 ^{ab}	2.03 ^a	2.5 ^{ab}	1.8 ^{ab}	0.67 ^a	106.7 ^a	153.0 ^{ab}	26.7 ^b	5.3 ^a
Two doses of 100 ppm	3.7 ^{ab}	0.36 ^a	1.9 ^a	2.3 ^{ab}	1.9 ^{ab}	0.72 ^a	112.7 ^a	115.3 ^{bc}	32.0 ^{ab}	4.7 ^a
Two doses of 200 ppm	4.01 ^a	0.42 ^a	2.3 ^a	2.7 ^a	1.9 ^{ab}	0.68 ^a	120.7 ^a	154.3 ^{ab}	33.0 ^{ab}	6.3 ^a

Combined analysis of two seasons of 2019 and 2020, superscripted alphabets represent the significant test between the treatments by Duncan test

Tables 5: Effect of phosphorus nano-fertilizer application on some macro (%) and micro (ppm) nutrients content in seeds of peanut grown on sandy soil

Phosphorus nano-fertilizer	N (%)	P (%)	K ⁺ (%)	Na ⁺ (%)	Ca ²⁺ (%)	Mg ²⁺ (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Control	3.76 ^a	0.021 ^c	0.51 ^a	0.15 ^a	0.14 ^a	0.21 ^a	14.7 ^a	5.3 ^{bc}	37.7 ^a	6.0 ^b
One dose of 100 ppm	3.93 ^a	0.029 ^b	0.51 ^a	0.15 ^a	0.13 ^a	0.21 ^a	14.3 ^a	5.0 ^c	36.7 ^a	15.7 ^a
One dose of 200 ppm	4.06 ^a	0.045 ^a	0.52 ^a	0.14 ^a	0.13 ^a	0.21 ^a	14.7 ^a	8.0 ^{ab}	40.7 ^a	15.0 ^a
Two doses of 100 ppm	3.90 ^a	0.041 ^a	0.48 ^a	0.15 ^a	0.13 ^a	0.20 ^a	14.0 ^a	6.0 ^{bc}	37.7 ^a	6.3 ^a
Two doses of 200 ppm	4.20 ^a	0.047 ^a	0.52 ^a	0.14 ^a	0.13 ^a	0.20 ^a	14.0 ^a	10.0 ^a	40.3 ^a	18.7 ^a

Combined analysis of two seasons of 2019 and 2020, superscripted alphabets represent the significant test between the treatments by Duncan test

DISCUSSION

As shown in the above results, the maximum response of Phosphorus nano-fertilizer was achieved by the treatment of one dose of 200 ppm in most of the measured parameters. Many studies on the effect of P application on soybean and other crop species' development, photosynthesis, nitrogen fixation and yield have been published²⁴⁻²⁶.

Phosphorus (P) is the second most important nutrient for optimal plant growth, after nitrogen, since it is an essential

component of energy transport molecules such as ATP, ADP (adenine triphosphate), phospholipids and sugar-phosphate and it plays an important role in processes such as photosynthesis, respiration and DNA biosynthesis²⁷. The availability of P has a significant impact on plant productivity parameters such as root and shoot weight, plant vigour, disease tolerance, number of reproductive buds, yield and efficiency²⁸. P in synthetic fertilizers, on the other hand, is poorly available due to its slow release time and high soil fixation. According to a recent report, Nano-fertilizers (NFs) will

steadily supply P for up to 40-50 days after application, while conventional P synthetic fertilizers deliver all nutrients within 8-10 days. As a result, it's been proposed that using NFs or slow-release materials could improve the Nutrient Usage Efficiency (NUE) of P in a variety of field crops. In addition to contributing to a high NUE, a biosafe nano fertilizer that is a source of P was found to dramatically increase fresh and dry biomass, increase fruit production and boost quality by several times²⁹. Similarly, using Nano-Sized Hydroxyapatite (nHA) in a soybean crop improved growth and resulted in a seed yield that was 20.4 percent greater than when using synthetic P fertilizer. Soliman *et al.*²⁷, who discovered a substantial increase in the growth and antioxidant content of *Adansonia digitata* L. plants treated with nHA foliar treatment.

It seems that the role of Phosphorus nano-fertilizer at the vegetative stage of peanut was a synergistic effect on the recommended conventional fertilizer for better absorption of nutrients and thereby resulting in optimal growth. Liu and Lal³⁰ reported similar results in soybeans, observing an average growth rate of 11.4 cm week 21 for soybeans under nano-Phosphorus treatment and 8.6 cm week 21 for normal Phosphorus treatment in the first 12 weeks, compared to 5.1 and 4.8 cm week 21 for controls, respectively. There was a small improvement in soybean growth when the plants were treated with non-Phosphorus fertilizer (N and K) instead of only tap water, but these two control treatments showed very low growth. As a result, P becomes the restricting and indispensable nutrient for healthy soybean and other legume development, relying solely on external inputs. Plants could pick up P nutrients in nanoparticle formulation and nanoparticles could be used as an efficient P nutrient supply as conventional soluble P fertilizers. Phosphorus applied in the form of NFs can be a good alternative, particularly in smart agriculture, because it has a long-term slow-release material that can minimize P leaching into groundwater while also improving crop productivity and quality.

In conclusion, from the results, optimized peanut yield can be obtained by any of the treatments, one dose of 200 ppm or two doses of 100 ppm, or two doses of 200 ppm. Jyothi and Hebsur³¹ mentioned that Phosphorus nano-fertilizer increased the growth rate of soybean by 33% which is reflected in the seed yield of peanuts. Also, Hagab *et al.*³² revealed similar results where using nano zeolite Phosphorus significantly increased peanut yield components, the weight of seeds and oil percent. The results also showed that the application of nano zeolite Phosphorus at a rate of 75% gave yield parameters significantly higher than those obtained by the application of conventional fertilizer at a rate of 100%.

In the case of leguminous plants, it has been shown that adding Phosphorus to plants growing in low soils improves nodulation and biomass yield significantly by Magadlela *et al.*³³ and Pérez-Fernández *et al.*³⁴. When P is scarce, nodules may serve as a P drain, which is then compensated by increased biological nitrogen fixation³⁵.

Needing Phosphorus fertilizer for both nodulation and nitrogen fixation, plants that are actually on nitrogen fixation will require more Phosphorus than those that uptake combined nitrogen³⁶. P availability is closely linked to nodulation, N₂ fixation and plant efficiency^{37,33,34}.

The high correlation between P, nutrients content and seed yield reflects the important role of Phosphorus nano-fertilizer in improving seed yield as Phosphorus is the store of energy in plants. Hagab *et al.*³² stated similar results where the highest significant increase in nutrient content (N, P, K) was achieved by using nano zeolite Phosphorus. The nano zeolite Phosphorus levels at the rate of 100 % significantly increase straw and seeds by 2.4, 4.0, 0.2, 0.3, 1.1 and 1.3% for N, P and K contents, respectively. This might be due to the nano form of zeolite particles that increased dissolution rate. Moreover, the finer size of nano zeolite Phosphorus enhanced the degree of contact between zeolite and soil, which caused a greater rate of dissolution. The slow release of N, P and K fertilizers provide a constant supply of nutrients to plants for a long time and decreases the leaching of these nutrients in the soil, which led to increasing the efficiency of nutrients by plants.

CONCLUSION

It could be concluded from this study that Phosphorus nano-fertilizer as a foliar application has evident benefits to enhance the growth, as well as increase seed yield, oil content and the chemical composition of peanut as the crop grown under new land conditions. The study indicated the maximum response of Phosphorus nano-fertilizer as a foliar application at the vegetative stage of peanuts. In addition, it has a synergistic effect on the recommended conventional fertilizer for better absorption of nutrients for optimal growth and a high correlation between P and seed yield, which reflects the important role of Phosphorus nano-fertilizer in improving seed yield of peanut.

SIGNIFICANCE STATEMENT

This study discovered Phosphorus nano fertilizer enhancement the peanut productivity and quality traits in sandy soil. So, it can be beneficial for researchers and farmers

to use Phosphorus nano fertilizer instead of chemical fertilizer to improve the growth and productivity of various crops grown under sandy soil conditions.

REFERENCES

1. Fakruddin, M., Z. Hossain and H. Afroz, 2012. Prospects and applications of nanobiotechnology: A medical perspective. J. Nanobiotechnol., Vol. 10. 10.1186/1477-3155-10-31.
2. Salama, D.M., M.E.A. El-Aziz, F.A. Rizk and M.S.A.A. Elwahed, 2021. Applications of nanotechnology on vegetable crops. Chemosphere, Vol. 266. 10.1016/j.chemosphere.2020.129026.
3. Mousavi, S.R. and M. Rezaei, 2011. Nanotechnology in Agriculture and Food Production. J. Appl. Environ. Biol. Sci., 1: 414-419.
4. Sultan, M., O.M. Hafez, M.A. Saleh and A.M. Youssef, 2021. Smart edible coating films based on chitosan and beeswax-pollen grains for the postharvest preservation of le conte pear. RSC Adv., 11: 9572-9585.
5. Roberts, T.L., 2009. The role of fertilizer in growing the world's food. Better Crops Plant Food, 93: 12-15.
6. Ogola, A.H., G.D. Odhiambo, J.R. Okalebo and F.N. Muyekho, 2012. Influence of Phosphorus on selected desmodium growth and nodulation parameters. ARPN J. Agric. Biol. Sci., 7: 294-301.
7. Gitari, J.N. and J.G. Mureithi, 2003. Effect of Phosphorus fertilisation on legume nodule formation and biomass production in mount Kenya region. East Afr. Agric. For. J., 69: 183-187.
8. Walley, F.L., S. Kyei-Boahen, G. Hnatowich and C. Stevenson, 2005. Nitrogen and Phosphorus fertility management for Desi and Kabuli chickpea. Can. J. Plant Sci., 85: 73-79.
9. Marschner, P., 2012. Marschner's Mineral Nutrition of Higher Plants. 3rd Edn., Academic Press Ltd., London, UK, Pages: 889.
10. Cordell, D., A. Rosemarin, J.J. Schroder and A.L. Smit, 2011. Towards global Phosphorus security: A systems framework for Phosphorus recovery and reuse options. Chemosphere, 84: 747-758.
11. Mahmoud, S.H., D.M. Salama, A.M. El-Tanahy and A.M. El-Bassiony, 2019. Effects of prolonged restriction in water supply and spraying with potassium silicate on growth and productivity of potato. Plant Arch., 19: 2585-2595.
12. Shebl, A., A.A. Hassan, D.M. Salama, M.E.A. El-Aziz and M.S.A.A. Elwahed, 2020. Template-free microwave-assisted hydrothermal synthesis of manganese zinc ferrite as a nanofertilizer for squash plant (*Cucurbita pepo* L.). Heliyon, Vol. 6. 10.1016/j.heliyon.2020.e03596.
13. Badsra, S. and L. Chaudhary, 2001. Association of yield and its components in Indian mustard (*Brassica juncea* L.). Agric. Sci. Digest, 21: 83-86.
14. Hamayun, M., S.A. Khan, A.L. Khan, Z.K. Shinwari, N. Ahmad, Y.H. Kim and I.J. Lee, 2011. Effect of foliar and soil application of nitrogen, Phosphorus and potassium on yield components of lentil. Pak. J. Bot., 43: 391-396.
15. Ali, S., A.R. Khan, G. Mairaj, M. Arif, M. Fida and S. Bibi, 2008. Assessment of different crop nutrient management practices for yield improvement. Aust. J. Crop Sci., 2: 150-157.
16. Selvakumar, G., M. Lenin, P. Thamizhiniyan and T. Ravimycin, 2009. Response of biofertilizers on the growth and yield of blackgram (*Vigna mungo* L.). Recent Res. Sci. Technol., 1: 169-175.
17. Brady, N.C. and R.R. Weil, 2008. The Nature and Properties of Soils. 14th Edn., Prentice Hall, Inc., New Jersey, ISBN: 13-978-0-13-227938-3.
18. El-Aziz, M.E.A., E. Saber and M. El-Khateeb, 2019. Preparation and characterization of CMC/HA-NPs/pulp nanocomposites for the removal of heavy metal ions. KGK Kautschuk, 72: 36-41.
19. Carter, M.R. and E.G. Gregorich, 2007. Soil Sampling and Methods of Analysis. 2th Ed., Taylor & Francis, United Kingdom, pages :1264.
20. Carter, M.R. and E.G. Gregorich, 2008. Soil Sampling and Methods of Analysis. 2nd Edn., USA, CRC Press, Boca Raton, FL, ISBN-13: 978-0-8593-3586-0, Pages: 1224.
21. Das, M., S.K. Das and S.H. Suthar, 2002. Composition of seed and characteristics of oil from karingda [*Citrullus lanatus* (Thumb) Mansf.]. Int. J. Food Sci. Technol., 37: 893-896.
22. Lawal, B., 2014. Applied Statistical Methods in Agriculture, Health and Life Sciences. 1st Edn., Springer International Publishing, Switzerland, ISBN-13: 978-3-319-37834-3, Pages: 799.
23. Smith, M.J., 2018. Statistical Analysis: A Comprehensive Handbook of Statistical Concepts, Techniques and Software Tools. 1st Edn., The Winchelsea Press, United Kingdom, ISBN-13: 978-1-912556-08-3, Pages: 99.
24. Lott, J.N.A., I. Ockenden, V. Raboy and G.D. Batten, 2000. Phytic acid and Phosphorus in crop seeds and fruits: A global estimate. Seed Sci. Res., 10: 11-33.
25. Wibisono, M.G., E. Veneklaas, D.S. Mendham and E.B. Hardiyanto, 2015. Nitrogen fixation of *Acacia mangium* Willd. from two seed sources grown at different levels of Phosphorus in an ultisol, South Sumatra, Indonesia. Southern Forest J. For. Sci., 77: 59-64.
26. Wang, J., Y. Chen, P. Wang, Y.S. Li, G. Wang, P. Liu and A. Khan, 2018. Leaf gas exchange, Phosphorus uptake, growth and yield responses of cotton cultivars to different Phosphorus rates. Photosynthetica, 56: 1414-1421.
27. Soliman, A.S., M. Hassan, F. Abou-Elell, A.H.H. Ahmed and S.A. El-Feky, 2016. Effect of nano and molecular Phosphorus fertilizers on growth and chemical composition of baobab (*Adansonia digitata* L.). J. Plant Sci., 11: 52-60.
28. Preetha, P.S. and N. Balakrishnan, 2017. A review of nano fertilizers and their use and functions in soil. Int. J. Curr. Microbiol. Appl. Sci., 6: 3117-3133.

29. Patra, P., S.R. Choudhury, S. Mandal, A. Basu and A. Goswami *et al.*, 2013. Effect sulfur and ZnO nanoparticles on stress physiology and plant (*Vigna radiata*) nutrition. In: Advanced Nanomaterials and Nanotechnology, Giri P.K., D.K. Goswami and A. Perumal (Eds.), Springer Berlin Heidelberg, Germany, ISBN-13: 978-3-642-34216-5, pp: 301-309.
30. Liu, R. and R. Lal, 2014. Synthetic apatite nanoparticles as a Phosphorus fertilizer for soybean (*Glycine max*). *Scient. Rep.*, Vol. 4. 10.1038/srep05686.
31. Jyothi, T.V. and N.S. Hebsur, 2017. Effect of nanofertilizers on growth and yield of selected cereals-A review. *Agric. Rev.*, 38: 112-120.
32. Hagab, R.H., Y.H. Kotp and D. Eissa, 2018. Using nanotechnology for enhancing Phosphorus fertilizer use efficiency of peanut bean grown in sandy soils. *J. Adv. Pharm. Educ. Res.*, 8: 59-67.
33. Magadlela, A., M.A. Pérez-Fernández, A. Kleinert, L.L. Dreyer and A.J. Valentine, 2016. Source of inorganic N affects the cost of growth in a legume tree species (*Virgilia divaricata*) from the mediterranean-type fynbos ecosystem. *J. Plant Ecol.*, 9: 752-761.
34. Pérez-Fernández, M.A., E. Calvo-Magro, J. Rodríguez-Sánchez and A. Valentine, 2017. Differential growth costs and nitrogen fixation in *Cytisus multiflorus* (L'Hér.) sweet and *Cytisus scoparius* (L.) link are mediated by sources of inorganic N. *Plant Biol.*, 19: 742-748.
35. Mortimer, P.E., M.R.L. Roux, M.A. Pérez-Fernández, V.A. Benedito, A. Kleinert, J. Xu and A.J. Valentine, 2013. The dual symbiosis between arbuscular mycorrhiza and nitrogen fixing bacteria benefits the growth and nutrition of the woody invasive legume *Acacia cyclops* under nutrient limiting conditions. *Plant Soil*, 366: 229-241.
36. Stevens, G.G., M.A. Pérez-Fernández, R.J.L. Morcillo, A. Kleinert and P. Hills *et al.*, 2019. Roots and nodules response differently to P starvation in the mediterranean-type legume *Virgilia divaricata*. *Front. Plant Sci.*, Vol. 10. 10.3389/fpls.2019.00073.
37. Vardien, W., J. Mesjasz-Przybylowicz, W.J. Przybylowicz, Y. Wang, E.T. Steenkamp and A.J. Valentine, 2014. Nodules from fynbos legume *Virgilia divaricata* have high functional plasticity under variable P supply levels. *J. Plant Physiol.*, 171: 1732-1739.