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Effect of nano nutrients on pea growth and yield (*Pisum sativum* L.)

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Abstract
The experiment was conducted at the research fields of school of agriculture Department of Agronomy, Lovely Professional University, Phagwara (Punjab) during rabi season in the year 2021-2022. The objective of the study was to evaluate "Effect of nano nutrients on pea growth and yield *Pisum sativum* L.''. The experiment was arranged with Randomized block design with 7 treatments and replicated thrice. Among various treatments 0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS showed a significant impact on the growth, yield, Economics of field pea. Higher growth parameters *viz.*, plant height, number of branches/plant, number of leaves/plant, plant dry matter, nodule number/plant, nodule weight/plant, crop growth rate etc. were observed in T4 (0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS) at every growth stage. It also showed significant impact on yield and its attributes while higher number of pods/plant, pod length, number of seeds/pod, fresh weight/plant, pod yield, stover yield and harvest index was noticed in T4 (0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS). Economics like higher gross returns, net returns, and B:C ratio was observed in T4 (0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS).

Keywords: Filed pea, nano urea, nano zinc, growth parameters, yield parameters

Introduction
Garden Pea (*Pisum sativum* L.) is one of the most important winter vegetable crops grown on commercial scale the world over and is consumed either as a fresh succulent vegetable or in processed form. Field pea is a critical economic and nutritive crop and is often called "poor man's meat" due to its high protein, vitamin and mineral, and prebiotic carbohydrate content yet affordability for poorer consumers (Choudhry 1967) [3]. In 2017, a total of 8,141,031 hectares of field pea were harvested globally with the top producers consisting of Canada, Russia, China, India, and the United States (FAOSTAT, 2019); however, this is only a minimal fraction compared to cereal production. Cultivated land acreage for field pea and other pulses has been in steady decline over the past 30 years. According to FAO statistics, India is one of the largest producers of field pea in the world and stands at the 5th place in the list of major field pea producers next to France. The Indian production contributes to around 7% in the world's total produce with the production figures of 7.8 lakh tonnes. Uttar Pradesh is a major field pea producing state in India producing about 60% of the country's produce. The other major pea producing state in India is Madhya Pradesh. The total area, production and productivity of pea in India in 2017-18 was 540.48 thousand Ha, 5422.14 thousand MT and 10.0 T/ ha respectively (Anonymous, 2018). Uttar Pradesh is the major field pea growing state. It alone produces about 49% of pea produced in India. Besides, Uttar Pradesh, Madhya Pradesh, Bihar and Maharashtra are the major pea producing states (DES, 2015-16).
Heavy use of nitrogen (N) and phosphorus (P) fertilizers has become the major anthropogenic factor leading to world-wide eutrophication problems in freshwater bodies and coastal ecosystems (Correll 1998; Conley *et al*. 2009) [2, 1]. To deal with such situation, it is very important to develop smart materials that can systematically release nutrients to specific targeted sites in plants which could be beneficial in controlling their deficiencies in agriculture, while keeping intact the natural soil structure. Such a strategy has a potential to contribute to clean the environment through controlled release of nutrients through site-targeted delivery, reduction in toxicity, and enhanced nutrient utilization of delivered fertilizers. Nano fertilizers possess unique features which enhance plants' performance in terms of ultrahigh absorption, increase in production, rise in photosynthesis, and significant expansion in the leaves' surface area. Besides, the controlled release of nutrients contributes in preventing eutrophication and pollution of water resources. Replacement of traditional fertilizer by nanofertilizer is beneficial as upon application, it releases nutrients into the soil steadily and in a controlled way, thus

preventing the water pollution (Naderi and Danesh-Shahraki 2013; Moaveni and Kheiri, 2011) [13, 10].

Nano Urea is a nanotechnology based revolutionary Agri-input which provides nitrogen to plants. Nano Urea is a sustainable option for farmers towards smart agriculture and combat climate change. These fulfil the plant nutrient requirement as a fertilizer since Nano urea is bio available to plants because of its desirable particle size about 20-50 nm and more surface area (10,000 times over 1 mm urea prill) and number of particles (55,000 nitrogen particles over 1 mm urea prill). Hence, Nano Urea increases its availability to crop by more than 80% resulting in higher Nutrient Use efficiency. In addition to this, Nano urea helps in minimizing the environmental footprint by reducing the loss of nutrients from agriculture fields in the form of leaching and gaseous emissions which used to cause environmental pollution and climate change.

Materials and Methods

The Field trail was conducted at Research Farm of Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab. The farm is situated at a latitude of 31.2560ºN, 75.7051ºE with 252m average elevation above mean sea level, 180 meters to the southwest, and more than 500 meters to the northeast boundary. Nutrient sources were Nano Urea, Nano zinc and Zinc Sulphate. The experiment was laid out in Randomized Block Design (RBD) which consisting of seven treatments. The treatment combinations are T1-Control, T2- 4mg/l ZnSO4 at 30 DAS + 0.2% Nano Urea, T3- 8mg/l ZnSO4 at 30 DAS + 0.2% Nano Urea, T4- 0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS, T5- No Zinc + 0.2% Nano Urea at 30 DAS, T6- No Zinc, 0.2% Nano Urea at 30, 50 DAS and T7- 0.1% Nano Zinc + 0.2% Nano Urea at 50 DAS. The growth parameters of the plants were recorded at frequent intervals from germination up until harvest and finally, the yield parameters were recorded after harvest. These parameters were statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design.

Results and Discussion

Plant height (cm)

At 15 DAS the maximum height of field pea was recorded in T_6 (8.32 cm). At 30 DAS the maximum plant height of field pea was recorded in T_4 (22.60 cm) which further found significantly at par with T_7 (21.80 cm) and the minimum height was recorded in treatment T_1 (18.50 cm). At 45 DAS and 60 das similar result was observed. At 75 DAS the maximum height was recorded in treatment T_4 (81.00 cm) which further found significantly at par with T_7 (80.80 cm), T_6 (80.20 cm) and T_3 (78.80 cm) and the minimum height was recorded in treatment T_1 (75.20 cm).

The reason for the superiority of high concentrations of nanoparticle fertilizer in increasing plant height may be due to the large permeability and high speed of nanoparticles, which means more ease in penetrating plant leaves that play an important role in promoting plant growth, where nitrogen has a positive role in increasing the activity of meristematic tissues and cell division and its importance in building amino acids such as Tryptophan, which is the basis for building Auxins that contribute to cell division and Expansion (Alqader *et al.* 2020) [4].

Number of branches/plant

At 30 DAS the maximum number of branches/plant of field pea was recorded in T_6 (8.32 cm). At 30 DAS the maximum plant number of branches/plant of field pea was recorded in T_7 (1.67). At 45 DAS the maximum plant number of branches/plant of field pea was recorded in T_4 (6.00) which further found significantly at par with T_7 (5.67), T_2 (4.67) and T_6 (4.67) and the minimum number of branches/plant was recorded in treatment T_1 (4.00). At 60 DAS and 75 DAS similar result was observed.

Zinc-containing nano materials are needed for chlorophyll production, fertilization, pollen function, and synthesis of auxins. Also, Zn protects the plants from drought stress (Sharma *et al.* 2009). Nano zinc also showed significant advantages in the form of branches and dry weight per plant at maturity over control. Application of zinc also improved growth attributes over control which was mainly due to their direct and indirect role in many physiological activities in plant. (Vairavan *et al.* 1997) [15].

Number of leaves per plant

At 15 DAS the maximum number of leaves/plant of field pea was recorded in T_4 (3.67). At 30 DAS the maximum plant number of leaves/plant of field pea was recorded in T_4 (11.00) which further found significantly at par with T_7 (10.33), T_6 (10.00) and the minimum number of leaves/plant was recorded in treatment T_1 (8.00). At 45 DAS the maximum plant number of leaves/plant of field pea was recorded in T_4 (33.00) which further found significantly at par with T_7 (31.33) and the minimum number of leaves/plant was recorded in treatment T_1 (27.33) At 60 DAS and 75 DAS similar result was observed.

The reason for the increase in the number of leaves in the plant (which was observed in the field) as well as the direct role of the nano-hydroxyapatite fertilizer in increasing cell division and expansion, especially the leaf cells, which was positively reflected in increasing the leaf area of the plant. (Alqader *et al.* 2020) [4].

Plant dry weight (g)

At 15 DAS the maximum plant dry weight of field pea was recorded in T_6 (0.19 g). At 30 DAS the maximum plant dry weight of field pea was recorded in T_4 (3.13 gm) which further found significantly at par with T_7 (3.10 gm), T_6 (3.03 gm) and the minimum plant dry weight was recorded in treatment T_1 (2.03 gm). At 45 DAS and 60 DAS similar result was observed. At 75 DAS the maximum plant dry weight of field pea was recorded in T_4 (40.57 gm) which further found significantly at par with T_7 (39.17 gm), T_6 (37.97 gm) T_5 (36.97 gm) and the minimum plant dry weight was recorded in treatment T_1 (32.63 gm).

The reason for efficient increase in dry weight of crop by the application of nano nutrients is that the Nano fertilizers or nano-encapsulated nutrients have properties to release nutrients effectively and chemical fertilizers on demand that regulate plant growth parameters like dry weight and enhance target activity (Nair *et al.*, 2010).

Number of nodules/plant

At 15 DAS the maximum number of nodules/plant of field pea was recorded in T_7 (4.00). At 30 DAS the maximum number of nodules/plant of field pea was recorded in T_4 (18.67) which further found significantly at par with T_7

(17.33) and the minimum number of nodules/plant was recorded in treatment T_1 (14.00). At 45 DAS and 60 das similar result was observed. At 75 DAS the maximum number of nodules/plant was recorded in treatment T_4 (30.00) which further found significantly at par with T_7 (27.00), T_6 (26.00) and the minimum number of nodules/plant was recorded in treatment T_1 (18.00).

Zinc played encouraging role on nodulation of field pea. The maximum number of nodules per plant was found with the application of Zn for all the nodule collection data. The minimum number of nodules per plant was recorded from control plot. Proper doses of zinc application may enhance the synthesis of carbohydrates, nutrient and protein content and their transport to the site of seed formation (Mali *et al.*, 2003) [12].

Nodule weight/plant

At 15 DAS the maximum plant nodule weight of field pea was recorded in T_5 (0.03 gm). At 30 DAS the maximum plant nodule weight of field pea was recorded in T_4 (0.31 gm) which further found significantly at par with T_7 (0.31 gm), T_6 (0.30 gm) and the minimum plant nodule weight was recorded in treatment T_1 (0.20 gm). At 45 DAS and 60 das similar result was observed. At 75 DAS the maximum plant nodule weight was recorded in treatment T_4 (1.93 gm) which further found significantly at par with T_7 (1.85 gm) and the minimum plant nodule weight was recorded in treatment T_1 (1.57 gm).

The zinc levels significantly increased the number of nodules per plant and nodule dry weight per plant. The level of zinc increased the number of nodule and nodule dry weight per plant. These results are in conformity with those of Tripathi *et al.*, 1999 [14] and Katoch *et al.*, 1983 [9].

Crop growth rate

At 15-30 DAS the maximum crop growth rate of field pea was recorded in T_4 (8.71 g/m^2/day) which further found significantly at par with T_7 (8.68 g/m^2/day), T_6 (8.41 g/m^2/day) and the minimum crop growth rate was recorded in treatment T_1 (5.51 g/m^2/day). At 30-45 DAS the maximum crop growth rate of field pea was recorded in T_4 (28.84 g/m^2/day) which further showed significant difference with other treatments. At 45-60 DAS and 60-75 DAS similar result was observed.

Relative growth rate

At 15-30 DAS the maximum relative growth rate of field pea was recorded in T_7 (0.1935 g/g/day) which further showed significant difference with other treatments. At 30-45 DAS, 45-60 DAS and 60-75 DAS similar result was observed.

Yield attributes and Yield

Number of pods/plant

At harvest the maximum number of pods/plant of field pea was recorded in T_4 (20.00) which further found significantly at par with T_7 (19.00), T_6 (18.00) and the minimum number of pods/plant was recorded in treatment T_1 (13.00).

The reason for the superiority from high concentration of nano fertilizer is the increase in the leaf area especially at the high level, making the leaf surface more vulnerable to spraying the fertilizer and then absorbing the element more by the leaves and this was reflected in the increase in the number of pods per plant, because it has a major role in increasing the flower nodes and the fertilization process through its role in increasing the speed of transport of sugars from their source to the places where they are needed in the plant during the reproductive phase, and this result agrees with (Hassan *et al.* 2019) [7].

Pod length

At harvest the maximum pod length of field pea was recorded in T_4 (8.67) which further found significantly at par with T_7 (8.17), T_6 (7.90) and the minimum pod length was recorded in treatment T_1 (7.00).

The concentration of nano fertilizer gave the highest average of pod length amounted to (23.0 cm). The higher concentrations of nitrogen Nano fertilizer in the trait of pod length for both seasons may be due to the increase in leaf area, and chlorophyll content in the leaves and then an increase in the division and elongation of their cells, which was reflected in increasing the length of the pod. (Alqader *et al.* 2020) [4].

Number of seeds/pod

At harvest the maximum number of seeds/pod of field pea was recorded in T_4 (9.33) which further found significantly at par with T_7 (8.67), T_6 (8.33) and the minimum seeds/pod was recorded in treatment T_1 (7.33).

The positive effect of nitrogen in increasing the percentage of pod fertilization was reflected positively in increasing the number of seeds per pod. (Alqader *et al.* 2020) [4].

Fresh weight/plant

At harvest the maximum fresh weight/plant of field pea was recorded in T_4 (114.00) which further found significantly at par with T_7 (110.00) and the minimum fresh weight/plant was recorded in treatment T_1 (93.33).

Pod yield (t/ha)

At harvest the maximum pod yield of field pea was recorded in T_4 (2.63 t/ha) which further found significantly at par with T_7 (2.60 t/ha), T_6 (2.53 t/ha) and the minimum pod yield was recorded in treatment T_1 (2.10 t/ha).

The reason for the increase in the seed yield trait is due to the increase in the number of pods per plant, as a result, there was an increase in the seed yield because it is a function of the yield components. This result agrees with the results of other studies that showed the positive effect of nitrogen on seed yield and for different legume crops (Drostkar *et al.* 2016 and Gomma *et al.* 2016) [5, 6].

Stover yield (t/ha)

At harvest the maximum stover yield of field pea was recorded in T_4 (3.70 t/ha) which further found significantly at par with T_7 (3.63 t/ha) and the minimum stover yield was recorded in treatment T_1 (3.20 t/ha).

The higher concentration of nitrogenous Nano fertilizer in the trait of the number of pods per plant, the number of seeds per pod and the seed yield were positively reflected in increasing the bio-yield. (Jasim *et al.* 2014 and Mahmoud *et al.* 2006) [8, 11].

Harvest index (%)

At harvest the maximum harvest index of field pea was recorded in T_6 (42.57%) which further found significantly at par with T_7 (41.77%), T_2 (41.64%), T_4 (41.56%) and the minimum harvest index was recorded in treatment T_3 (38.29%).

Table 1: Effect of Nano Nutrients on growth attributes of field pea

S. No.	Treatment combinations	Plant height	Number of branches per plant	Number of leaves per plant	Plant dry weight	Number of nodules per plant	Weight of nodules per plant	Crop growth rate	Relative growth rate
1.	Control (54 kg/ha DAP)	75.20	8.00	75.00	32.63	18.00	1.57	48.49	0.0466
2.	4mg/l ZnSO4 at 30 DAS + 0.2% Nano Urea	78.20	9.33	80.00	35.63	23.00	1.68	53.14	0.0467
3.	8mg/l ZnSO4 at 30 DAS + 0.2% Nano Urea	78.80	8.33	82.00	35.97	20.67	1.71	52.64	0.0456
4.	0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS	81.00	11.33	93.00	40.57	30.00	1.93	60.44	0.0466
5.	No Zinc + 0.2% Nano Urea at 30 DAS	76.40	9.33	78.00	36.97	22.00	1.70	57.87	0.0503
6.	No Zinc, 0.2% Nano Urea at 30,50 DAS	80.20	10.67	86.00	37.97	26.00	1.74	57.48	0.0480
7.	0.1% Nano Zinc + 0.2% Nano Urea at 50 DAS	80.80	11.00	90.33	39.17	27.00	1.85	56.79	0.0450
	F-Test	S	S	S	S	S	S	NS	NS
	S.Em (±)	0.75	0.64	1.78	1.18	2.15	0.04	3.57	0.00
	CD (p=0.05)	2.30	1.97	5.48	3.63	6.62	0.11	--	--

Table 2: Effect of Nano Nutrients on growth attributes of field pea

S. No.	Treatment details	Yield and yield attributes						
		Pods/ plant	Pod length	Seeds/ pod	Fresh weight/ plant	Pod yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Control (54 kg/ha DAP)	13.00	7.00	7.33	93.33	2.10	3.20	39.69
2.	4mg/l ZnSO4 at 30 DAS + 0.2% Nano Urea	16.00	7.17	7.67	95.00	2.42	3.41	41.64
3.	8mg/l ZnSO4 at 30 DAS + 0.2% Nano Urea	16.33	7.13	7.67	96.00	2.31	3.72	38.29
4.	0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS	20.00	8.67	9.33	114.00	2.63	3.70	41.56
5.	No Zinc + 0.2% Nano Urea at 30 DAS	16.33	7.17	8.00	98.00	2.34	3.52	40.05
6.	No Zinc, 0.2% Nano Urea at 30,50 DAS	18.00	7.90	8.33	106.00	2.53	3.44	42.57
7.	0.1% Nano Zinc + 0.2% Nano Urea at 50 DAS	19.00	8.17	8.67	110.00	2.60	3.63	41.77
	F-Test	S	S	S	S	S	S	S
	S.Em (+)	0.68	0.33	0.33	1.76	0.06	0.08	0.75
	CD (p=0.5)	2.10	1.02	1.03	5.43	0.20	0.24	2.32

Conclusion

It was concluded that growth parameters increased with the usage of nano urea and nano zinc. Application of 0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS directly influence the growth and development of field pea. Different parameters such as plant height, number of branches/plant, number of leaves/plant, plant dry weight, number of nodules/plant, nodule weight/plant, crop growth rate found maximum with 0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS. Also, the highest yield and yield parameters, maximum gross return, net returns maximum B:C ratio were observed with the application of 0.1% Nano Zinc + 0.2% Nano Urea at 30 DAS.

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