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Effect of phosphorus and nano urea on growth and yield attributes of maize (*Zea mays* (L.)

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Abstract
The field experiment was conducted during *kharif* season of 2023 at Crop Research Farm, Department of Agronomy. The experiment was laid out in a Randomized Block Design with ten treatments which have replicated thrice. The treatment details are as follows T_1: Phosphorus 40 kg/ha + Nano Urea 1 ml/l, T_2: Phosphorus 60 kg/ha + Nano Urea 1 ml/l, T_3: Phosphorus 80 kg/ha + Nano Urea 1 ml/l, T_4: Phosphorus 40 kg/ha + Nano Urea 3 ml/l, T_5: Phosphorus 60 kg/ha + Nano Urea 3 ml/l, T_6: Phosphorus 80 kg/ha + Nano Urea 3 ml/l, T_7: Phosphorus 40 kg/ha + Nano Urea 4 ml/l, T_8: Phosphorus 60 kg/ha + Nano Urea 4 ml/l, T_9: Phosphorus 80 kg/ha + Nano Urea 4 ml/l, and Control Plot. The results of the experiment revealed that the Application of Phosphorus at 60 kg/ha along with Nano Urea 4 ml/l (Treatment 8) recorded significantly higher plant height (202.00 cm), maximum plant dry weight (310.00 g/plant), maximum crop growth rate (27.00 g/m^2/day) maximum rows per cob (12.93), grains per row (22.67), seed index (22.70 g), grain yield (5.54 t/ha), Stover yield (9.92 t/ha), harvest index (35.86%).

Keywords: Maize, phosphorus, nano urea, growth and yield.

Introduction

Maize (*Zea mays L.*) is one of the most important cereal crop after rice and wheat and occupies a prominent place in global agriculture. It ranks third after rice and wheat in India. In India it is grown for grain and fodder purpose, as well as component in poultry and cattle feed mixture and for other industrial purpose. Maize also called as corn, is one of the most crucial and strategic crops in the world. Its origin is in Mexico (Central America). It is C4 plant known as 'Queen of cereals', because of its high production potential and wider adaptability across the seasons. It efficiently utilizes solar energy and has immense potential for higher yield, so called as "Miracle Crop". Maize plays a vital role in ensuring food security as well as nutritional security through quality protein. The nutritional composition of maize (per 100 g) is as follows protein 4 g. 30 g carbohydrate, 3.5 g dietary fiber, 1.5 g fat, 3.6 g sugar, 4 mg calcium, 0.72 mg zinc etc. (Dragana *et al.* 2015) [8]. Every part of the maize plant has economic value (the grain, leaves, stalk, tassel, and cob) and all are used to produce a large variety of food and non-food products.

Maize is grown on 188 million ha area in more than 170 countries across the globe with 1423 million MT of production. Since 2005, India ranks 4th in terms of area with 9.89 million ha land under maize and ranks 6th with annual production of 31.65 million MT. Among Indian states Madhya Pradesh and Karnataka has highest area under maize (15% each) followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%), Bihar (7%), Telangana (6%). Currently 47% of maize produced in India is consumed for poultry feed, while 13% goes as livestock feed, 13% for food, Starch industry consumes around 14%, processed food contributes 7% and 6% for export and other purposes. (IIMR, 2021).

The application of phosphorus Plant growth behavior is influenced. It is needed for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division, fat and albumen formation.

Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and reproduction (Ayub *et al.* 2002) [5]. It is readily translocated within the plants, moving from older to younger tissues as the plant forms cells and develops roots, stems and leaves (Ali *et al.* 2002) [1]. Adequate P results in rapid growth and earlier maturity and improves the quality of vegetative growth. Phosphorus deficiency is responsible for crooked and missing rows as kernel twist and produce small ears nubbies in maize.

Phosphorus in adequate amount is necessary for earlier maturity, rapid growth and improves the quality of vegetative growth. Phosphorus has many essential functions in plant life; its role in energy storage and transfer is singly the most important. Large quantity of Phosphorus is found in seed and it is considered essential for seed formation. Phosphorus is essential for inflorescence, grain formation; ripening and reproductive parts of maize plant.

It is needed for growth, nucleus formation, photosynthesis, utilization of sugar and starch, cell division and fat and albumen formation. Phosphorus is readily translocated within the plants and it moves from older tissues to younger tissues (Ali *et al.* 2002) [1].

Phosphorus alone or high quantity did not increase the yield of maize. However, the combined application of Phosphorus with nitrogen increased the yield significantly.

Nanotechnology is emerging as the sixth revolutionary technology in the current era after the Industrial Revolution of mid 1700s, the nuclear energy revolution of the 1940s, the green revolution of 1960s, the information technology revolution of 1980s and the biotechnology revolution of the 1990s. It is now an emerging and fast-growing field of science which is being exploited over a wide range of disciplines such as physics, chemistry, biology, material science, electronics, medicine, energy, environment, and health sectors.

The modern fertilizer or alternative technology known as nano fertilizers (NFs) is more effective, environmentally friendly, non-toxic, and more efficient. It has a strong potential to boost plant production and quality due to its role in improving nutrient use efficiency. Due to their enormous surface area, nano fertilizers have tremendous activity. (Lee *et al.* 2010) [14]. It played a significant impact in agriculture, including germination rates, growth, improving the availability of nutrients, chlorophyll generation, and dry matter production. They can quickly penetrate the soil and plant roots, which enhances plant growth. (Dhoke *et al.* 2013) [6].

The Nano-fertilizers are getting importance in sustainable agriculture in increasing crop production, enhancing nutrient use efficiency and reduction in wastage of chemical fertilizers and cost of cultivation. The new developments on application of nano-fertilizer in agriculture, plant mineral nutrition, soil health and interactions with soil microorganism directed to sustainable way by replacing conventional fertilizers with their nano-particulate counterparts possessing superior properties to overcome the current challenges of availability and uptake of nutrients, increasing crop yield and protecting the environment.

Nano-fertilizers are very effective tool for precise nutrient management in precision agriculture with matching the crop growth stage for nutrient and may provide nutrient throughout the crop growth period.

Nano fertilizers are more reactive and can penetrate through cuticle, ensuring controlled release and targeted delivery. Regarding Nitrogen fertilizers, the application of nanotechnology can provide fertilizers that release Nitrogen when crops need it, eventually leading to increases in Nitrogen efficiency through decreasing Nitrogen leaching and emissions and long-term incorporation by soil microorganisms (Naderi and Danesh-Shahraki, 2013) [15].

The nutrient release pattern of nano-fertilizer formulations carrying nitrogen. The nano-clay based fertilizer formulations (zeolite and montmorillonite with a dimension of 30-40 nm are capable of releasing the nitrogen for a longer period of time (> 1000 hrs) than conventional fertilizers (< 500 hrs) in cereal crops.

Materials and Methods

During the *Kharif* season of 2023, a field experiment was conducted at the Crop Research Farm of the Department of Agronomy, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh. which is located at 25.43’58’’ N latitude, 81.84’ 63” E longitude and 98 m altitude above the mean sea level (SL). The soil of experimental plot was sandy loam, having a nearly neutral soil reaction (pH 7.1), electrical conductivity 0.48 ds/m, medium in available nitrogen (270.81 kg/ha) and potassium (215.9 kg/ha), and low in available phosphorous (11.5 kg/ha). The experiment was conducted in a Randomized Block Design consisting of ten treatment combinations and three replications. Fertilizers were applied as band placement, for which 4-5 cm deep furrows were made along the seed rows with a hand hoe. The nutrient sources were urea, Single super phosphate (SSP) and murate of potash (MOP), applied as per the recommended dose of 120:80:40 NPK kg/ha.

The plot size of each treatment was 3m x 3m. Factors are Phosphorus (40, 60 and 80 kg/ha) and Nano Urea (01, 03 and 04 ml/l). The maize crop was sown on 06 August 2023. Harvesting was done by taking $1m^2$ area from each plot. And from it five plants were randomly selected for recording growth and yield parameters. The observations were recorded for plant height (cm), dry weight (g), Crop growth rate, Relative growth rate, number of cobs/plant, number of rows/cob, number of grain/row, test weight (g), seed yield (t/ha) and stover yield (t/ha) & Harvest Index (%). The observed data was statistically analysed using analysis of variance (ANOVA) as applicable to randomized block design.

Results and Discussions

Growth parameters

Plant height (cm)

At 80 DAS, significantly highest plant height (202.00 cm) was recorded with application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l. However, treatment 4, 5, 6, 7, & 9 (188.99 cm, 188.90 cm, 193.00 cm, 198.47 cm & 195.36 cm, respectively) were statistically at par with application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l.

The significant and higher plant height observed with phosphorus (60 kg/ha) may be the result of phosphorus encouraging the formation of new cells, promoting plant vigor, and hastening leaf development, which help in harvesting more solar energy and better utilizing nitrogen, which help towards higher growth attributes. This rapid increase in plant height of maize may be the result of phosphorus applied with nano urea. Similar results also found by Alias *et al.* (2003) [3].

It has been demonstrated that nano urea increases the efficiency of nutrient uptake and utilization and releases nitrogen in a regulated way, minimizing losses from volatilization and leaching. Plant growth and development can be enhanced by higher nutrient efficiency, which may result in an increase in plant height.

It has been proposed that nano urea can improve a number of physiological functions in plants, including enzyme activity, photosynthesis, and nutrient uptake. Better growth and development may result from these advancements in plant physiology, which may raise plant height.

Plant dry weight (gm)

At 80 DAS, Similarly at 80 DAS, when plant reached maturity and get highest plant dry matter (310.33 g) was observed with application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l while treatments 9 found to be statistically at par with highest.

Significant and higher plant dry weight was recorded with phosphorus (60 kg/ha) might be due to an adequate supply of phosphorus, which is associated with the enhancement of leaf area index which in turn put forth more photosynthetic surface, thus contributing to more dry matter production. Similar result was also reported by Kumari *et al.* (2018).

Nano urea can enhance the uptake and utilization of nutrients, including nitrogen, by plants. Improved nutrient availability and utilization can lead to increased biomass and ultimately contribute to higher plant dry weight (Jahan *et al.* 2021) [11].

Nano urea has been reported to positively influence various physiological processes in plants, such as photosynthesis, enzymatic activities, and nutrient metabolism. These enhancements can promote plant growth and biomass accumulation, resulting in increased plant dry weight (Kumar *et al.* 2021) [13].

Crop Growth Rate (g/m^2/day)

Similarly during 60-80 DAS, the maximum CGR (27.00 g/m^2/day) was recorded with application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l. However, all treatment found to be statistically at par with highest.

The application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l resulted in higher crop growth rate, this might be due to increase in leaf area, photosynthesis improvement resulting in higher dry matter accumulation and increase in crop growth rate. Similar result was also reported by Thakur *et al.* (2022).

Nano urea has the potential to influence hormone regulation in plants, including the synthesis and transport of growth-promoting hormones like auxins and cytokinin. These hormones play a vital role in promoting crop growth and development, thereby potentially increasing the growth rate (Kumar *et al.* 2021) [13]. Nano urea has the potential to improve and enhance the uptake and utilization of nutrients, including nitrogen, by plants. Improved nutrient availability and utilization can promote crop growth and increase the growth rate (Jahan *et al.* 2021) [11].

Relative Growth Rate (g/g/day)

Similarly at 60-80 DAS, the maximum relative growth rate (0.028 g/g/day) was recorded with application of Phosphorus 80 kg/ha along with Nano Urea 1 ml/l. There was no significant difference among treatments.

Yield Attributes

Number of cobs/plant

At harvest, Treatment-8 with the application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l was recorded significant and maximum number of cobs/plant (01.80) which was superior over all other treatments.

Number of rows/cob

At harvest, Treatment-8 with the application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l was recorded significant and maximum number of rows/cob (12.93) which was superior over all other treatments.

Seed Index (g)

At harvest, the application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l was recorded significantly highest seed index (22.73 g) which was superior over all other treatments. However, the treatment-7 Phosphorus 60 kg/ha along with Nano Urea 4 ml/l, treatment-9 Phosphorus 60 kg/ha + Nano Urea 4 ml/l were found to be statistically at par with the treatment-8 Phosphorus 60 kg/ha + Nano Urea 4 ml/l.

The yield attributes like No. of rows/cob, No. of grains/row and seed index were significantly increased with application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l. Significantly Phosphorus (60kg/ha) might he due to physiological process occur within a developing and maturing stages of plant and also involved in enzymatic reaction in plant which is essential for cell division and cell development. Similar result was also reported by Sharma *et al.* (2018).

Nano urea has the potential to improve nutrient availability and uptake in plants. It enhances nutrient use efficiency, which can contribute to better crop growth and development, including the formation of more cobs per maize plant. Nano urea has the potential to enhance photosynthetic efficiency in plants.

Improved photosynthesis can lead to increased carbohydrate production, which is essential for reproductive development and the formation of cobs (Raliya *et al.* 2017) [16].

Nano Urea has been reported to influence hormonal regulation in plants and transport of growth -promoting hormones such as auxins and cytokininis. These hormones play a vital role in reproductive and grain development. Nano Urea lead to an increased number of grains/cob.

Nano urea has the potential to improve pollination and fertilization processes in maize. It can enhance pollen viability, germination, and pollen tube growth, leading efficient fertilization and potentially resulting in improved seed set and seed index (Sharma *et al.* 2021) [17].

Seed yield (t/ha)

At harvest, the data showed that significantly highest grain yield (5.54 t/ha) was found with application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l whereas treatments 3, 4, 5, 6, 7 and 9 (4.71, 4.85, 5.12, 5.05, 4.90 and 5.35 t/ha respectively) which was found to be statistically at par with all treatments.

Significant and higher seed yield was recorded with Phosphorus (60 kg/ha) might be due to phosphorus application, enhanced the yield potential and reproductive parts and the fraction of the total duration devoted to grain filling which leads increase in total grain yield. Similar result was reported.

Nano urea enhance their solubility and improve nutrient availability. This increased nutrient uptake nitrogen, can contribute to improved plant growth, development. and ultimately, higher maize yields (Kumar *et al.* 2019) [12]. Nano urea has been reported to particularly enhance plant growth parameters such as plant height, leaf area, and chlorophyll content, improved photosynthetic efficiency can contribute to increased biomass accumulation and gain yield in maize.

Stover yield(t/ha)

At harvest, Treatment-8 with the application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l was recorded significantly higher stover yield (9.92 t/ha) which was superior over all other treatments. However, the treatment- 4, 5, 7, 9 and 10 (9.23, 9.32, 9.36, 9.88 and 9.40 t/ha, respectively) found to be statistically at par with the treatment. significant and higher stover yield was recorded with Phosphorus (60kg/ha) might be due to positive influence of phosphorus on both vegetative and reproductive growth of the crop, which led to increase in stover yield. Similar result was also reported by Kumari *et al.* (2018) in sorghum.

Nano urea formulations are often developed to improve nutrient uptake efficiency. By enhancing the availability and uptake of nutrients, including nitrogen, nano urea has the potential to promote plant growth, including stover biomass production (Kumar *et al.* 2019, Ananth *et al.* 2020) [12, 4].

Harvest index (%)

At harvest, highest harvest index (35.86%) was recorded in treatment-8 with the application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l, though there was significant difference among the treatments.

Table 1: Influence of phosphorus and nano urea on growth attributes of maize, At 80 DAS

S. No.	Treatments	Plant Height (cm)	Plant dry weight (gm)	Crop growth rate (g/m^2/day)	Relative growth rate (g/g/day)
1.	Phosphorus 40 kg/ha + Nano urea 1 ml/l	177.75	200.33	17.00	0.019
2.	Phosphorus 60 kg/ha + Nano urea 1 ml/l	180.28	195.00	22.40	0.027
3.	Phosphorus 80 kg/ha + Nano urea 1 ml/l	185.32	209.67	25.00	0.028
4.	Phosphorus 40 kg/ha + Nano urea 3 ml/l	188.99	230.33	13.96	0.013
5.	Phosphorus 60 kg/ha + Nano urea 3 ml/l	188.90	252.19	18.58	0.015
6.	Phosphorus 80 kg/ha + Nano urea 3 ml/l	193.00	258.07	19.33	0.016
7.	Phosphorus 40 kg/ha + Nano urea 4 ml/l	198.47	224.00	12.74	0.011
8.	Phosphorus 60 kg/ha + Nano urea 4 ml/l	202.00	310.33	27.00	0.019
9.	Phosphorus 80 kg/ha + Nano urea 4 ml/l	195.36	264.33	25.56	0.021
10.	N P K 120 80 40 kg/ha	175.30	218.00	14.65	0.015
	Ftest	S	S	S	S
	S.Em (+)	7.79	16.64	3.62	1.29
	CD (P= 0.05)	16.38	49.45	10.04	-

Table 2: Influence of phosphorus and nano urea on yield attributes of maize, Yield attributes

S. No.	Treatments	No. of cobs/plant	No. of grains/row	No. of rows/cob	Seed index (g)
1.	Phosphorus 40 kg/ha + Nano urea 1 ml/l	1.67	18.67	12.26	20.59
2.	Phosphorus 60 kg/ha + Nano urea 1 ml/l	1.60	19.33	12.20	20.48
3.	Phosphorus 80 kg/ha + Nano urea 1 ml/l	1.73	20.00	12.13	20.17
4.	Phosphorus 40 kg/ha + Nano urea 3 ml/l	1.73	20.00	12.33	20.46
5.	Phosphorus 60 kg/ha + Nano urea 3 ml/l	1.80	20.67	12.40	20.65
6.	Phosphorus 80 kg/ha + Nano urea 3 ml/l	1.73	20.67	12.26	20.62
7.	Phosphorus 40 kg/ha + Nano urea 4 ml/l	1.53	22.67	12.33	22.60
8.	Phosphorus 60 kg/ha + Nano urea 4 ml/l	1.80	22.67	12.93	22.73
9.	Phosphorus 80 kg/ha + Nano urea 4 ml/l	1.67	22.07	12.77	22.70
10.	N P K 120 80 40 kg/ha	1.40	18.67	10.66	20.56
	Ftest	S	S	S	S
	S.Em (+)	0.10	1.16	0.53	0.91
	CD (P= 0.05)	0.22	2.44	1.11	1.91

Table 3: Influence of phosphorus and nano urea on yield of maize, Yield

S. No.	Treatments	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Phosphorus 40 kg/ha + Nano urea 1 ml/l	4.37	8.48	34.07
2.	Phosphorus 60 kg/ha + Nano urea 1 ml/l	4.34	8.17	34.40
3.	Phosphorus 80 kg/ha + Nano urea 1 ml/l	4.71	8.79	34.90
4.	Phosphorus 40 kg/ha + Nano urea 3 ml/l	4.85	9.23	34.42
5.	Phosphorus 60 kg/ha + Nano urea 3 ml/l	5.12	9.32	35.42
6.	Phosphorus 80 kg/ha + Nano urea 3 ml/l	5.05	9.02	35.80
7.	Phosphorus 40 kg/ha + Nano urea 4 ml/l	4.90	9.36	34.33
8.	Phosphorus 60 kg/ha + Nano urea 4 ml/l	5.54	9.92	35.86
9.	Phosphorus 80 kg/ha + Nano urea 4 ml/l	5.35	9.88	35.11
10.	N P K 120 80 40 Kg/ha	3.16	9.40	25.19
	Ftest	S	S	S
	SEm (+)	0.45	0.42	2.72
CD (P= 0.05)		0.94	0.89	5.72

Conclusion

From the results, it is concluded that application of Phosphorus 60 kg/ha along with Nano Urea 4 ml/l (Treatment 8) in Maize has recorded that better production and economics return.

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