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Influence of Phosphorus and Plant Growth Regulators on Growth, Yield and Economics of Pearl Millet (*Pennisetum glaucum* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Rabi* 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P).The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH7.8), low level of organic carbon (0.62%), available N (225 Kg/ha), P (38.2 kg/ha) and K (240.7 kg/ha). To determine the "Influence of phosphorus and plant growth regulators on growth, yield and economics of pearl millet (*Pennisetum glaucum* L.) to study the response of phosphorus levels *viz* (30 kg/ha), (40 kg/ha) and (50 kg/ha) with combination of 3 plant growth regulators *viz*. NAA (50ppm), Chlormequat chloride (250 ppm), Triacontanol (500 ppm). The experiment was laid out in RBD with 10 treatments each replicated thrice The results showed that significant and higher plant height (178.10cm), plant dry weight (69.60g) and crop growth rate (5.53 $g/m^2/day$), relative growth

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rate (0.0058 g/g/day),higher ear head length (26.00 cm),maximum number of grains per ear head (1757.67), higher test weight (11.73 g), higher grain yield (2.69 t/ha), maximum stover yield (4.05 t/ha),higher harvest Index (39.96%),maximum gross return (INR 109625), net return (INR 74389) and B:C ratio (2.11) were observed in treatment 7 (Phosphorous50 kg/ha + NAA50 ppm).

Keywords: Economics; growth; plant growth regulators; phosphorous and yield.

1. INTRODUCTION

Small and marginal farmers in Asia and Africa typically plant pearl millet (*Pennisetum glaucum* L.) as a staple grain. "Bajra is a C4 plant with high photosynthetic efficiency, more dry weight production, and the ability to survive in a variety of agro-climatic conditions with lower input costs and higher economic returns." Because pearl millet matures quickly, can withstand drought, and can resist high temperatures up to 42°C during the reproductive stage, it is essential for the food and nutritional security of people and animals in arid and semiarid countries. These traits make it possible to grow the crop under challenging conditions. When it comes to drought, low soil fertility, and high temperatures, pearl millet is well adapted to flourish in these unfavorable agro-climatic circumstances. [1]. When compared to other cereals and millets, pearl millet has a relatively high nutritional content. It contains a lot of protein and has a somewhat better amino acid profile. 13–14% protein, 5% fat, 74% carbohydrates, and 2% minerals are included in pearl millet grain. Due to a scarcity of additional land available for food cultivation and declining soil fertility, there is concern about agriculture's ability to satisfy the demands of a population that is growing at an exponential rate. Intercropping makes optimal use of resources to boost overall production per unit area per unit time in comparison to solo cropping. Since there will be less competition because of their various peak times, planting short-lived crops like pearl millet alongside cluster beans and green gram crops may boost economic returns per unit of land [2].

In terms of output and area, pearl millet is the most common; it is planted throughout the majority of tropical and sub-tropical regions of many nations. With a production of 11.83 million tonnes and a productivity of 1200 kg/ha, pearl millet is grown on a surface area of around 9.5 million hectares worldwide (USDA, 2022).The total area covered by pearl millet in Uttar Pradesh during 2020–21 was 0.91 million hectares, with production of 2.01 million tonnes and productivity of 2221 kg/ha, accounting for 11.99% of the total cultivable area and productivity 18.54% of pearl millet in India. In India, pearl millet is grown over an area of about 7.57 million hectares, with production of 10.86 million tonnes and productivity of 1436 kg/ha by 2021 [3].

Lack of phosphorus is one of the main issues with crop productivity. P has a unique feature that limits it because of slow diffusion and strong soil fixation. Phosphorus, which is a crucial component of several biochemicals, including nucleic acids, nucleotides, phospholipids, and phosphoproteins, is the second most important nutrient for plant growth after nitrogen. Proper P nutrition increases a plant's ability to perform a variety of tasks, including as photosynthesis, nitrogen fixation, flowering, seed formation, root development, and crop maturity. It has been discovered that P fertilizer increased rice survival, growth, and yield by reducing the level of Na+ in shoots. Phosphorus also plays a significant role in the molecule ATP, which provides that plant with energy for processes like respiration, [4].

Plant growth regulators have the ability to increase crop yield when the environment is stressed. "Growth regulators" are substances that alter how organisms develop and grow, which may increase productivity, improve grain quality, or simplify harvesting. The quantity of nutrients and the application of plant growth regulators had a significant impact on the growth metrics of Pearl millet. the exogenous use of NAA to increase growth and production under a variety of conditions, including salt, drought, extremely hot or low temperatures, and heavy metal toxicity. Additionally, they have a key role in the development of important agronomic processes such seed germination, leaf angle, flowering duration, and seed yield [5].

Bio-stimulants and bio-inhibitors, also referred to as plant growth regulators, can alter physiological processes in plants. In field crops, plant growth regulators enhance the efficient partitioning and translocation of nutrients from source to sink. Since naphthalene acetic acid is an auxin, it helps to improve growth characteristics and stimulate reproductive growth by promoting vegetative growth through active cell division, cell expansion, and cell elongation. The growth and yield of pearl millet were positively impacted by growth regulator spray [6]. Plant growth regulators have the ability to increase crop yield when the environment is stressed. "Growth regulators" are substances that alter how organisms develop and grow, which may increase productivity, improve grain quality, or simplify harvesting.The quantity of nutrients and the application of plant growth regulators had a significant impact on the growth metrics of Pearl millet. the exogenous use of NAA to increase growth and yield in response to a variety of stressors, including salt, drought, incredibly high or low temperatures, and heavy metal toxicity. Additionally, they have a key role in the development of important agronomic processes such seed germination, leaf angle, flowering duration, and seed yield [7].

Numerous elements of plant growth, including flowering, fruiting, root growth, and yield components of several crops, are improved by adequate phosphorus feeding. The extremely low solubility of P in the soil frequently restricts P uptake in plants. Agricultural systems remove the phosphorus from harvested crops, leaving the soil deficient in P if no more P is added as fertilizer (Singh *et al*., 2016). The intricate nucleic acid structure of flowers, which controls the synthesis of proteins, includes phosphorus. Phosphorus is therefore crucial for cellular function and the growth of new tissue. Phosphorus is also connected to a number of differences in internal plant strength. For early boom growth, phosphorus is typically advised as a row-carried beginning fertilizer. Less than 40% of the test fields in University of Nebraska starter fertilizer study conducted in the 1980s had early enhanced response to phosphorus confirmed. Starter packets may also boom early even if phosphorus does not increase grain yield. Manufacturers must carefully balance greater revenue from higher production against the aesthetic effects of fertilizer application [8]. The experiment was carried out to determine the "Influence of phosphorus and plant growth regulators on growth and yield of pearl millet" keeping in mind the aforementioned fact (*Pennisetum glaucum* L.)"

2. MATERIALS AND METHODS

The experiment was conducted during *Rabi* season of 2022 at Crop Research Farm ,Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P).The soil of the field constituting a part of central gangetic alluvium is neutral and deep. The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH7.8),low level of organic carbon (0.62%), available N (225 Kg/ha), P (38.2 kg/ha) and K (240.7 kg/ha). The treatment consisted of 3 levels of phosphorous *viz.*(30 kg/ha), (40 kg/ha) and (50 kg/ha) with combination of 3 plant growth regulators *viz*. NAA (50 ppm), Chlormequat chloride (250ppm),Triacontanol (500ppm). The experiment was laid out in RBD with 10 treatments each replicated thrice. The treatment combinations were as follows: Treatment 1 Phosphorus (30 kg/ha) + (NAA (50 ppm), Treatment 2 Phosphorus (30 kg/ha) + Chlormequat chloride (250 ppm), Treatment 3 Phosphorus (30 kg/ha) + Triacontanol (500 ppm), Treatment 4 Phosphorus (40 kg/ha)+ NAA (50 ppm), Treatment 5 Phosphorus (40 kg/ha) + Chlormequat chloride (250 ppm), Treatment 6 Phosphorus (40kg/ha) + Triacontanol (500ppm), Treatment 7Phosphorous (50kg/ha) + NAA (50ppm),Treatment 8 Phosphorus (50kg/ha) + Chlormequat chloride (250 ppm) T9 Phosphorus (50 kg/ha) + Triacontanol (500 ppm), Treatment 10 Control [RDF: 80:40:40] NPK Kg/ha. Growth parameters (plant height(cm), dry weight(g), crop growth rate ($g/m^2/day$), relative growth rate (g/g/day), yield attributes (ear head length(cm), number of grains/ear head, test weight (g), grain yield(t/ha), straw yield (t/ha), harvest index (%) were subjected to statistical analysis of variance method [9].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height(cm)

The data revealed that significantly higher plant height (178.10 cm) was recorded in treatment 7 [Phosphorus (50 kg/ha) + NAA (50ppm)]. However, treatment 9 [Phosphorus (50 kg/ha) + Triacontanol (500 ppm)] was found to be statistically at par with treatment 7 [Phosphorus (50 kg/ha) + NAA (50ppm)] (Table 1). The administration of phosphorus (50 kg/ha) resulted in significantly higher plant height, which may be related to the efficient absorption of nutrients through the large root system that crop plants formed under appropriate phosphorus fertilizer treatment. Similar results were reported by Singh et al. [10]. Additionally, the regulatory function of NAA, which produces the shoot apex primary in the leaf primordial and root system, dramatically stimulates stem growth as well as cell division, cell elongation, and enzyme secretion, all of which lead to an increase in plant height.Similar results were reported by Mourya and Singh [7].

3.1.2 Plant dry weight (g)

Data showed that significantly higher plant dry weight (69.60 g) was recorded in treatment 7 [Phosphorus (50 kg/ha) + NAA (50ppm)]. However, treatment 9 [Phosphorus (50 kg/ha) + Triacontanol (500 ppm)] was found to be statistically at par with treatment 7 [Phosphorus (50 kg/ha) + NAA (50ppm)] (Table 1). It may have provided a favorable nutritional environment for the plants, which contributes to their essential role in several physical and chemical processes that remain critical for plant growth and development, resulting in the significant and higher plant dry weight(g) that was observed with application of phosphorus(50kg/ha).Similar results were reported by Reddy et al. [1]. Further, the increase in plant dry weight following application of NAA(50ppm) may be attributable to the fact that it encourages cell proliferation during plant developmental stages as a result of the regulation of their own metabolism and promotes cell development by increasing turgor pressure in addition to activating various enzymes and having a positive impact on plant growth.Similar results were reported by Mourya and Singh [7].

3.1.3 Crop growth Rate(g/m^2/day)

The data recorded that significantly higher crop growth rate (5.53 g/m$^{2/}$day) was observed in treatment 7 with [Phosphorus (50 kg/ha) + NAA (50 ppm)]. However, treatment 4 [Phosphorus (40 kg/ha) + NAA (50ppm)],treatment 6 [Phosphorus (40 kg/ha)+ Triacontanol (500 ppm)], treatment 8 [Phosphorus (50 kg/ha) + Chlormequat chloride (250 ppm)] and treatment 9 [Phosphorus (50 kg/ha) + Triacontanol (500 ppm)] was found to be statistically at par with treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)] (Table 1). The application of phosphorus (50 kg/ha) resulted in a significant and greater crop growth rate, which may be explained by the larger accumulation of photosynthates in different sinks.Similar results were reported by Sowjanya et al. [11].

3.1.4 Relative growth rate (g/g/day)

Data showed that highest relative growth rate (0.0058 g/g/day) was recorded with the treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)] (Table 1). However, there was no significant difference among the treatments.

3.2 Yield Attributes and Yield

3.2.1 Ear head length (cm)

The data showed that significantly higher ear head length (26.00 cm) was observed in treatment 7 [Phosphorus (50 kg/ha) + NAA (50ppm)]. However, treatment 9 [Phosphorus (50 kg/ha)+ Triacontanol (500 ppm)] was found to be statistically at par with the treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)] (Table 2). The application of phosphorus (50 kg/ha), which is known to be an essential component of all living organisms and plays a crucial role in the conservation and transfer of energy in the metabolic reactions of living cells, including biological energy transformation, resulted in a significant and higher ear head length being recorded.Similar results were reported by Gojariya et al. (2020). Further, increase in ear head length with the application of NAA (50 ppm) might be due to rapid cell division and increased elongation of individual cells, resulting in increase in ear head length. Similar results were reported by Suresh et al. [12].

3.2.2 Number of grains/ear head

The data showed that a significantly maximum number of grains/ear head (1957.67) was observed in treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)].However, 8 [Phosphorus (50 kg/ha) + Chlormequat chloride (250 ppm)] and treatment 9 [Phosphorus (50 kg/ha) + Triacontanol (500 ppm)] was found to be statistically at par with the treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)] (Table 2). With the application of phosphorus (50 kg/ha), a significant and maximum number of grains/ear heads were observed. This may be related to an overall improvement in plant development as evidenced by increased dry weight, which increased the supply of phosphorus and other nutrients to plants and nutrient availability to plants during the flower primordial initiation stage, which may have improved tiller formation and increased thinning .Similar results were reported by Reddy et al. [1]. Further, increase in number of grains/ear head with the application of NAA (50ppm) might be due to plants may have benefited from an earlier delivery of nutrients during the floral primordial initiation stage through plant growth regulators, resulting in a higher number of functional tillers and eventually more grains/ear heads. Similar results were reported by Gurrala et al. (2018).

3.2.3 Test weight(g)

Data showed that highest test weight(11.73g)was recorded in Treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)] (Table 2). However, there was no significant difference among the treatments

3.2.4 Grain yield(t/ha)

The data revealed that significantly higher grain yield (2.69 t/ha) was recorded in treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)]. However, treatment 3 [Phosphorus (30 kg/ha) + Triacontanol (500 ppm)], treatment 8 [Phosphorus (50 kg/ha) + Chlormequat chloride (250 ppm)] and treatment 9 [Phosphorus (50 kg/ha) + Triacontanol (500 ppm)] was found to be statistically at par with the treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)] (Table 2). Application of phosphorus (50 kg/ha) resulted in a significant and higher grain yield (t/ha), which could be attributed to its optimal availability increasing nutrient use efficiency by providing adequate energy and an early proliferation of growth traits that increased the grain yield potential.Similar results were reported by Dharmendra and Umesha [13] in finger millet. Further, increase in grain yield (t/ha) was recorded with application of NAA(50ppm) may be due to it plays a vital role in increasing seed yield because they takes place in many physiological process of plant such as plant growth, chlorophyll formation, stomatal regulation, starch utilization and resistance to various biotic and abiotic stress which enhances seed yield. Similar results were reported by Mourya and Singh [7].

3.2.5 Stover yield(t/ha):

The data showed that significantly maximum stover yield (4.05 t/ha) was recorded in treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)]. Treatment 4 [Phosphorus (40 kg/ha) + (NAA 50 ppm)],treatment 8 [Phosphorus (50 kg/ha) + Chlormequat chloride (250 ppm)] and treatment 9 [Phosphorus (50 kg/ha) + Triacontanol (500 ppm)] was found to be statistically at par with the treatment 7 [Phosphorous (50 kg/ha) + NAA (50 ppm)] (Table 2). The application of phosphorus (50 kg/ha) resulted in significant and maximum stover yield (t/ha), which may have increased straw yield. Biological yield is determined by the amount of straw produced, so it's possible that the increased vegetative growth associated with phosphorus fertilization was caused by the plant's large root system. Similar results were reported by Ganesh et al. [8]. Further, increase in stover yield (t/ha) was recorded with application of NAA (50ppm) may be due to it has unique role in delaying senescence process, hastening root and shoot growth, higher fertility rate of reproductive organ due to creation of favorable balance of hormones and setting more fruits, resulted increased in stover yield. Similar results were reported by Suresh et al. [12].

3.2.6 Harvest index(%)

Data showed the highest harvest index (39.96%) was recorded in Treatment 7 [Phosphorus (50 kg/ha) + NAA (50 ppm)]. However, there was no significant difference among the treatments.

3.3 Economic Analysis

3.3.1 Economics

The result showed maximum gross returns (109625INR/ha), maximum netreturn (74389.08INR/ha) and highest benefit cost ratio(2.11) were observed in the treatment7 [Phosphorus (50 kg/ha) + NAA (50 ppm)] as compared to other treatments (Table 3). The maximum gross return, net return and benefit cost ratio was recorded with application of phosphorus (50kg/ha) might be due to it is an essential plant nutrient, it involves in various physiological process like seed formation, maximum number of grains/ ear head, which increases grain yield resulted with higher benefit cost ratio. Similar results were reported by Krishna et al. [14] in finger millet [15-22].

Table 1. Effect of phosphorus and PGR on growth attributes of pearl millet

S No.	Treatment combinations	100 DAS		80- 100 DAS	
		Plant Height (cm)	Dry weight (g)	Crop Growth Rate ($g/m^2/day$).	Relative Growth Rate (g/g/day)
1.	Phosphorus 30 kg/ha +NAA 50 ppm	172.40	57.20	3.85	0.0049
2.	Phosphorus 30 kg/ha + Chlormequat chloride 250 ppm	170.30	54.87	3.62	0.0048
3.	Phosphorus 30 kg/ha + Triacontanol 500 ppm	171.60	56.70	3.85	0.0049
4.	Phosphorus 40 kg/ha + NAA 50 ppm	174.60	66.00	5.09	0.0056
5.	Phosphorus 40 kg/ha +Chlormequat chloride 250 ppm	172.80	57.20	3.85	0.0049
6.	Phosphorus 40 kg/ha + Triacontanol 500 ppm	173.60	64.00	4.79	0.0055
7.	Phosphorus 50 kg/ha + NAA 50 ppm	178.10	69.60	5.53	0.0058
8.	Phosphorus 50 kg/ha + Chlormequat chloride 250 ppm	176.60	66.80	5.14	0.0056
9.	Phosphorus 50 kg/ha + Triacontanol 500 ppm	177.30	67.90	5.28	0.0057
10.	Control [RDF: 80:40:40]NPK Kg/ha	169.20	53.30	3.34	0.0046
	F-test	S	S	S	NS
	Sem(±)	0.43	0.73	0.28	0.0004
	CD (p=0.05)	1.27	2.17	0.84	--

Table 2. Effect of phosphorus and PGR on yield and yield attributes of pearl millet

S. No.	Treatment combinations	Ear head length (cm)	Grains/ear head	Test weight (g)	Grain yield (t/ha)	Straw Yield (t/ha)	Harvest Index (%)
1.	Phosphorus 30 kg/ha +NAA 50 ppm	25.33	1721.33	10.10	2.17	3.51	38.32
2.	Phosphorus 30 kg/ha + Chlormequat chloride 250 ppm	25.20	1702.67	9.20	2.13	3.47	38.00
3.	Phosphorus 30 kg/ha + Triacontanol 500 ppm	25.27	1720.67	9.60	2.15	3.50	38.12
4.	Phosphorus 40 kg/ha + NAA 50 ppm	25.67	1734.67	10.87	2.51	3.79	39.78
5.	Phosphorus 40 kg/ha +Chlormequat chloride 250 ppm	25.47	1722.67	10.60	2.21	3.55	38.38
6.	Phosphorus 40 kg/ha + Triacontanol 500 ppm	25.66	1730.33	10.80	2.30	3.64	38.67
7.	Phosphorus 50 kg/ha + NAA 50 ppm	26.00	1757.67	11.73	2.69	4.05	39.96
8.	Phosphorus 50 kg/ha + Chlormequat chloride 250 ppm	25.73	1749.00	11.20	2.57	3.92	39.63
9.	Phosphorus 50 kg/ha + Triacontanol 500 ppm	25.90	1754.00	11.60	2.61	3.95	39.82
10.	Control [RDF: 80:40:40]NPK Kg/ha	25.07	1700.33	10.07	2.02	3.36	37.57
	F-Test	S	S	NS	S	S	NS
	SEm(±)	0.08	3.81	0.91	0.07	0.10	1.11
	CD (p=0.05)	0.23	11.31	--	0.20	0.29	--

Table 3. Effect of phosphorus and PGR on economics of pearl millet

S.No	Treatment combinations	Total cost of cultivation	Gross Returns	Net Returns	B:C ratio
1.	Phosphorus 30 kg/ha +NAA 50 ppm	33986	88555	54569	1.60
2.	Phosphorus 30 kg/ha + Chlormequat chloride 250 ppm	34142	86935	52793	1.54
3.	Phosphorus 30 kg/ha + Triacontanol 500 ppm	34705	87750	53045	1.52
4.	Phosphorus 40 kg/ha + NAA 50 ppm	34611	102295	67684	1.95
5.	Phosphorus 40 kg/ha +Chlormequat chloride 250 ppm	34767	90175	55408	1.59
6.	Phosphorus 40 kg/ha + Triacontanol 500 ppm	35330	93820	58490	1.65
7.	Phosphorus 50 kg/ha + NAA 50 ppm	35236	109625	74389	2.11
8.	Phosphorus 50 kg/ha + Chlormequat chloride 250 ppm	35392	104760	69368	1.95
9.	Phosphorus 50 kg/ha + Triacontanol 500 ppm	35955	106375	70420	1.95
10.	Control [RDF: 80:40:40]NPK Kg/ha	34580	82480	47900	1.38

4. CONCLUSION

It is concluded that with the application of phosphorus (50kg/ha) along with NAA(50ppm) (Treatment 7)was observed highest grain yield and benefit cost ratio.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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