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Effect of Phosphorus and Hydrogel on Growth and Yield of Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All 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) India. To evaluate the effect of phosphorus and hydrogel on growth and yield of maize (*Zea mays* L.). Both phosphorus and Hydrogel was broadcasting in the field before sowing and mixed well in the soil. The growth attributes which was plant height (231.54 cm) and dry weight (178.19 g/plant) was significantly increased with increasing the level of phosphorus (25, 50, 75 kg/ha) and hydrogel (2.5, 5, 7.5 kg/ha) and maximum was obtained with application of phosphorus (75 kg/ha) and hydrogel (7.5 kg/ha) with highest effective number of cobs/plant (2.60), cob length (14.63 cm), number of rows/cob (11.91), number of grains/cob (326.39), grain yield (4.95 t/ha), stover yield (6.72 t/ha), harvest index (42.30%).

Keywords: Maize; phosphorus; hydrogel; growth and yield attributes.

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1. INTRODUCTION

After rice and wheat, maize (*Zea mays* L.), a cereal grain, is referred to as the "queen of cereals" and is the third most important cereal crop in India. It is a large and versatile crop that is grown for human consumption, animal feed for livestock and poultry, and as a raw material for several industries. The nutritious content of maize benefits both people and animals. Maize has progressively shifted from being a cereal crop to an industrial one. Over 100 million man-days are engaged as a result of maize farming in India, which generates revenue of rupees 100 billion. It is a top source of essential vitamins and minerals, as well as proteins, lipids, and carbohydrates. Additionally, it is utilized to create alcoholic beverages, carbohydrates, oil, proteins, and food sweeteners.

Due to its multiple applications as food, feed, fodder, and raw materials for different industrial items, it is highly regarded all over the world. Maize can be grown in areas with altitudes as low as sea level and as high as 3000 m above mean sea level because of its wide range of adaptation. It is grown on 188 million hectares of land in more than 170 countries, producing 1423 million MT globally. China and the United States, which together make up 39% of the world's total maize acreage, are the two countries with the most land planted with the crop. India is the fourth-largest producer of maize, with 9.89 million acres grown since 2005. The top two producers of maize are the USA and China, with 36% and 25% of global production, respectively. India is now rated sixth among the top 10 producers of maize in the world, with an annual production of 31.65 million MT. About 3.19 t/ha of maize are produced in India each year, which is somewhat more than the global average of 5.6 t/ha. The yearly production of maize in India, however, is comparable to that of many industrialized countries. In terms of geography and strategy for selling maize to the international market, India has an advantage over other countries. This includes the year-round production of maize in our country, reasonable freight costs, a well-established seed manufacturing and distribution network, and the accessibility of seaports. However, there is a very high degree of domestic demand. As a result, the importance of India's maize exports has diminished [1].

For the crop, water is an essential resource that can save its existence. Cell division, respiration, absorption, translocation, and the use of mineral nutrients are all significantly impacted. In order to make the most of India's limited irrigation water resources, it is essential to increase agricultural water output and irrigation efficiency. This might be achieved by reducing water loss and enhancing the circumstances for crop development. Superabsorbent polymer (hydrogel), one type of soil conditioner, has a huge potential to increase agricultural crops' productivity by using the water already present in the soil. In fact, the polymer has the ability to hold onto more water in the soil, giving plants more time to utilize it. Hydrogel (a super absorbent polymer) is a cross-linked, biodegradable, water-retaining amorphous polymer that can absorb and retain water at least 400 times its original weight and make at least 95% of the stored water available for crop absorption. When a polymer is mixed with soil, it hydrates to form an amorphous, gelatinous substance that may absorb and desorb over a long time, serving as a soil source for delayed water release. Water is extracted from the hydrogel particles when the roots need it due to an osmotic pressure differential. The hydrogel particles may be thought of as "miniature water reservoirs" in the soil [2].

Phosphorus, which has a constrained range of mobility over time in soil, is regarded as an "immobile nutrient" in this context. The effectiveness of P absorption is enhanced by both temperature and the availability of soil moisture. The ability of the root system to absorb water might suffer from dry soil. The soil contains phosphorus in both organic and inorganic forms. A crop cannot use most of the phosphorus in the soil in a single growing season because it is chemically bonded. The amount of phosphorus that is easily absorbed by plants is relatively small when compared to the total amount of phosphorus in the soil. In light of this, even though an acre of soil may contain around 800 to 1,000 pounds of total phosphorus, only 0.04 to 0.13 pounds may be available to plants in the soil solution. Phosphorus promotes growth in all stages of the maize crop and, if it is insufficient, tends to delay maturity with poor ear development. Although a deficit is first noticeable at the seedling stage, it becomes most critical after flowering [3]. Plants require P for growth throughout their entire life cycle, but notably during the first stages of growth and development. The conversion of solar energy into the chemical energy needed by plants to produce proteins, carbohydrates, and starches depends on phosphorus. An organism has to transport the energy it produces during photosynthesis in order to grow and reproduce. In order to promote shoot and root growth and aid in crop establishment, adequate P levels during early-season growth are necessary. Enough P increases agricultural potential and water usage efficiency. When P levels are inadequate, maize is unable to generate, grow, or endure stresses. Hence, the present investigation was conducted to study the effects of phosphorus and hydrogel on the growth and yield of maize (*Zea mays* L.).

2. MATERIALS AND METHODS

The experiment was carried out during *rabi* season of 2022 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (Allahabad) which is located at 25˚ 24' 42" N latitude, 81˚ 50' 56" E longitude and 98 m altitude above the mean sea level. The experiment was laid down in Randomized Block Design and comprised of levels of phosphorus (25, 50, 75 kg/ha) and hydrogel (2.5, 5, 7.5 kg/ha) along with 10 treatment combinations and replicated thrice viz. T1 - Phosphorus 25 kg/ha + Hydrogel 2.5 kg/ha, T2 - Phosphorus 50 kg/ha + Hydrogel 2.5 kg/ha, T3 - Phosphorus 75 kg/ha + Hydrogel 2.5 kg/ha, T4 - Phosphorus 25 kg/ha + Hydrogel 5 kg/ha. T5 - Phosphorus 50 kg/ha + Hydrogel 5 kg/ha, T6 - Phosphorus 75 kg/ha + Hydrogel 5 kg/ha, T7 - Phosphorus 25 kg/ha + Hydrogel 7.5 kg/ha, T8 - Phosphorus 50 kg/ha + Hydrogel 7.5 kg/ha, T9 - Phosphorus 75 kg/ha + Hydrogel 7.5 kg/ha and T10 - Control (RDF-120-60-40 NPK).

Maize variety 'Shaktiman-5' was used for the experiment. Sowing was carried out on 20 December. Row to Row distance 35 cm and plant to plant distance 15 cm were maintained in all plots and furrows were opened at 4 to 5 cm depth. The soil application of phosphorus and hydrogel done at sowing time. The annual rainfall observed in cropping period was (4.68 mm). The observation was recorded for Plant height (cm), Plant Dry weight (g/plant), Number of cobs/plant, Cob length (cm), Number of rows/cob, Number of grains/cob, Seed index (g), Grain yield (t/ha), Stover yield (t/ha) and Harvest index (%).

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

The data regarding plant height presented in Table 1. At 80 DAS, significantly higher plant height (231.54 cm) recorded in phosphorus 75kg/ha + hydrogel 7.5kg/ha and lowest was obtained in control plot (215.13 cm) significantly. Whereas phosphorus 50kg/ha + hydrogel 7.5kg/ha (230.52 cm) and phosphorus 25kg/ha + hydrogel 7.5kg/ha (228.02cm) respectively found to be statistically at par with application of phosphorus 75kg/ha + hydrogel 7.5kg/ha. Application of hydrogel in maize can improve the plant height; the results are in conformity with the results of Pal et al*.* [4].

3.2 Plant Dry Weight of (g)

The data regarding dry weight presented in Table 1. With the maturation of the crop, plant height gradually increased until it peaked at harvest. T9 with phosphorus 75kg/ha + hydrogel 7.5 kg/ha had a considerably greater dry weight. At 80 DAS, significantly plant dry weight (178.19 g) recorded in phosphorus 75 kg/ha + hydrogel 7.5 kg/ha and lowest was obtained in control plot (154.49 g) significantly. Whereas phosphorus 50kg/ha + hydrogel 7.5 kg/ha (176.02 g), phosphorus 25kg/ha + hydrogel 7.5 kg/ha (175.40 g), phosphorus 75 kg/ha + hydrogel 5 kg/ha (171.16 g), phosphorus 50 kg/ha + hydrogel 5 kg/ha (168.71 g), phosphorus 25 kg/ha + hydrogel 5 kg/ha (164.65) and phosphorus 75 kg/ha + hydrogel 2.5 kg/ha (163.71) respectively found to be statistically at par with application of phosphorus 75 kg/ha + hydrogel 7.5 kg/ha. The total amount of dry matter produced is a sign of higher light absorption and overall resource use Khadem et al. [5]. Application of hydrogel in maize can improve the plant dry matter accumulation; the results are in conformity with the results of Sharma and Jat [6].

3.3 Number of Cobs/Plant

The data regarding number of cobs/plant presented in table 2. The maximum cobs per plant (2.60) was obtained in T9 with Phosphorus 75 kg/ha + Hydrogel 7.5kg/ha, while the minimum cobs per plant (1.31) was reported in T10 with no fertilizer application (RDF). The results are in conformity with the results of Pal et al*.* [4].

3.4 Cob Length (cm)

The data regarding cob length presented in Table 2. The application of hydrogel and phosphorus had a significant impact on maize cob length. T9 with phosphorus 75 kg/ha +

hydrogel 7.5 kg/ha had a considerably greater cob length. The maximum cob length (14.63 cm) was obtained in T9 with Phosphorus 75 kg/ha + Hydrogel 7.5 kg/ha, while the minimum cob length (12.50 cm) was reported in T10 with no fertilizer application (RDF). Whereas phosphorus 50 kg/ha + hydrogel 7.5 kg/ha (14.10 cm), phosphorus 25 kg/ha + hydrogel 7.5 kg/ha (13.99 cm), phosphorus 75 kg/ha + hydrogel 5 kg/ha (13.76 cm), and phosphorus 50kg/ha + hydrogel 5 kg/ha (13.46 cm) respectively found to be statistically at par with application of phosphorus 75 kg/ha + hydrogel 7.5 kg/ha. The results are in conformity with the results of Paramasivam et al. [7].

3.5 Number of Rows/Cob

The data regarding number of rows/cob presented in Table 2. The application of hydrogel and phosphorus had not influenced rows cob^{-1} significantly by different treatments. The maximum rows cob^{-1} (11.91) was obtained in T9 with phosphorus 75 kg/ha + hydrogel 7.5kg/ha, while the minimum rows per cob (9.13) was reported in T10 with no fertilizer application. (RDF). Whereas phosphorus 50 kg/ha + hydrogel 7.5 kg/ha (11.86), phosphorus 25 kg/ha + hydrogel 7.5 kg/ha (11.85), phosphorus 75 kg/ha + hydrogel 5 kg/ha (11.68), phosphorus 50 kg/ha + hydrogel 5 kg/ha (11.53), phosphorus 25 kg/ha + hydrogel 5 kg/ha (11.35), phosphorus 75 kg/ha + hydrogel 2.5 kg/ha (11.29), phosphorus 50 kg/ha + hydrogel 2.5 kg/ha (11.2) and phosphorus 25 kg/ha + hydrogel 2.5 kg/ha (11.15) respectively found to be statistically at par with application of phosphorus 75 kg/ha + hydrogel 7.5 kg/ha.

3.6 Number of Grains/Cob

The data regarding number of grains/cob presented in Table 2. The application of hydrogel and phosphorus had a significant impact on no. of grains cob^{-1}. The maximum number of grains (326.39) was obtained in T9 with phosphorus 75 kg/ha + hydrogel 7.5 kg/ha, while the minimum number of grains (242.91) was reported in T10 with no fertilizer application. Whereas phosphorus 50 kg/ha + hydrogel 7.5 kg/ha (323.55), phosphorus 25 kg/ha + hydrogel 7.5 kg/ha (321.74), phosphorus 75 kg/ha + hydrogel 5 kg/ha (315.14), phosphorus 50 kg/ha + hydrogel 5 kg/ha (309.94), phosphorus 25 kg/ha + hydrogel 5 kg/ha (303.97), phosphorus 75 kg/ha + hydrogel 2.5 kg/ha (301.23), phosphorus 50 kg/ha + hydrogel 2.5 kg/ha (297.37) and phosphorus 25 kg/ha + hydrogel 2.5 kg/ha (294.93) respectively found to be statistically at par with application of phosphorus 75kg/ha + hydrogel 7.5 kg/ha. The results are in conformity with the results of Pal et al. [4].

3.7 Seed Index (g)

The data regarding seed index presented in Table 2. The application of hydrogel and phosphorus had no significant impact on seed index. T9 with Phosphorus 75kg/ha + Hydrogel 7.5 kg/ha had considerably greater harvest index than T10, T8, T7, T6, T5, T4, T3, T2, and T1 treatments, respectively. The maximum seed index (29.61) was obtained in T9 with phosphorus 75 kg/ha + hydrogel 7.5 kg/ha, while the minimum seed index (29.30) was reported in T10 with no fertilizer application (RDF).

Table 1. Effect of phosphorus and hydrogel on growth parameter of Maize

S. No	Treatment combination	Plant height (cm)	Plant dry weight (g)
1	Phosphorus 25 Kg/ha + Hydrogel 2.5 Kg/ha	209.06	160.27
2	Phosphorus 50 Kg/ha + Hydrogel 2.5 Kg/ha	207.97	161.71
3	Phosphorus 75 Kg/ha + Hydrogel 2.5 Kg/ha	208.08	163.71
4	Phosphorus 25 Kg/ha + Hydrogel 5 Kg/ha	209.16	164.65
5	Phosphorus 50 Kg/ha + Hydrogel 5 Kg/ha	210.64	168.71
6	Phosphorus 75 Kg/ha + Hydrogel 5 Kg/ha	209.42	171.16
7	Phosphorus 25 Kg/ha + Hydrogel 7.5 Kg/ha	228.02	175.40
8	Phosphorus 50 Kg/ha + Hydrogel 7.5 Kg/ha	230.52	176.02
9	Phosphorus 75 Kg/ha + Hydrogel 7.5 Kg/ha	**231.54**	**178.19**
10	Control (RDF)	215.13	154.49
F-test		S	S
Sem (±)		6.31	4.89
CD (P=0.05)		18.74	14.54

Table 2. Effect of phosphorus and hydrogel on yield attributes of maize

S. No	Treatment combination	Number of cobs/plant	Cob length (cm)	Number of rows/cob	Number of grains/cob	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1	Phosphorus 25 Kg/ha + Hydrogel 2.5 Kg/ha	1.71	12.30	11.15	294.93	29.35	3.34	5.86	36.32
2	Phosphorus 50 Kg/ha + Hydrogel 2.5 Kg/ha	1.88	12.55	11.2	297.37	29.41	3.60	5.96	37.65
3	Phosphorus 75 Kg/ha + Hydrogel 2.5 Kg/ha	1.91	12.86	11.29	301.23	29.45	3.87	6.01	39.20
4	Phosphorus 25 Kg/ha + Hydrogel 5 Kg/ha	1.98	13.10	11.35	303.97	29.53	4.04	6.12	39.78
5	Phosphorus 50 Kg/ha + Hydrogel 5 Kg/ha	2.39	13.46	11.53	309.94	29.56	4.27	6.22	40.70
6	Phosphorus 75 Kg/ha + Hydrogel 5 Kg/ha	2.45	13.76	11.68	315.14	29.57	4.45	6.3	41.41
7	Phosphorus 25 Kg/ha + Hydrogel 7.5 Kg/ha	2.51	13.99	11.85	321.74	29.58	4.66	6.45	41.93
8	Phosphorus 50 Kg/ha + Hydrogel 7.5 Kg/ha	2.55	14.10	11.86	323.55	29.60	4.78	6.55	42.20
9	Phosphorus 75 Kg/ha + Hydrogel 7.5 Kg/ha	**2.60**	**14.63**	**11.91**	**326.39**	29.61	**4.95**	**6.72**	**42.30**
10	Control (RDF)	1.31	12.50	9.13	242.91	29.3	3.12	5.78	35.75
	F-test	S	S	S	S	NS	S	S	S
	Sem (±)	0.18	0.40	0.36	15.23	0.80	0.19	0.19	1.19
	CD (P=0.05)	-	1.21	1.07	45.25	-	0.59	0.57	3.54

3.8 Grain Yield (t/ha)

The data regarding grain yield presented in Table 2. The application of hydrogel and phosphorus had a significant impact on grain yield. T9 with Phosphorus 75 kg/ha + Hydrogel 7.5 kg/ha had considerably greater grain yield than T10, T8, T7, T6, T5, T4, T3, T2, and T1 treatments, respectively. The maximum grain yield (4.95 t) was obtained in T9 with phosphorus 75 kg/ha + hydrogel 7.5 kg/ha, while the minimum grain yield (3.12 t) was reported in T10 with no fertilizer application (RDF). Whereas phosphorus 50 kg/ha + hydrogel 7.5 kg/ha (4.78 t), phosphorus 25 kg/ha + hydrogel 7.5 kg/ha (4.66 t) and phosphorus 75 kg/ha + hydrogel 5 kg/ha (4.45 t) respectively found to be statistically at par with application of phosphorus 75kg/ha + hydrogel 7.5kg/ha. The results are in conformity with the results of Magalhaes et al. [8].

3.9 Stover Yield (t/ha)

The data regarding stover yield presented in Table 2. The application of hydrogel and phosphorus had a significant impact on straw yield. T9 with Phosphorus 75 kg/ha + Hydrogel 7.5kg/ha had considerably greater straw yield than T10, T8, T7, T6, T5, T4, T3, T2, and T1 treatments, respectively. The maximum straw yield (6.72 t) was obtained in T9 with phosphorus 75 kg/ha + hydrogel 7.5 kg/ha, while the minimum straw yield (5.78 t) was reported in T10 with no fertilizer application (RDF). Whereas phosphorus 50 kg/ha + hydrogel 7.5 kg/ha (6.55 t), phosphorus 25 kg/ha + hydrogel 7.5 kg/ha (6.45 t), phosphorus 75 kg/ha + hydrogel 5 kg/ha (6.3 t) and phosphorus 50 kg/ha + hydrogel 5 kg/ha (6.22 t) respectively found to be statistically at par with application of phosphorus 75kg/ha + hydrogel 7.5 kg/ha. The results are in conformity with the results of Raskar et al. [9].

3.10 Harvest Index (%)

The data regarding harvest index presented in Table 2. The application of hydrogel and phosphorus had a significant impact on harvest index. T9 with Phosphorus 75kg/ha + Hydrogel 7.5kg/ha had considerably greater harvest index(42.30) than T10, T8, T7, T6, T5, T4, T3, T2, and T1 treatments, respectively. Whereas phosphorus 50 kg/ha + hydrogel 7.5 kg/ha (42.20), phosphorus 25 kg/ha + hydrogel 7.5 kg/ha (41.93), phosphorus 75 kg/ha + hydrogel 5 kg/ha (41.41), phosphorus 50 kg/ha + hydrogel 5 kg/ha (40.70), phosphorus 25 kg/ha + hydrogel 5 kg/ha (39.78) and phosphorus 50 kg/ha + hydrogel 2.5 kg/ha (37.65) respectively found to be statistically at par with application of phosphorus 75 kg/ha + hydrogel 7.5 kg/ha. The maximum harvest index (42.30) was obtained in T9 with phosphorus 75 kg/ha + hydrogel 7.5 kg/ha, while the minimum harvest index (35.75) was reported in T10 with no fertilizer application (RDF). The results are in conformity with the results of Kumar et al. [10].

4. CONCLUSION

It is concluded that Phosphorus 75 kg/ha + Hydrogel 7.5 kg/ha was found to be significantly more productive (4.95 t/ha), when compared to other treatments. Since the conclusions are based only on research conducted over the course of one season, more verification is needed before making any recommendations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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