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Effect of phosphorus and molybdenum on growth and yield of maize (*Zea mays* L.)

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ABSTRACT

A field experiment was conducted during *Rabi* 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) on the topic "Effect of phosphorus and molybdenum on growth and yield of maize (*Zea mays* L.)", to study treatments consisting of three levels of Phosphorus *viz.* 30 kg, 40 kg and 60 kg/ha and three levels of Molybdenum *viz*. 30, 40 and 50 g/ha. There were 10 treatments each being replicated thrice and laid out in Randomized Block Design. The results revealed that treatment 9 (Phosphorus – 60 kg/ha + Molybdenum – 50g/ha) recorded significantly higher Plant Height (106.10 cm), Plant Dry weight (51.52 g), Crop Growth Rate (12.93 g/m^2/day), number of cobs per plant (2), number of grains per cob (357.67), Seed index (24.55 g), Grain yield (6.61 t/ha), Stover yield (8.85 t/ha), Harvest Index (42.78 %), Maximum gross return (INR 1,32,266.67), net return (INR 91,932.97) and B:C ratio (2.28) as compared to other treatments.

Key words : *Phosphorus, Molybdenum, Growth, Yield, Economics.*

Introduction

Maize (*Zea mays* L.) is considered as one of the most important food grains in India after the main cereals rice and wheat. India ranks fifth in the area and third in production and productivity over other cereal crops and members of the Gramineae family. It is the third most important crop in Uttar Pradesh and is also regarded as the "Queen of Cereals". It has great potential to meet the food demands of living beings which collectively include both humans and animals. Nutrient composition of maize includes crude protein 7.6%, crude fiber2.3%, crude fat 3.6%, and starch 63.8%, and Total sugar 1.7%, Gross energy3840kcal/kg. In India maize is cultivated over an area of 8.49 million hectares with the production of 21.28 million tones and productivity of 2057 kg/ha. With maize world's average yield production of 27.8 q/ha, considering Uttar Pradesh has reported 8.33% of the total maize area and 9.65% of total maize production in the country. It almost contributes 9% in national food basket. Mostly maize is cultivated throughout the year in every state for different requirements like grains, fodder, green cobs, baby corn, sweet corn, popcorn in different areas. The highest maize growing states which produce more than 80% of total maize produced in the country include Andhra Pradesh (21%), Karnataka (17%), Rajasthan (10%), Bihar (9%), Maharashtra (8%), Uttar Pradesh (7%), Madhya Pradesh (6%) and Himachal Pradesh (4.4%). Some contribution is also done by Jammu Kashmir and few North-East states. Besides, human consumption and animal feed it can also be used in certain industries like corn starch industries, corn oil production, baby corn, etc. Starch extracted from corn is considered one of the major ingredients in every home of India. From maize starch, many bi-products like

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corn syrups and also alcoholic beverages include beer, whiskey, etc. In India, about 28% of maize produced is used for food purposes, about 11% as livestock feed, 48%for poultry feed, 12% in the milling industry, and 1% for seeds purpose. Due to many multiple uses of maize as food, feed and fodder improves its demand and had a very great shot over low demand situation. These kind of characteristics of maize accounts for improving farmer's income and standard 65-75% acreage of maize hybrids and most of it is used as a feed for animals, also for industrial purpose where food grade maize is cultivated using traditional cultivars. Farmers are slowly replacing traditional cultivars with new high yielding hybrids now days.

Phosphorous

Phosphorus plays a major role in existence of all living creatures. It is an essential constituent of nucleic acid. Among other things it ensures the transfer and storage of energy and permits the conservation and transmission of genetic characteristics in plants as well as in men and animals. Nothing at all happens within living things without energy. Living creatures have an absolute need with this indispensable element. Phosphorus therefore plays a leading role in living things and it is not without reason that it is said to be the key element in metabolism. Phosphorus is second major nutrient after nitrogen for high crop yield especially for maize, because it is frequently deficient for crop production and is required by crops in relatively large amounts. The total P concentration in agricultural crops generally ranges from 0.1 to 0.5 percent. Phosphorus is taken up mostly as the primary orthophosphate ion (H_2PO_4), but some is also absorbed in the secondary orthophosphate form (HPO_4 —). The later form increases as the soil pH increases. Phosphates are vital component of all living things. In plants, P is necessary for photosynthesis, respiration, cellular function, gene transfer and reproduction. Once aware of the critical link between P and life itself, it becomes apparent that "Without phosphorus, there is no cell, plant and grain and without adequate phosphorus, there is a lot of hunger". Phosphorus deficiency is widespread in 90% of the soils and the application of phosphatic fertilizers is considered essential for a crop production (Rashid and Memon, 2012).

Molybdenum

Molybdenum (Mo) is an essential micronutrient for plant growth, especially for more demanding species in nitrogen or carrying out the process of biological nitrogen fixation (BNF). The importance of this micronutrient is due to its participation in the formation of nitrate reductase and nitrogenase enzymes, which play an important role in the synthesis of nitrogen assimilation in plants. Molybdenum is a microelement found in the soil and is needed for the growth of biological organisms which includes the plants. This necessary nature of Mo was first shown by Plants which are grown in a purified solution cultures shown deficiency symptoms, because of the lack of molybdenum, and symptoms were prevented by adding 0.01 mg·l-1 Mo to the root. Normal growth was restored to deficient plants if molybdenum was placed onto the foliage, therefore showing that molybdenum has its effect directly on the growth and not indirectly by changing the root environment. The availability of Mo in the soil depends on the adsorption-desorption processes, which are influenced by soil pH and the content of Fe and Al oxides.

Materials and Methods

A field trial was conducted during *Rabi,* 2022 at Crop Research Farm (CRF), Department of Agronomy, SHUATS, Prayagraj (U.P.), India which is located at 25.40° N latitude, 81.85° E longitude, and 98 m altitude above the mean sea level (MSL). The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.28%), available N (225 kg/ha), available P (19.50 kg/ha) and available K (92 kg/ha). Nutrient sources were Urea, Single Super Phosphate, Murate of Potash and ammonium molybdate to fulfill the requirement of Nitrogen, Phosphorus, Potassium and molybdenum respectively. The experiment was laid out in Randomized Block Design (RBD) with ten treatments replicated thrice. The treatments were 1. Phosphorus – 30kg/ha + Molybdenum – 30g/ha 2. Phosphorus – 30kg/ha + Molybdenum – 40g/ha 3. Phosphorus – 30kg/ha + Molybdenum – 50g/ha 4. Phosphorus – 40kg/ha + Molybdenum – 30g/ha 5. Phosphorus – 40kg/ha +Molybdenum – 40g/ha 6. Phosphorus – 40kg/ha + Molybdenum – 50g/ha 7. Phosphorus – 60kg/ha + Molybdenum – 30g/ha 8. Phosphorus – 60kg/ha + Molybdenum – 40g/ha 9. Phosphorus – 60 kg/ha + Molybdenum – 50g/ha 10. Control Plot (RDF N: P: K-

120:60:60 kg/ha). 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)

The significantly taller plant height (146.10 cm) at 60 DAS was recorded in treatment 9 with Phosphorus – 60 kg/ha + Molybdenum – 50 g/ha recorded significantly highest plant height (146.10 cm). However, treatments with Phosphorus – 60 kg/ha + Molybdenum – 40 g/ha and Phosphorus – 40 kg/ha + Molybdenum – 50 g/ha were statistically at par with the treatment Phosphorus – 60 kg/ha + Molybdenum – 50 g/ha.

Phosphorus encourage formation of new cells, promote plant vigorously and hastens leaf development, which help in harvesting more solar energy and better utilization of nitrogen, which help towards higher growth attributes (Sankadiya *et al.*, 2021). Similar results also found by Alias *et al.* (2003) and Naomi *et al*. (2021). Improvement in plant height with higher phosphorus levels over and above 40 kg P_2O_5 ha^{-1} (P2) might be attributed to the fact that phosphorus is a constituent of nucleic acids, phospholipids, coenzymes and most importantly ATP. It activates coenzymes for amino acid production used in protein synthesis which might have resulted in better plant height (Thakur *et al.,* 2020). Similar results were obtained by Gemechu (2011) and Reddy *et al.,* (2018). Mo probably contributed for the increase in plant reserves production, which, according to Magalhães and Jones (1990) are allocated in the height, source of photo-assimilated for several parts of the vegetal.

Plant dry weight (g)

The significantly maximum dry weight (59.20 g) at 60 DAS was recorded with treatment 9 with Phosphorus – 60 kg/ha + Molybdenum – 50g/ha recorded significantly the highest plant dry weight (59.20 g). However, treatment with Phosphorus – 60kg/ha + Molybdenum – 40 g/ha was statistically at par with the treatment Phosphorus – 60 kg/ha + Molybdenum – 50g/ha.

It seems the reason is increase in leaf area, photosynthesis improvement resulting in higher dry matter (Thakur *et al.*, 2020). He also recorded the highest dry weight and leaf area of maize by applying 60 kg P/ha P_2O_5.

Crop growth rate ($g/m^2/day$) and Relative growth rate (g/g/day) between 40-60 DAS Crop Growth Rate was recorded highest (14.67 $g/m^2/day$) in treatment 9 with Phosphorus – 60kg/ha + Molybdenum – 50g/ha.

Yield attributes

Number of cobs per plant: Treatment 9 with Phos-

Table 1. Effect of phosphorus and molybdenum levels on growth attributes of maize

S. No.	Treatments	60 DAS		40 DAS- 60 DAS	
		Plant height (cm)	Dry weight (g)	Crop Growth Rate ($g/m^2/day$)	Relative Growth Rate ($g/m^2/day$)
1.	Phosphorus – 30kg/ha + Molybdenum – 30g/ha	‘138.30	52.20	13.06	0.0459
2.	Phosphorus – 30kg/ha + Molybdenum – 40g/ha	139.60	53.10	13.25	0.0457
3.	Phosphorus – 30kg/ha + Molybdenum – 50g/ha	140.80	55.20	13.67	0.0451
4.	Phosphorus – 40kg/ha + Molybdenum – 30g/ha	140.40	53.60	13.25	0.0450
5.	Phosphorus – 40kg/ha + Molybdenum – 40g/ha	141.60	56.60	14.04	0.0452
6.	Phosphorus – 40kg/ha + Molybdenum – 50g/ha	145.30	58.00	14.33	0.0450
7.	Phosphorus – 60kg/ha + Molybdenum – 30g/ha	142.60	57.40	14.29	0.0456
8.	Phosphorus – 60kg/ha + Molybdenum – 40g/ha	145.27	58.50	14.46	0.0450
9.	Phosphorus – 60kg/ha + Molybdenum – 50g/ha	146.10	59.20	14.67	0.0451
10.	Control Plot (RDF N: P: K-120:60:60 kg/ha)	137.20	51.52	12.93	0.0461
	F-test	S	S	S	NS
	Sem±	0.47	0.31	0.18	0.0008
	CD at 5%	1.41	0.93	0.55	—

phorus – 60kg/ha + Molybdenum – 50g/ha recorded significantly highest Number of cobs per plant (1.40). However, treatments with Phosphorus – 40 kg/ha + Molybdenum – 50 g/ha, Phosphorus – 60 kg/ha + Molybdenum – 30 g/ha and Phosphorus – 60 kg/ha + Molybdenum – 40 g/ha were statistically at par with the treatment Phosphorus – 60 kg/ ha + Molybdenum – 50 g/ha.

Application of P @ 75 kg ha^{-1} recorded highest values of yield attributes and yield of maize due to physiological process occur within a developing and maturing stages of plant. It is also involed in enzymatic reaction in plant and essential for cell division because it is a constituent element of nucleoproteins which are involved in the cell development (Onasanya *et al*., 2009).

Number of grains/pod: Treatment 9 with Phosphorus – 60kg/ha + Molybdenum – 50 g/ha recorded significantly highest Number of grains per cobs (269.67). However, treatments with Phosphorus – 40kg/ha + Molybdenum – 50g/ha and Phosphorus – 60kg/ha + Molybdenum – 40g/ha were statistically at par with the treatment Phosphorus – 60kg/ ha + Molybdenum – 50g/ha.

The application of Mo led to greater number of grains, regardless of the application form. According to Taiz and Zeiger (2009), by participating in the assimilation of N by plants, Mo may contribute to greater supply to this element to plants during the processes involved in grains formation, which may have favored the increase in number of grains by the application of this micronutrient.

Seed index (g): Highest seed index (22.55 g) was recorded in Treatment 9 with application of Phosphorus – 60 kg/ha + Molybdenum – 50g/ha, though there was significant difference among the treatments.

Table 2. Effect of phosphorus and molybdenum levels on Yield and Yield attributes of maize.

S. No.	Treatments	No. of cobs/ plant	No. of grains/ Cob	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Phosphorus – 30kg/ha + Molybdenum – 30g/ha	0.93	234.00	22.22	5.93	8.27	41.76
2.	Phosphorus – 30kg/ha + Molybdenum – 40g/ha	0.93	236.00	22.26	5.95	8.30	41.77
3.	Phosphorus – 30kg/ha + Molybdenum – 50g/ha	1.07	237.67	22.36	6.01	8.35	41.86
4.	Phosphorus – 40kg/ha + Molybdenum – 30g/ha	1.00	239.33	22.31	5.97	8.31	41.83
5.	Phosphorus – 40kg/ha + Molybdenum – 40g/ha	1.13	244.00	22.38	6.10	8.44	41.95
6.	Phosphorus – 40kg/ha + Molybdenum – 50g/ha	1.27	261.00	22.49	6.20	8.72	41.54
7.	Phosphorus – 60kg/ha + Molybdenum – 30g/ha	1.20	246.67	22.42	6.31	8.59	42.33
8.	Phosphorus – 60kg/ha + Molybdenum – 40g/ha	1.33	266.67	22.53	6.41	8.75	42.29
9.	Phosphorus – 60kg/ha + Molybdenum – 50g/ha	1.40	269.67	22.55	6.61	8.85	42.78
10.	Control Plot (RDF N: P: K-120:60:60 kg/ha)	0.87	232.00	22.19	5.82	8.16	41.64
	F-Test	S	S	NS	S	S	NS
	SEm(±)	0.08	3.81	0.10	0.08	0.10	0.46
	CD (p=0.05)	0.23	11.31	—	0.22	0.29	—

Table 3. Effect of phosphorus and molybdenum levels on Economics of maize.

Sl. No	Treatments	Cost of Cultivation	Gross returns	Net Return	B:C ratio
1.	Phosphorus – 30kg/ha + Molybdenum – 30g/ha	36721.20	118666.67	81945.47	2.23
2.	Phosphorus – 30kg/ha + Molybdenum – 40g/ha	37121.20	119066.67	81945.47	2.21
3.	Phosphorus – 30kg/ha + Molybdenum – 50g/ha	37521.20	120266.67	82745.47	2.21
4.	Phosphorus – 40kg/ha + Molybdenum – 30g/ha	37658.70	119466.67	81807.97	2.17
5.	Phosphorus – 40kg/ha + Molybdenum – 40g/ha	38058.70	122000.00	83941.30	2.21
6.	Phosphorus – 40kg/ha + Molybdenum – 50g/ha	38458.70	123933.33	85474.63	2.22
7.	Phosphorus – 60kg/ha + Molybdenum – 30g/ha	39533.70	126133.33	86599.63	2.19
8.	Phosphorus – 60kg/ha + Molybdenum – 40g/ha	39933.70	128266.67	88332.97	2.21
9.	Phosphorus – 60kg/ha + Molybdenum – 50g/ha	40333.70	132266.67	91932.97	2.28
10.	Control Plot (RDF N: P: K-120:60:60 kg/ha)	38333.70	116400.00	78066.30	2.04

* Data was not subjected to statistical analysis

Yield

Grain yield (t/ha): Treatment 9 with Phosphorus – 60kg/ha + Molybdenum – 50g/ha recorded the highest grain yield (6.61 t/ha). However, treatment with Phosphorus – 60 kg/ha + Molybdenum – 40g/ha was statistically at par with the treatment Phosphorus – 60 kg/ha + Molybdenum – 50g/ha.

The increase in seed yield due to Phosphorus application is attributed to source and sink relationship. It appears that greater translocation of photosynthates from source to sink might have increased Grain yield as Reported by (Sankadiya *et al.*, 2021) and Sharma *et al.* (2018).

Stover yield (kg/ha): Treatment 9 with Phosphorus – 60kg/ha + Molybdenum – 50g/ha recorded the highest stover yield (8.85 t/ha). However, treatments with Phosphorus – 40kg/ha + Molybdenum – 50g/ha, Phosphorus – 60kg/ha + Molybdenum – 30g/ha and Phosphorus – 60kg/ha + Molybdenum – 40g/ha were statistically at par with the treatment Phosphorus – 60kg/ha + Molybdenum – 50g/ha.

Higher straw yield at medium phosphorus level could be attributed to adequate and balanced nutrient supply over higher and lower levels.

Harvest Index (%): Treatment 9 with Phosphorus – 60kg/ha + Molybdenum – 50g/ha recorded the highest harvest index (42.78 %) and there was significant difference among the treatments.

Economics

Maximum gross return (INR 1,32,266.67), net return (INR 91,932.97) and B:C ratio (2.28) were recorded in treatment 9 (Phosphorus – 60 kg/ha + Molybdenum – 50 g/ha).

Conclusion

Based on my research trail, the treatment combination of 60 kg/ha Phosphorus with 50 kg/ha Molybdenum recorded higher grain yield and maximum net returns and benefit cost ratio in Maize crop.

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