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Effect of phosphorus and magnesium on growth and yield characteristics of Indian mustard (*Brassica juncea* L.) in Kanpur

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Abstract
A field experiment was conducted during *rabi* 2018-19 at Students' Instructional Farm, C.S. Azad University of Agriculture and Technology, Kanpur, U.P. to find out the "Effect of Phosphorus and Magnesium on growth, yield, nutrients uptake and quality characteristics of Indian mustard with twelve treatment combinations T_1: P_0 Mg_0, T_2: P_0 Mg_{15}, T_3: P_0 Mg_{30}, T_4: P_{20} Mg_0, T_5: P_{20} Mg_{15}, T_6: P_{20} Mg_{30}, T_7: P_{40} Mg_0, T_8: P_{40} Mg_{15}, T_9: P_{40} Mg_{30}, T_{10}: P_{60} Mg_0, T_{11}: P_{60} Mg_{15} and T_{12}: P_{60} Mg_{30} in factorial randomised block design with three replications. The result showed highest seed yield of (21.30 q ha^{-1}) at 60 kg P_2O_5 ha^{-1} and (20.38 q ha^{-1}) at 30 Mg ha^{-1} and stover yield of (67.90 q ha^{-1}) at 60 kg P_2O_5 ha^{-1} and (59.54 q ha^{-1}) at 30 Mg ha^{-1}. The interaction effect of phosphorus and magnesium on seed yield was 22.30 q ha^{-1} and on stover yield was 70.60 q ha^{-1}. Seed and stover yields increased due to combined effect of phosphorus and magnesium i.e. 66.44 and 69.95 per cent over control, respectively. Oil content, oil yield and protein content increased till P_{60} and Mg_{30} when used alone. However, it further increased when phosphorus and magnesium were applied together of Uttar Pradesh.

Keywords: Seed yield, stover yield, oil yield, protein and phosphorus

Introduction
Mustard is the major *rabi* oilseed crop of India and world. It occupies a prominent place being next to groundnut both in area and production in India. It belongs to family cruciferae. It is known by different common names Rai, Raya, Laha in India. It can be grown as pure crop or as intercrop. Rapeseed mustard group of crop is grown in more than 70 countries globally on an area of 34.74 million ha, with the production of 76.23 million tonnes of seed. Canada, China, India, France, Germany and Australia are the major producers which account for 76.26% of area under rapeseed mustard contributing about 73.85% of production. Canada ranks first in area with 8.44 million ha and in production with 21.32 million tonnes followed by China Singh *et al.*, (2021) [7].

In India, area, production and productivity of rapeseed mustard is 6.41 million ha, 6.33 million tonnes and 6979 kg ha^{-1} respectively according to the Solvent Extractor's Association of India (2020-21). India contributes about 18.45% of area and 8.30% production at global level. The mustard growing states in Indian are Rajasthan, Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Gujarat and West Bengal. Based on area and production of 2019-20, these states accounted for 81.90% of acreage and 86.96% of production. Rajasthan is India's top rapeseed and mustard producing state, followed by Madhya Pradesh and Haryana. Rajasthan alone accounted for 33% of acreage and 38.70% of production and Gujarat occupies first position as far as productivity is concerned with 1373 kg ha^{-1}. The total area and production of rapeseed-mustard in Uttar Pradesh was 0.78 million ha and 0.82 million tone in 2019-20 which increased to 0.9 million ha and 0.95 million tonne in 2020-21, respectively. Its cultivation extended to non traditional areas of southern states like Karnataka, Tamil Nadu, Andhra Pradesh and eastern states of India Anonymous, (2021) [1].

Materials and Methods
The experiment was conducted during *rabi* season of 2018-19 at Students' Instructional Farm, C. S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. Soil of the experimental plot was slightly alkaline in nature having organic carbon 0.42%, total nitrogen 0.03%, available P_2O_5 16.5 Kg ha^{-1}, available K_2O 131.50 kg ha^{-1}, pH 7.9, electrical conductivity 0.35 dS m^{-1}, permanent wilting point 6.3%, field capacity 18.4%, maximum water

holding capacity 29.5%, bulk density 1.46 Mg m^{-3}, particle density 2.56 Mg m^{-3} and porosity 42.9%. The experiment was conducted in a factorial randomized block design with 3 replications and 12 treatments *viz.* T_1: P_0 Mg_0, T_2: P_0 Mg_{15}, T_3: P_0 Mg_{30}, T_4: P_{20} Mg_0, T_5: P_{20} Mg_{15}, T_6: P_{20} Mg_{30}, T_7: P_{40} Mg_0, T_8: P_{40} Mg_{15}, T_9: P_{40} Mg_{30}, T_{10}: P_{60} Mg_0, T_{11}: P_{60} Mg_{15} and T_{12}: P_{60} Mg_{30}. The fertilizer used were Urea, DAP, Muriate of potash and $MgSO_4$. Mustard cv Rohini was sown in rows 45 cm apart using 5 kg seed ha^{-1} on 23.10.2018. Available moisture at sowing time upto 100 cm soil profile was 282.5 mm whereas amount of rainfall received during the crop period was 8.6 mm against the average annual rainfall of about 800 mm. Recommended package of practices were applied in different treatments. Soil moisture was monitored gravimetrically using the sample collected from 0-25, 25-50, 50-75 and 75-100 cm soil depths at regular monthly intervals to quantify the soil moisture content and growth parameters by randomly selecting three plants for each plots till the harvest.

The oil content of the oven dried seeds was estimated by extracting oil using petroleum ether (60-80 °C) as solvent and Soxhlet apparatus as given by Sadasivum and Manickam, (1992) [6]. The oil yield (kg ha^{-1}) was calculated using following formula:

Oil yield (kg ha^{-1}) = Seed oil content (%) x Seed yield (kg ha^{-1})

The data collected on growth and yield attributes were statistically analyzed (Fisher and Yates, 1958) [4]. Recommended package of practices and fertilizers doses were applied in different treatments.

Results and Discussion

Plant height (cm): Plant height at harvest stage showed increasing effect due to addition on phosphorus upto its highest level. However, significant response was recorded only upto 60 kg P_2O_5 ha^{-1}. Above 60 kg P_2O_5 ha^{-1} plant height increased but non-significantly. Effect of Mg on plant height showed similar response. Significant increase in plant height at this stage of crop showed only upto 30 kg Mg ha^{-1}. The obtained findings are akin with the findings of Singh *et al.*, (2017) [8].

Number of siliqua plant^{-1}: The number of siliquae per plant increased with different levels of P and Mg. The highest number of siliquae per plant was obtained at P_{60} and Mg_{30} ha^{-1}. The values were 251.33 and 238.25. The maximum number of siliquae was received at 60Kg Phosphorus + 30Kg Magnesium. The corresponding value was 260.00. Similar results were reported by Thaneshar *et al.*, (2017) [9].

No. of seed siliqua^{-1}: Different levels of P and Mg also increased the number of seed per siliqua being highest 19.09 and 18.37 at P_{60} and Mg_{30} levels. The maximum number of seeds per siliqua, 20.84 was obtained when at P_{60} + Mg_{30} combined. Similar results were reported by Vyas, (2015) [10].

Test Weight (g): Test weight (1000 seeds) of mustard also increased with each incremental dose of phosphorus and magnesium. The highest test weight was noted at 60 kg P_2O_5 ha^{-1} and 30 kg Mg ha^{-1}. The corresponding values were 4.73 and 4.57 g. The highest value of test weight of mustard was found when phosphorus + magnesium were applied together. The interaction effect gave a value of 4.77 g. 1000 seed weight which was 12.57 per cent higher to their respective control. Similar results were reported by Banjara *et al.*, (2017) [3].

Grain & stover yield (q ha^{-1}): The grain and stover yield of mustard increased with increase in phosphorus and magnesium levels. The highest grain yields 21.30 and 20.38 q ha^{-1} were obtained at 60 kg phosphorus and 30 kg magnesium. However, the highest seed and stover yields were recorded when phosphorus and magnesium was applied together. The highest seed yield was recorded at 60 kg P_2O_5 + 30 kg Mg ha^{-1} which was 66.44 per cent higher than at control. On the other hand the highest stover yield was produced by the application of 60 kg phosphorus + 30 kg magnesium which was also 69.95 per cent higher than at control. Similar results were reported by Bamboriya *et al.*, (2017) [2].

Oil content (%) & Oil yield (kg ha^{-1}): Oil content and oil yield of mustard also showed an incremental response to phosphorus and magnesium upto their highest level. The highest oil content of 35.40 and 34.48 per cent and oil yield of 754.75 and 705.73 kg ha^{-1} were obtained at 60 kg phosphorus and 30 kg magnesium ha^{-1}, respectively. The oil concentration and oil yield were found to be maximum when phosphorus and magnesium were used together at P_{60} + Mg_{30} level. Similar results were reported by Ranjan *et al.*, (2018) [5].

Protein content (%): Protein content in mustard seed enhanced with increase in levels of phosphorus and magnesium. The maximum protein content was noted at 60 kg phosphorus and at 30 kg magnesium ha^{-1} was applied individually. The corresponding values with P_{60} and Mg_{30} were 22.49 and 21.38 per cent which were 21.78 and 8.81 per cent higher to their respective controls. The maximum protein percent was achieved when P and Mg were applied simultaneously the value being 23.12 per cent which was 39.10 per cent higher to their respective control. Similar results were reported by Singh *et al.*, (2017) [8].

Table 1: Effect of phosphorus & magnesium on plant height, No. of siliqua plant^{-1} and No. of seed siliqua^{-1} under different treatments in Indian mustard

Levels	Plant height at harvest (cm)				Levels	No. of siliqua plant^{-1}				Levels	No. of seed siliqua^{-1}			
	Mg_0	Mg_{15}	Mg_{30}	Mean		Mg_0	Mg_{15}	Mg_{30}	Mean		Mg_0	Mg_{15}	Mg_{30}	Mean
P_0	99.40	103.50	105.35	102.75	P_0	202.00	209.00	212.00	207.66	P_0	11.50	12.75	14.75	13.00
P_{20}	104.70	109.10	109.59	107.79	P_{20}	218.00	227.00	231.00	225.33	P_{20}	13.80	17.05	17.15	16.00
P_{40}	107.65	111.80	113.40	110.95	P_{40}	232.00	243.00	250.00	241.66	P_{40}	15.20	19.55	20.75	18.50
P_{60}	109.30	113.20	113.50	112.00	P_{60}	240.00	254.00	260.00	251.33	P_{60}	16.45	20.00	20.84	19.09
Mean	105.26	109.40	110.46	-	Mean	223.00	233.25	238.25	-	Mean	14.23	17.33	18.37	-
	P	Mg		P x Mg		P	Mg		P x M		P	Mg		P x Mg

SE (m)	0.678	0.587	1.175	SE (m)	0.687	0.595	1.189	SE (m)	0.682	0.590	1.181
CD at 5%	2.002	1.734	NS	CD at 5%	2.027	1.755	3.510	CD at 5%	2.012	1.743	NS

Table 2: Effect of phosphorus & magnesium on Test weight, Grain yield and Stover yield under different treatments in Indian mustard

Levels	Test Weight (g)				Levels	Grain yield (q ha^{-1})				Levels	Stover yield (q ha^{-1})			
	Mg_0	Mg_{15}	Mg_{30}	Mean		Mg_0	Mg_{15}	Mg_{30}	Mean		Mg_0	Mg_{15}	Mg_{30}	Mean
P_0	4.23	4.29	4.31	4.28	P_0	13.40	14.55	17.78	15.24	P_0	41.54	44.76	48.92	45.07
P_{20}	4.43	4.45	4.53	4.47	P_{20}	15.90	18.25	20.94	18.36	P_{20}	46.10	52.90	54.95	51.31
P_{40}	4.58	4.66	4.70	4.65	P_{40}	18.74	20.40	20.50	19.88	P_{40}	51.56	61.20	63.70	58.82
P_{60}	4.68	4.74	4.77	4.73	P_{60}	20.05	21.55	22.30	21.30	P_{60}	64.16	68.96	70.60	67.90
Mean	4.48	4.53	4.57	-	Mean	10.02	18.68	20.38	-	Mean	50.84	56.95	59.54	-
	P	**Mg**		**P x Mg**		**P**	**Mg**		**P x Mg**		**P**	**Mg**		**P x Mg**
SE (m)	0.024	0.021		0.041	SE (m)	0.691	0.599		1.197	SE (m)	0.959	0.830		1.661
CD at 5%	0.071	0.061		NS	CD at 5%	2.041	1.767		NS	CD at 5%	2.830	2.451		NS

Table 3: Effect of phosphorus & magnesium on Oil content, Oil yield and Protein content under different treatments in Indian mustard

Levels	Oil Content (%)				Levels	Oil Yield (Kg ha^{-1})				Levels	Protein Content (%)			
	Mg_0	Mg_{15}	Mg_{30}	Mean		Mg_0	Mg_{15}	Mg_{30}	Mean		Mg_0	Mg_{15}	Mg_{30}	Mean
P_0	36.10	31.40	31.50	33.00	P_0	483.78	457.00	560.07	500.28	P_0	16.62	19.18	19.62	18.47
P_{20}	33.65	33.90	34.80	34.11	P_{20}	535.03	618.72	728.95	627.56	P_{20}	19.50	20.31	20.62	20.14
P_{40}	33.80	34.45	35.55	34.60	P_{40}	633.64	702.78	728.77	688.39	P_{40}	20.86	21.93	22.18	21.65
P_{60}	34.35	35.75	36.10	35.40	P_{60}	688.71	770.41	805.13	754.75	P_{60}	21.62	22.75	23.12	22.49
Mean	34.47	33.87	34.48	-	Mean	585.29	637.22	705.73	-	Mean	19.62	21.04	21.38	-
	P	**Mg**		**P x Mg**		**P**	**Mg**		**P x Mg**		**P**	**Mg**		**P x Mg**
SE (m)	0.718	0.622		1.244	SE (m)	3.821	3.309		6.618	SE (m)	0.519	0.362		1.179
CD at 5%	2.235	1.905		NS	CD at 5%	11.278	9.767		NS	CD at 5%	1.51	1.16		NS

Conclusion

Therefore, it may be concluded from the results of the present investigation that the application of phosphorus and magnesium levels in different combinations is essential to get highest yield of mustard. In this present study, addition of 60 kg phosphorus and 30 kg magnesium resulted in highest yields which could be practised by the cultivators, especially in Kanpur, Uttar Pradesh.

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