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Effect of phosphorus application options on productivity of cotton wheat cropping system and nutrient status of soil

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Abstract : Although cotton (C) and wheat (W) are exhaustive crops, the continuous application of phosphatic fertilizers contributed for the build up of soil phosphorus (P) levels. However, its availability to commercial cultivation is reduced by either fixation or precipitation process. Further, the literature on additional P application at high fertility levels is limited. Therefore, a series of field studies (2020- 2022) was conducted with cotton-wheat rotation to understand phosphorus role on yield in loamy soil of Indo-gangetic plain. There are nine treatment combinations of P with three replications. Yield parameters and nutritional status was determined for the cropping system. The results revealed that seed cotton yield and wheat grain yield parameters are varied with year to year and there is no consistent. Similarly, no significant differences observed with available P. Organic carbon was also found to increase with the application of recommended dose of fertilizer and inclusion of FYM. Thus, even the soil which have high available phosphorus status require P application in both season for heavy feeder crops like cotton and wheat for getting higher yield and maintaining P status of soil.

Keywords: Cotton, nutrient status, phosphorus, wheat, yield

Cotton is known as "White Gold" and cultivated as one of important cash crop throughout the world and India is no exception in harvesting the major economies in agriculture through this "King of Fibre". In India cotton covers the area of 123.72 lakh hectare while in Haryana it captured 6.36 lakh hectare area during 2021-2022. Wheat is staple cereal of India and majorly consumed in northern India. India is second largest producer of wheat and have highest acreage under wheat cultivation in world. The total area under the crop is about 29.8 million hectares in the country. The production of wheat in the country has increased significantly from 75.81 million tons in 2006-2007 to an all-time record high of 106.84 million tons in 2021-2022. The productivity of wheat which was 2602 kg/hectare in 2004-2005 has increased to 3521 kg/hectare in 2021-2022. The major increase in the productivity of wheat has been observed in the states of Haryana, Punjab and Uttar Pradesh (Ministry of Agriculture and farmer's welfare report).

Crop yield and soil nutrient status is influenced by P (Phosphorus) application even in high P status soil. Phosphorus is one of the essential elements and play pivot role in various plant metabolic processes and contributes in the synthesis of energy currency of cell, adenosine triphosphate (ATP), nucleic acids and proteins also (Heuer *et al.*, 2017). Compared to the its vast biological role, its availability is limited (~0.1%) in the soil and severely limits the yield of various field crops in tropical soils. (Granada *et al.*, 2018). Crop utilization of applied fertilizer phosphorus is generally low due to sorption and precipitation reactions in soils. Consequently, a large accumulation of phosphorus takes place over the years, particularly in the soils that receive regular and liberal rates of P applied to each crop in a cropping system. Cotton wheat cropping system is nutrient exhaustive in nature and every year it requires P application which is also a common practice among farmers and about two bag (100 kg) DAP is consumed/acre, every year. As a result, the build up of P was obtained in farmer's field and about 80 per cent

area is under medium to high level of available P. For getting high profitability and yield there is a need to apply right amount of P at right time. So, it is necessary to find out optimum amount of P required to apply in high P status under cotton-wheat cropping system.

MATERIALS AND METHODS

The present study was conducted at Soil Research Farm, Department of Soil Science, CCS HAU, Hisar, Haryana during 2019-2020 to 2022-2023 to study the effect of phosphorus application in the soil which have high phosphorus content. The experiment was conducted in randomized blocked design and replicated thrice with following treatments details:

T_1: Recommended dose fertilizers [(C+W)RDF]

T_2: Soil test based fertilizer recommendation [(C+W)STFR]

T_3: 50 per cent each [(C+W)50%]

T_4: Nil fertilizer and 100 per cent [C0+W100]

T_5: Full dose on alternate year and 100 per cent in every year [C100AY + W100EY)]

T_6: Full dose once in two year and 100% in every year [(C100TY+W100EY)]

T_7: Phosphorus solubilizing bacteria on each year and 100 per cent for [CPSB-EY +W100]

T_8: Full dose on every fourth year and 100 per cent on each year [(C100-4Y+W100EY)]

T_9: Nil fertilizer and 15 ton farm yard manure ha and combined 50 per cent of P [(C0+W15 t FYM+50% P)]

The varieties selected for wheat and cotton were WH 1105 and RCH 776 which were sown in first fortnight of November in both years for wheat and first week of May for cotton crop. The crop was cultivated as per the recommendations of HAU guidelines. All the cultural operations were done on time and both the crop, wheat and cotton were sown under irrigated conditions. In the first year of experimentation, during *rabi* season, recommended dose of phosphorus was appliedin all the treatments while in *kharif* season RDP was applied in all the treatments except treatments T_4, T_7 and T_9. In second year, phosphorus was applied only in T_1, T_2 and T_3 treatments as per the treatment formulation. The initial soil pH and EC was 8.20 and 0.27 d/Sm. Available nutrient content of soil was 129 kg/ha nitrogen, 42 kg/ha phosphorus, 304 kg/ha potassium and 0.44 per cent organic carbon. The soil samples were collected after two years for determining post-harvest nutrient status and standard procedures was adopted as outlined by Jackson *et al.*, 1973.

RESULTS AND DISCUSSION

Effect of phosphorus on crop yield

In the year 2021, the grain yield of wheat varied from 31.0 to 34.6 q/ha (Table 1.) under various treatments. Grain and straw yield of

Table 1. Effect of Phosphorus application on wheat yield in two consecutive years (q\ha) (2021)

Treatments	Wheat (2021)			Wheat (2022)		
	Grain	Straw	Harvest index (%)	Grain	Straw	Harvest index (%)
T1	32.4	48.0	40.30	46.5	70.7	39.68
T2	31.0	45.6	40.47	45.5	69.9	39.43
T3	31.6	47.0	40.20	44.0	66.4	39.86
T4	32.2	48.1	40.10	43.6	66.7	39.53
T5	32.0	47.5	40.25	46.0	69.8	39.72
T6	33.0	49.0	40.24	45.8	70.0	39.55
T7	32.1	48.2	39.98	44.2	66.5	39.93
T8	31.7	47.4	40.08	46.2	70.6	39.55
T9	34.6	52.6	39.68	42.4	64.0	39.85
CD (p=0.05)	1.73	2.01		2.0	2.1	

wheat was numerically less in T_2,T_3 and T_8 in comparison to other treatments. Significantly highest grain and straw yield of wheat (34.6 and 52.6 q/ha) was observed in T_9, where FYM was applied @ 15 t/ha along with 50 per cent of recommended dose of P. This was followed by the T_6 where full dose of P was applied in both *kharif* and *rabi* season, in this year. Grain yield of treatments T_1, T_4, T_5 and T_7 were statistically *on par* with each other. Similar trend was followed by straw yield and highest yield was obtained in the treatment T_9 (52.6 q/ha) which is followed by T_6 (49.0 q/ha), T_7 (48.2q/ha), T_4 (48.1 q/ha), T_1 (48.0 q/ha). This might be due to the improved soil physio-chemical properties and solubilization of native P in the presence of FYM. The acid release during mineralization of FYM helped in releasing the native P. The *kharif* application of FYM leads to congenial condition for P release due to faster mineralization of it. Similarly, Singh *et al.*, 2007, Devraj *et al.*, (2011), and Hoshamani *et al.*, (2013) observed increase in yield with inclusion of FYM and use of balance fertilization. The lower yield of wheat, then itsvarietal potential yield, was due to terminal heat in this year. The harvesting Index (H.I) varied from 39.68 to 40.47 per cent in 2021 and lowest was recorded in T9 treatment and highest in the treatment T_2. In the year 2022, the grain and straw yield pattern of wheat crop was astonishingly variant (Table 2) and higher yield was obtained in T_1 (46.5 q/ha) treatment which is followed by T_8 (46.2 q/ha) and T_5 (46.0 q/ha) treatments which was due to omission of phosphorus application in *kharif* season. Only 50 per cent P application leads to excessive mining of native P in *kharif* season hence less availability of P for next crop, thereby negatively affected the crop yield. The straw yield also varied in similar fashion with mean values from 42.4 to 46.5 q/ha. Devraj *et al.*, 2012 also reported higher seed cotton yield and wheat yield in

Table 2. Effect of Phosphorus application on cotton yield in two consecutive years (q\ha) (2022)

Treatments	Cotton (2021)			Cotton (2022)		
	Seed cotton	Stover	Harvest index (%)	Seed cotton	Stover	Harvest index (%)
T1	28.6	38.8	42.43	17.4	27.6	38.67
T2	28.2	38.2	42.47	17.8	28.1	38.78
T3	26.1	34.9	42.79	15.2	25.4	37.44
T4	24.0	32.2	42.70	13.1	24.1	35.22
T5	29.0	39.1	42.58	13.4	24.7	35.17
T6	28.3	38.5	42.37	13.0	24.0	35.14
T7	26.0	34.8	42.76	15.0	25.6	36.95
T8	28.7	39	42.39	13.8	24.8	35.75
T9	25.2	33.7	42.78	15.0	25.2	37.31
CD (p=0.05)	2.1	2.2		1.8	2.01	

Table 3. Effect of differential phosphorus application on available nutrient content

Treatments	Organic carbon (%)	Nitrogen(Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
T1	0.45	125.6	39.2	305
T2	0.45	126.0	37.4	298
T3	0.44	126.5	31.0	308
T4	0.44	127.2	29.5	308
T5	0.45	128.0	38.5	309
T6	0.45	128.0	38.7	308
T7	0.43	127.7	32.0	307
T8	0.43	127.8	38.2	307
T9	0.46	125.6	33.4	310
CD (p=0.05)	0.02	2.1	1.0	3.0

cotton-wheat system under balanced (RDF) fertilization in both the crops.

In the year 2021seed cotton yield varied from 24 (T_4) to 29 (T_5) q/ha. The treatments where no P (T_4, T_7, T_9) was applied in *kharif* season recorded lower yield. The Stover yield varied from 32.2 to 39.1 q/ha (Table 1.) among different treatments. In the consecutive next year, the yield of seed cotton varied from 25 (T_4) to 32 (T_5) q/ha and similar trend was observed for all the treatments. These results showed that the application of phosphorus in both the season, is inevitable for attaining higher yield. These results are in agreement with the findings of Grant *et al.*, 2001. Cotton being one of the exhaustive crop requires balanced nutrition and phosphorus is among the major primary nutrient and thus required in large quantity. In the present experiment, wherever there is application of phosphorus in both *kharif* and *rabi* season, maximum yield was obtained while in the treatment which receives phosphorus only in one season, either *rabi* or *kharif* have ancillary grain and straw and stover yield.

Effect of phosphorus on post harvest soil nutrient status

Post harvest available nutrient status differed significantly under the influence of imposed treatments. Available nitrogen and available potassium varied from 125.6 to 128.0 kg/ha and from 298 to 310 kg/ha, (Table 3) respectively. Highest value of soil available N was obtained in T_5 and T_6 treatments. This was due to lower uptake of nutrient in low yielding treatments resulting in more available N in soil. This was on par with T_7 and T_8 treatments. Phosphorus was found higher in T_1 treatment due to application of phosphatic fertilizer in both the seasons. T_1 was on par with T_9 where FYM was applied along with full dose of phosphorus in rabi season. The application of FYM leads to indirect addition of nutrient in soil and also moderate the release of nutrients present in soil from non-available form to available form (Meena *et al.*, 2014; Devraj *et al.*, 2013). These results were supported by the earlier findings of Das *et al.*, (2003) who reported that, soil available K was increased with the application of FYM over control. Similar results were also reported by Halemani *et al.*, (2004) and Singh *et al.*, 2006. Application of inorganic and organic fertilizers promotes soil microbial activity and diversity which ultimately improves soil fertility and productivity (Dong *et al.*, 2012; Chen *et al.*, 2015; Tian *et al.*, 2017). The available phosphorus varied from 29.5 to 38.7 kg/ha under different treatments and highest amount of available phosphorus was found in the treatment T_1 where RD phosphorus was applied in both the season as per the specification of each crop. Messiga *et al.*, (2010) found that a higher increase in Olsen P synchronized with higher P fertilization. Crop raising leads to uptake of soil nutrient from the soil and thus nutrient were removed from the soil which causes negative balance in soil and hence post-harvest nutrient status of experimental soil differ significantly. Potassium was higher in the experimental soil and even after the harvesting of crop it remained in high status. Organic carbon was not much affected by various practices except treatment (T_9) which had highest organic carbon (0.46 %) content which is due to the addition of FYM in this treatment. This was followed by T1 due to higher crop yield which also associated to increase in root and shoot biomass and more leaf fall of cotton in this treatment which led to more contribution of organic matter in soil and hence enhances soil organic carbon.

CONCLUSION

Phosphorus is essential element for optimum crop yield. Its quick transformation into non available form mandate its application as per the crop requirement. Cotton wheat cropping system is commercially important but exhaustive system which deplete the soil nutrient content and thus to acquire optimum yield in both crops regular and optimum

application of phosphorus is needed. Omission of phosphorus application in any of *kharif* and *rabi* season drastically affects the crop yield. Thus, this study emphasizes the recommended dose of application of phosphorus fertilizer in both season for better crop yield and sustainable soil fertility status.

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