The Bioscan 8(4): 1331-1335, 2013
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

UPTAKE OF NUTRIENTS BY WHEAT AS INFLUENCED BY LONG-TERM PHOSPHORUS FERTILIZATION

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KEYWORDS
Phosphatic fertilizers
Wheat
Nutrients uptake

Received on :
06.07.2013

Accepted on :
29.10.2013

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ABSTRACT

The study was undertaken to monitor the fate of applied P into its nutrition using a 40 years old long-term fertility experiment started since *rabi* 1968-69 with pearl millet-wheat cropping system for the present investigation during 2009 and 2010. All the water soluble phosphatic fertilizers (SSP, DAP, UAP) were found significantly superior over partially water soluble (nitrophosphate) and mineral acid soluble (RP) sources in terms of nutrients uptake by wheat. On an average, 45 to 55% increase of N, P and K uptake were found upon application of water soluble phosphatic fertilizers over mineral acid soluble sources viz. RP. With increasing levels of P from 60 to 120 kg P_2O_5 ha^{-1}, N, P, K and Mn uptake increased significantly, whereas, Fe, Zn and Cu uptake decreased significantly. The increase of 25.6 and 32.4 kg ha^{-1} N uptake, 4.9 and 6.5 kg ha^{-1} P uptake and 28.1 and 36.9 kg ha^{-1} K uptake was recorded with the application of 60 and 120 kg P_2O_5 ha^{-1} phosphatic fertilizers, respectively, over control. Cumulative mode of P application was found the best for NPK and Mn uptake by wheat as compared to direct and residual mode.

INTRODUCTION

Phosphorus is one of the major elements; the essentiality of which as a nutrient for plant growth is well established as it plays a vital role in the metabolism of plants. After nitrogen stress, P is the second most widely occurring nutrient deficiency in cereal systems around the world. It is also a structural component of metabolically active compounds present in plants (Tisdale *et al.*, 2002). However, its concentration and solubility in soils is low due to its interacting nature, and consequently P is a critical nutrient limiting plant growth. Thus, phosphate reactions in the soil have important implications for crop growth, its nutrition to plants and also fertilizer use efficiency. Due to its low solubility and interacting nature in soil, the efficiency of P fertilizers is quite low (Aulakh *et al.*, 2007). Eighty per cent of Indian soils are either low or medium in available P (Motsara, 2002). Availability of P to plants also varies with the nature of soil, fertilizers and reaction products, the solubility of which largely depends upon the ionic form of P present in the added fertilizer (Bahl and Singh, 1997). Long-term experiments reflect not only the crop response to current fertilizer application of varying solubilities but also the response to residual fertility from previous application. In addition, such experiments also make it possible to determine the long-term effects of soil fertility and nutrient balances between amount applied and those removed by crops over a long period which could not be obtained in a single crop experiment. Therefore, knowledge of the rate of increase or decrease of available P and the fate of residual P resulting from fertilization and crop removal is essential for long-term planning of fertilization strategies to sustain crop production. The P utilization by crop plants, its residual effects and accumulation in the soil have been studied extensively mostly from short-term or medium-term studies. There are very few reports on the effect of a long-term application of phosphatic fertilizers on grain yields, nutrient uptake and their effects on the same soil are largely unknown. Therefore, the present study was undertaken to study the effect of long-term P fertilization on nutrients (N, P, K, Fe, Mn, Zn and Cu) uptake by wheat.

MATERIALS AND METHODS

A long-term field experiment on pearl-millet-wheat rotation on the use of different levels of various phosphatic fertilizers applied under three modes was initiated in *rabi* 1968 at Soil Research Farm, CCS HAU, Hisar (Haryana). The field experiment was conducted with a fixed layout plan using split-plot design with two replications in 10 × 3.33 square metre plots. There were eleven treatment combinations related to sources (five) and three levels of P including one control (P_0) which were in main plots and three modes of P application were in sub-plots. Phosphorus @ 0, 60 and 120 kg P_2O_5 ha^{-1} was applied through nitrophosphate (20% N + 20% P_2O_5), single superphosphate (16% P_2O_5), diammonium phosphate (18% N + 46% P_2O_5), urea ammonium phosphate (28% N + 28% P_2O_5) and rock phosphate which is mineral acid soluble (20% P_2O_5) introduced later on in *rabi* 1978-1979. There were three modes of P application i.e. M_1 (Residual) - applied to *kharif* crop only (Pearl millet - *Pennisetum typhoides*), M_2 (Direct) - to *rabi* crop only (wheat - *Triticum aestivum*) and M_3 (Cumulative) - to both *kharif* and *rabi* crops.

Nitrogen was applied @ 150 kg ha^{-1} through urea as a basal dose in all the treatments after compensating the N added through the N containing phosphatic fertilizers. Potassium @ 60 kg K_2O ha^{-1} through muriate of potash (MOP) and 25 kg $ZnSO_4.7H_2O$ ha^{-1} were also given as basal doses. All the P, K, Zn and half of N were applied at the time of sowing of wheat and remaining half of N was top dressed at the time of first irrigation after 21 days of sowing. Wheat variety UP-2338 was sown. The crop was harvested at the time of maturity.

The representative straw and grain samples were collected treatment wise at the time of threshing of wheat. The samples were air dried for 24 hrs and finally in an oven at 60 ± 2°C for 48 hrs. These samples were ground in stainless steel grinder, and were analyzed for N, P, K, Fe, Mn, Zn and Cu by following the standard procedures as outlined by Jackson (1973). Analysed data of the aforesaid experimental trial were also pooled for the consecutive two years i.e. 2009 and 2010 and presented.

RESULTS AND DISCUSSION

Soil properties

The soil of the field at the start of the experiment was calcareous, sandy loam having pH 8.2, EC 0.67 dSm^{-1}, organic carbon 0.34%, $CaCO_3$ 1.7%, CEC 9.1 cmol(p^+) kg^{-1}, available N 173 kg ha^{-1} and available P 13.2 kg ha^{-1}. The soil of the field before sowing of wheat crop in 2009-10 was calcareous, sandy loam in texture having pH 7.6, EC 0.49 dSm^{-1}, organic carbon 0.39%, $CaCO_3$ 1.9%, CEC 12.4 cmol(p^+) kg^{-1}, available N 196 kg ha^{-1} and available P 19.4 kg ha^{-1} (Table 1). It was observed that pH of the soil decreased from 8.2 to 7.6 and available P status of the soil increased from 13.2 to 38.8 kg ha^{-1} with the application of P for 40 years where highest dose of P (120 kg P_2O_5 ha^{-1}) was applied. However, the $CaCO_3$, organic carbon, CEC, available N increased and EC decreased slightly without changing its texture (Table 1). Available P content of the soil decreased from its original level of 13.2 to 4.8 kg ha^{-1} where no P was added over the last 40 years.

Nutrients uptake

N uptake

The N uptake by wheat increased with the application of phosphatic fertilizers over the control. The water soluble sources were found superior than the partially water soluble and mineral acid soluble sources (RP). The increase of 25.3 kg ha^{-1} and 31.8 kg ha^{-1} N uptake was observed with the application of 60 kg and 120 kg P_2O_5 ha^{-1} phosphatic fertilizers, respectively, over the control. The application of 120 kg P_2O_5 ha^{-1} significantly increased the N uptake over 60 kg P_2O_5 ha^{-1} (Table 2). Nitrogen uptake by wheat followed the trend: DAP > SSP > UAP > nitrophosphate > RP. The application of DAP increased N uptake significantly over all other phosphatic fertilizers indicated that as water solubility of P fertilizers decreased, N uptake by wheat also decreased simultaneously. Garcia *et al*. (1995) reported that application of DAP significantly increased the N uptake by plant. Increase in N uptake with the increasing P levels was also reported by Dhindwal *et al*. (1992) and Shafshak *et al*. (2003). The interaction of N with P can be termed as the single most important nutrient interaction of practical significance in achieving consistently high yield of wheat (Aulakh and Malhi, 2005). Direct and cumulative modes of P application significantly increased N uptake over residual mode, suggesting that residual value of P fertilizers were relatively less in calcareous soils where large proportion of applied fertilizers converted to insoluble compounds. But after long-term application of P fertilizers, there was a buildup of labile P pool in soil, for that reason, residual mode of P application is highly superior over control in terms of N uptake by wheat.

P uptake

Results revealed that on an average, P uptake by wheat varied from 4.2 to 15.2 kg ha^{-1} with a mean value of 11.7 kg ha^{-1}. Application of all the P sources increased total P uptake by wheat over control and RP. The total P uptake was maximum with water soluble sources (SSP, DAP and UAP) followed by partially water soluble nitrophosphate and the least effective was insoluble RP. The trend of yield with respect to P sources also reflected in the total P uptake by wheat. Such a trend might be explained on the basis of availability of P and solubility of fertilizer in the soil system. Highly water soluble P sources added continuously on long-term basis to maintain available P levels in the soil system are able to maintain effective concentration of P in soil solution which might ultimately lead to its uptake by plants. In case of RP (water insoluble source) such concentration in soil solution phase might not be expected and hence very low uptake by the crop (Table 2). The highest total P uptake was recorded in case of SSP which was followed by UAP, DAP, nitrophosphate and RP. Sulphur containing P source SSP was found significantly superior over nitrophosphate and RP, but remained at par with UAP and DAP. It is evident from the results that in calcareous sandy loam soil, the effectiveness of phosphatic fertilizers decreased with decrease in their water soluble P content. Rishi and Goswami (1977) also reported increased plant utilization of added P by wheat with increasing water solubility. Increasing P levels significantly increased total P uptake by wheat. The increase of 4.9 and 6.5 kg ha^{-1} P uptake was observed with the application of 60 and 120 kg P_2O_5 ha^{-1} phosphatic fertilizers,

Table 1: Basic physico-chemical properties of soil

Properties	At initial (1968-69)	At present (2009-10)*
pH	8.2	7.6
EC (dS m^{-1})	0.67	0.49
$CaCO_3$ (%)	1.7	1.9
Organic C (%)	0.34	0.39
CEC (cmol(p^+)kg^{-1})	9.1	12.4
Available N (kg ha^{-1})	173.0	195.8
Available P (kg ha^{-1})	13.2	19.4
Available K (kg ha^{-1})	163.8	186.0

*60 kg P_2O_5 ha^{-1} treated plot

Table 2: Influence of different phosphatic fertilizers, their levels and modes of application on N, P and K uptake (kg/ha) by wheat

Treatments	N uptake				P uptake				K uptake			
	Modes			Mean	Modes			Mean	Modes			Mean
	D	R	C		D	R	C		D	R	C	
Control	27.6				4.2				34.0			
RP-60	28.3	23.4	31.2	27.6	4.7	3.8	6.0	4.8	34.1	30.5	40.1	34.9
RP-120	30.7	25.9	33.5	30.0	5.6	4.6	6.9	5.7	37.9	32.5	43.2	37.9
Mean	29.5	24.6	32.3	28.8	5.2	4.2	6.5	5.3	36.0	31.5	41.6	36.4
N Phos-60	58.1	51.2	63.1	57.5	9.2	8.1	10.3	9.2	64.6	55.5	74.5	64.9
N Phos-120	62.9	56.4	70.3	63.2	10.3	9.1	12.8	10.7	72.9	65.3	82.7	73.6
Mean	60.5	53.8	66.7	60.3	9.8	8.6	11.5	10.0	68.8	60.4	78.6	69.3
SSP-60	59.2	53.1	65.0	59.1	10.1	8.7	12.7	10.5	66.3	58.3	73.1	65.9
SSP-120	69.3	58.0	75.0	67.4	12.0	9.9	15.2	12.4	76.8	64.8	89.7	77.1
Mean	64.2	55.6	70.0	63.3	11.0	9.3	14.0	11.4	71.5	61.5	81.4	71.5
DAP-60	60.7	56.5	66.8	61.3	9.8	8.3	12.3	10.1	73.4	64.7	78.1	72.1
DAP-120	69.6	60.9	76.8	69.1	12.4	9.9	14.3	12.2	86.6	72.3	94.7	84.5
Mean	65.2	58.7	71.8	65.2	11.1	9.1	13.3	11.2	80.0	68.5	86.4	78.3
UAP-60	59.6	51.9	64.5	58.7	10.3	8.6	12.7	10.6	73.9	62.3	82.0	72.7
UAP-120	67.6	60.3	74.0	67.3	12.1	10.1	14.3	12.2	82.7	70.7	90.8	81.4
Mean	63.6	56.1	69.2	63.0	11.2	9.4	13.5	11.4	78.3	66.5	86.4	77.1
Overall mean	56.6	49.8	62.0	56.1	9.7	8.1	11.7	9.8	66.9	57.7	74.9	66.5
CD at 5%												
Sources	4.58				0.64				6.9			
Levels	2.9				0.4				4.36			
Modes	1.76				0.5				2.89			
Sources × levels	NS				NS				NS			
Sources × modes	NS				NS				NS			
Levels × modes	NS				NS				NS			
Sources × levels × modes	NS				NS				NS			

D = Direct, R = Residual, C = Cumulative

Table 3: Influence of different phosphatic fertilizers, their levels and modes of application on Fe, Mn, Zn and Cu uptake (g/ha) by wheat

Treatments	Fe uptake				Mn uptake				Zn uptake				Cu uptake			
	Modes			Mean	Modes			Mean	Modes			Mean	Modes			Mean
	D	R	C		D	R	C		D	R	C		D	R	C	
Control	652				164				187				27			
RP-60	1285	788	1536	1203	162	134	206	167	231	178	273	227	38	29	48	38
RP-120	768	517	1269	851	180	147	242	190	158	122	177	152	29	25	35	30
Mean	1,026	652	1,403	1,027	171	141	224	179	195	150	225	190	34	27	42	34
N Phos-60	1096	901	1231	1076	277	223	302	267	427	344	461	411	69	57	76	67
N Phos-120	997	847	1118	987	329	279	360	323	290	247	308	282	51	39	60	50
Mean	1,047	874	1,174	1,032	303	251	331	295	359	296	385	346	60	48	68	59
SSP-60	1383	1115	1210	1236	297	244	338	293	453	413	467	444	70	67	63	67
SSP-120	1033	937	974	981	364	307	416	362	333	319	340	331	56	52	55	54
Mean	1,208	1,026	1,092	1,109	330	275	377	328	393	366	404	387	64	60	59	61
DAP-60	1470	1387	1326	1394	271	231	296	266	407	399	409	405	62	63	64	63
DAP-120	1107	1168	1262	1179	346	268	386	333	342	308	348	333	50	51	48	50
Mean	1,288	1,278	1,294	1,287	309	249	341	300	375	353	378	369	56	57	56	56
UAP-60	1144	1237	1254	1212	282	240	296	273	386	360	353	366	65	60	56	60
UAP-120	983	1152	1077	1071	335	283	361	326	271	306	297	291	49	49	48	49
Mean	1,064	1,194	1,165	1,141	308	262	328	300	329	333	325	329	57	55	52	54
Overall mean	1,126	1,005	1,226	1,119	284	236	320	280	330	300	343	324	54	49	55	53
CD at 5%																
Sources	153				33				21				7			
Levels	97				21				13				5			
Modes	82				18				15				4			
Sources × levels	NS				NS				30				NS			
Sources × modes	184				NS				33				8			
Levels × modes	NS				NS				NS				NS			
Sources × levels × modes	NS				NS				NS				NS			

D = Direct, R = Residual, C = Cumulative

respectively, over control. These results are in conformity with the results obtained by Setia and Sharma (2007) and Kumar *et al.* (2008). Cumulative mode (11.74 kg ha^{-1}) of P application was significantly superior over direct (9.66 kg ha^{-1}) or residual mode (8.11 kg ha^{-1}) of P application in increasing P uptake by wheat. The maximum uptake was recorded at 120 kg P_2O_5 ha^{-1} level with SSP application in cumulative mode (15.20 kg ha^{-1}) and the minimum at 60 kg P_2O_5 ha^{-1} when RP was applied in residual mode (3.83 kg ha^{-1}). The residual effects of P fertilizers on total P uptake by wheat were also reported by Ryan *et al.* (2008).

K uptake

On an average, potassium uptake by wheat ranged from 30.5 to 94.7 kg ha^{-1}. The lowest potassium uptake (30.5 kg ha^{-1}) was obtained when RP was applied at the rate 60 kg P_2O_5 ha-

[1] under residual mode and highest potassium uptake (94.7 kg ha^{-1}) was obtained when DAP was applied at the rate 120 kg P_2O_5 ha^{-1} under cumulative mode. Increased application of phosphatic fertilizers significantly increased K uptake by wheat. The increase of 28.1 and 36.9 kg ha^{-1} K uptake was recorded with the application of 60 and 120 kg P_2O_5 ha^{-1} phosphatic fertilizers, respectively, over control. Application of phosphatic fertilizers significantly increased the K uptake by wheat over control. Application of DAP significantly increased K uptake by wheat than SSP, nitrophosphate and RP, whereas, DAP and UAP remained at par and application of UAP significantly increased K uptake than application of nitrophosphate and RP. Ammonium containing fertilizers like DAP and UAP were found superior than other phosphatic fertilizers might be due to release of some non-exchangeable potassium with the application of ammonium containing phosphatic fertilizers because ionic size of potassium is nearly same as ammonium.

Micronutrients uptake

Fe- Iron uptake by wheat followed the trend: DAP > UAP > SSP > nitrophosphate > RP and it ranged from 517 g ha^{-1} to 1536 g ha^{-1} with a mean value of 1119 g ha^{-1} (Table 3). The DAP significantly increased Fe uptake as compared to SSP, nitrophosphate and RP but UAP remained at par with DAP. The application of higher doses of phosphorus (120 kg P_2O_5 ha^{-1}) over lower doses (60 kg P_2O_5 ha^{-1}) significantly decreased Fe uptake by wheat in all the sources except in case of nitrophosphate. Cumulative mode of P application was found superior over direct and residual mode.

Mn- Manganese uptake by wheat ranged from 134 g ha^{-1} when RP was applied @ 60 kg P_2O_5 ha^{-1} in residual mode to 416 g ha^{-1} when SSP was applied @ 120 kg P_2O_5 ha^{-1} in cumulative mode. Mn uptake by wheat followed the trend: SSP > DAP = UAP > nitrophosphate > RP. The application of SSP, DAP and UAP was found significantly superior over partially water soluble nitrophosphate and mineral acid soluble RP. The application of higher doses of P fertilizers significantly increased Mn uptake by wheat than lower doses irrespective of all the sources. The increase in Mn uptake of 89 and 143 g ha^{-1} was observed with the application of 60 and 120 kg P_2O_5 ha^{-1} phosphatic fertilizers, respectively, over control. The higher uptake of Mn at higher doses of P application might be due to synergistic effect between P and Mn. The results of the present investigation are also in conformity with the findings of Murphy *et al.* (1981) and Tiwana and Narang (1997).

Zn- Zinc uptake by wheat ranged from 122 to 467 g ha^{-1} with a mean value of 324 g ha^{-1}. Zn uptake by wheat followed the trend: SSP > DAP > nitrophosphate > UAP > RP; SSP and DAP were found significantly superior over nitrophosphate, UAP and RP while DAP was remained at par with SSP. This indicated that water soluble sources of P fertilizers were significantly superior over less water soluble and water insoluble sources. Application 120 kg P_2O_5 ha^{-1} significantly decreased the Zn uptake by wheat over 60 kg P_2O_5 ha^{-1} and control irrespective of all the sources of P fertilizers. Cumulative mode of P application significantly decreased the Zn uptake by wheat than residual mode, whereas, direct and cumulative modes were remained at par. A significant decrease in Zn uptake with increased rate of P application also reported by Reddy and Yadav (1994) and Malewar (2003).

Cu- Copper uptake by wheat ranged from 25 to 70 g ha^{-1} with a mean value of 53 g ha^{-1} (Table 3). Copper uptake by wheat followed the trend: SSP > nitrophosphate > DAP > UAP > RP; SSP was found significantly superior over UAP and RP but remained at par with DAP and nitrophosphate. The increase of 32.2 and 19.5 g ha^{-1} Cu uptake by wheat was observed with the application of 60 and 120 kg P_2O_5 ha^{-1} phosphatic fertilizers, respectively, over control. However, the higher doses of P application significantly decreased Cu uptake by wheat than lower doses irrespective of the sources of phosphatic fertilizers. The decrease of Cu uptake by wheat with higher doses of P fertilization might be due to antagonistic effect between P and Cu P in plants.

All the water soluble sources were significantly superior to water insoluble source (RP) with respect to nutrients uptake by wheat. Effectiveness of nitrophosphate reached statistically at par with water soluble phosphatic fertilizers after 40 years of P fertilization. With increasing levels of P from 60 kg P_2O_5 ha^{-1} to 120 kg P_2O_5 ha^{-1} N, P, K and Mn uptake increased significantly, whereas, Fe, Zn and Cu uptake decreased significantly. Cumulative mode of P application resulted into significantly higher N, P, K and Mn uptake and lower Fe, Zn and Cu uptake by wheat.

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