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Effect of levels of phosphorus and solubilization of rock phosphate by spent wash on physico-chemical properties of soil by wheat (*Triticum aestivum* L.) In an inceptisol

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Abstract
The experiment were conducted field experiment at Agriculture Research Farm, Institute of Agricultural Science during 2014-15 and 2015-16. The experiments comprising five levels of phosphorus (control, 100% Recommended dose of N & K +50% P through SSP, 100% Recommended dose of N & K +75% P through SSP, 100% Recommended dose of N & K +50% P through rock phosphate and 100% Recommended dose of N & K +75% P through rock phosphate) in main plots and four levels of solubilization of rock phosphate treatments (control, RP:SW@1:10, RP:SW@1:40 and RP:SW@1:80) in sub-plots thereby making twenty treatment combinations were tested in split plot design with three replications. The variety HUW-468 (wheat) was sown in rows spaced at 22.5 cm, using the seed of 100 kg ha^{-1}. Results revealed indicate that solubilization of rock phosphate remained at par with RP:SW@1:80 but recorded significantly higher EC (dSm^{-1}), OC (%) and available N, P, K and S in soil as compared to remaining levels of rock phosphate and control and Results further indicate that solubilization of rock phosphate remained at par with RP:SW@1:80 but recorded significantly lower pH as compared to remaining levels of rock phosphate and control. Results revealed that application of 100% N&K + 75% P through SSP recorded significantly The application of 100% N&K + 75% P through SSP also recorded highest available N, P, K and S in soil found significantly superior to their lower levels.

Keywords: Rock phosphate, spent wash, nutrients, wheat

Introduction

Rock phosphate cheapest raw materials needed in the manufacture of phosphatic fertilizers like single super phosphate, nitro phosphates, diammonium phosphate etc. Apatites is a naruraly deposits P as commercial rock phosphate, apatites (P bearing minerals) along with other accessory minerals such as quartz, silicates, carbonates, sulphates, sesquioxides etc. Four types of rock phosphate minerals are 1. Fluoro apatite [$3Ca_3(PO_4)_2.CaF_2$], 2. Carbonate apatite [$3Ca_3(PO_4)_2.CaCO_3$], 3. Hydroxy apatite [$3Ca_3(PO_4)_2.Ca(OH)_2$] and 4. Sulpho apatite [$3Ca_3(PO_4)_2.CaSO_4$]. The apatites origin igneous and metamorphic is well-developed crystalline and generally less reactive. However, the apatites of sedimentary rock are major commercial importance due to soft minerals possessing micro-crystalline structure use for direct application in the soil (Biswas and Narayanasamy, 2002) [6].

In India, Total resources of rock phosphate and apatite as per UNFC system as on 1.4.2010 are placed at 296.3 and 24.23 million tonnes receptively and The consumption of apatite and rock phosphate in 2011-12 was about 3.96 million tonnes. Manufacturing P fertilizers only 39% is of high grade which could meet hardly 35-40% of the demand of P fertilizers, High-grade rock phosphate contain P_2O_5 >30% is (Indian Bureau of Mines 2014). The remaining P fertilizers import for met demand which increase the price of P fertilizers. It is well known that the rock phosphate could be applied as a source of P in acid soils but about two-third area of the country comes under soils which are either neutral or alkaline in reaction (Sreenivas and Narayanasamy 2003) [37]. Therefore, there is a need to generate technologies for solubilizing P from indigenous low-grade rock phosphate to be applied directly in these soils. In this direction, various efforts have made *viz*., acidulation (Bolland 1994; Narayanasamy and Biswas 1998) [7] and composting of rock phosphate with agricultural wastes (van de Berghe 1996) [39] *viz*., rice straw, coir dust, wheat straw, green manuring, farmyard manure and urine. While exploring other feasible options, it was thought that the spent wash (SW) i.e. distillery effluent, Spent wash (SW) is usually considered as waste of distillery processes contain high potassium content and can be classified as a dilute organic liquid fertilizer. In recent years, disposal of spent wash has an acute become problem due to expansion of distilleries in sugar cane growing countries. In India, about 246 distilleries from which 15,000 million liters of spent wash is produced annually. Spent wash characterized by foul odor, undesirable color, high chemical oxygen demand (COD: 25,000–30,000 mg l−1) and biological oxygen demand (BOD: 5,000–8,000 mg l−1) (Joshi *et al*. 1996) [18]. Such situation has created a problem of spent wash disposal with the expansion of distilleries of growing contries. Spent wash has generated in huge quantities (6.8xl010 L yr-1) in the country and highly acidic (pH 3.5-4.5) in nature and having considerable manurial potential (Chhonkar *et al*. 2000; Kumari and Phogat 2010) [8, 21], as well as problem of disposal. Spent wash is very harmful to aquatic fauna and flora if discharged directly into water bodies, land disposal is the only option. So, it will be worthwhile to study the effect of spent wash on P solubilization from indigenous low-grade rock phosphate. Spent wash has revealed that factors such as pH, electrical conductivity (EC), BOD, COD and the organic C, N, P and K contents may affect plant growth (Mahimairaja and Bolan, 1995) [27]. Low grade rock phosphate which is unacceptable to the P fertilizer industry and the spent wash-a foul smelling and problem of environmental pollution so, aimed at achieving an eco-friendly alternative for utilizing abundant resources.

P is one of the major nutrient elements for increasing crop growth and crop yield. Applied phosphorus fertilizers soluble forms of P rapidly become unavailable to plants and fixed in to soil by chemical adsorption and precipitation. Similarly, soil organic matters are immobilized organic P fractions in soil (Sanyal and De Dutta, 1991) [35]. When P is applied as phosphatic fertilizer in soil, its recovery very low (15-20%) in a growing season of crops. Most of the P (80%) gets rapidly fixed into soil as insoluble compounds as Fe-P and Al-P in acid soils and as Ca-P in alkaline. The soluble P in soil ranges from 0.05 to 10 ppm at any time, out of which only a small part is available to plant (Bhattacharyya and Jain, 2000) [5].

Materials and methods

Field Experiment conducted at Agriculture Research farm Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.). Which is situated at an altitude of meters above mean sea level and located between $25^0$18' North latitude and 80^0 36' East longitude. Varanasi falls in a semi-arid to sub humid climate with moisture deficit index between 20-40. The normal period for onset of monsoon in this region is the 3rd week of June which lasts up to end of September or sometimes extends up to the first week of October. Showers of rain are often experienced during winter season. The annual rainfall of this region is about 1100 mm. Generally, the maximum and minimum temperature ranged between 20^0 - 42^0 C and 9^0 - 28^0 C, respectively. May and June are the hottest months with maximum temperature ranging from 39^0 to 42^0 C. The cold period lies between November and January with minimum temperature varying between 9^0-10^0C. The mean relative humidity is about 68% which rise to 82% during wet season and goes down to 30% during dry season.

Sources

A. Rock Phosphate

Finely ground 100 mesh low grade Udaipur Rock Phosphate which is sold under the brand name 'Rajphos' was procured from Rajasthan State Mines and Minerals Ltd., Udaipur, Rajasthan.

B. Spent wash

The spent wash from different distilleries of K.M. Sugar Mill Faizabad, Utter Pardesh.

Fertilizer application

The sources used for applying nitrogen through urea. Murate of potash (MOP) used to supply K. Half dose of nitrogen given as basal application at the time of sowing. The remaining half dose of nitrogen was apply in equal two splits. The full dose of phosphorus and potassium was given as basal application at the time of sowing and thoroughly mix in the soil.

Soil analysis

Soil samples were collected from experimental site and brought into laboratory in a separate one kg polythene bag and dried at room temperature. After drying, broken clods were ground on wooden plank with wooden roller and passed through a 2 mm sieve. The soil samples were then stored in polythene bags. The homogenized soil samples were analysed for selected physico-chemical properties.

The analyzed of initial soil results of physical and chemical properties of soil and procedures adopted have been given in Table 1.

Treatments details

The experiments comprising five levels of phosphorus (control, 100% Recommended dose of N & K +50% P through SSP, 100% Recommended dose of N & K +75% P through SSP, 100% Recommended dose of N & K +50% P through rock phosphate and 100% Recommended dose of N & K +75% P through rock phosphate) in main plots and four levels of solubilization of rock phosphate treatments (control, RP:SW@1:10, RP:SW@1:40 and RP:SW@1:80) in sub-plots thereby making twenty treatment combinations were tested in split plot design with three replications.

Results

pH

Levels of phosphorus

The data presented in Table 2 regarding pH of soil after crop harvest indicate that application of different levels of phosphorus non-significantly decreased the soil pH during both the years as well as in pooled analysis. This fact has already been suggested by Joshi *et al*. (1996) [18], Chhonkar *et al*. (2000) [8], Vasanthy *et al*. (2004) [40]. Addition of single super phosphate (SSP) also resulted in reduction of soil pH from 7.72 to 7.64 due to its acidic reaction in the soil.

Solubilization of rock phosphate

The data (Table 2) indicate that the application of solubilizaton of rock phosphate at increasing levels brought significant decreased in soil pH in both the years as well as in pooled. The application of solubilization rock phosphate of B_4 (RP:SW @ 1:80) decreased soil pH by 4.79, 4.95 and 4.94 per cent during both the years and in pooled analysis, over B_1 (No SW), respectively. However, remained statistically at par with rest of the treatments. Addition of SW increased soil has also studied by Devarajan and Oblisami (1995) [9] and Kailasam *et al*. (2002) [19]. Micro-organisms released some concentration of organic acids by (Roy *et al*., 1999; Goenadi *et al*., 2000; Laxminarayana, 2005) [33, 12, 25] reason of the decreased soil pH may be within five days of incubation.

Electrical conductivity
Levels of phosphorus
It is obvious from Table 2 that ECe of soil recorded at harvest was not affected significantly with increasing levels of phosphorus over the years and in pooled also.

Solubilization of rock phosphate
A perusal of data in Table 2 revealed that the ECe of soil at harvest increased significantly with increase in rock phosphate of B4 (RP:SW@1:80) over control during both the years and in pooled analysis. The maximum ECe of soil was recorded under A_4 (RP:SW@ 1:80) and minimum under A_1 (control). The data showed 61.90 and 9.68, 56.00 and 21.88, 80.87 and 15.63 per cent increase in ESP of soil due to application of B_3 (RP:SW@ 1:40), respectively over No SW (B_1) and B_1 (RP:SW@ 1:10) during both the years and in pooled analysis and followed by B_4 (RP:SW@ 1:80). Accumulated high amount of soluble salts in the soil may be due to increase in EC with addition of SW. Annadurai *et al*. (1999) [1], Kayalvizhi *et al*. (2001) [20], Goyal *et al*. (2002) [14], Kailasam *et al*. (2002) [19] and Saliha (2003) [34] have also reported application of SW an increase EC of soil. Bhalerao *et al*. (2004) [4] has observed application of secondary treated bio-methanated effluent to the soil slight increase in EC of soil.
In rice poor growth by application of SW at higher rates studied (Behera and Mishra, 1982) [3]; in pearl millet, finger millet and black gram (Vijayakumari and Kumudha, 1990) [41], sugarcane (Senthil *et al*., 2001) [36] and maize (Patil *et al*., 2000) [32]. Goldschmidt and Mayber (1969) [13]. Joshi *et al*. (1996) [18], Nagappan *et al*. (1996) [30], Chhonkar *et al*. (2000) [8], Baskar *et al*. (2003) [2] and Vasanthy *et al*. (2004a) [40] have also studied very high values of EC of the spent wash. Baskar *et al*. (2003) [2] review that excessive BOD, COD and EC of spent wash

Organic carbon (%)
Levels of phosphorus
It is further apparent from the data (Table 2) that organic carbon of soil non-significantly influenced with the application of different levels of phosphorus in both the years as well as in pooled.

Solubilization of rock phosphate
It is evident from the data summarized in Table 2 that different solubilization of rock phosphate increased the organic carbon of soil significantly over control (B_1) during both the years and in pooled analysis. The data showed 34.38 and 16.22, 26.47 and 13.16, 30.30 and 13.16 per cent increase in OC of soil due to application of B_3 (RP:SW@1:40) during both the year and in pooled analysis, respectively over control (B_1) and RP:SW@1:10 (B_2) followed by B_4 (RP:SW@ 1:80). Organic carbon status of soils increasing by Distillery spent wash. these reported by Mattiazo and Ada Gloria, (1985), Devarajan *et al*. (1994) [10], Zalawadia *et al*. (1996), Annadurai *et al*. (1999) [1], Patil *et al*. (2000) [32], Baskar *et al*. (2003) [2], Saliha (2003) [34]. Manickam (1996). A Jeyaraman and Kannappan (2003) have stated that since spent wash is mainly a microbial residue and a plant extract contains more of organic carbon/organic matter. Majumdar *et al*. (2007) and Mahanta and Rai (2008) Application of PROM increased the organic carbon content in soil.

Available N
Levels of phosphorus
Data (Table 3) reflect that application of different levels of phosphorus significantly increased the available nitrogen content in soil after crop harvest during both the years of experimentation and in pooled analysis. However, the level A_3, A_4 and A_5 remained at par among them during both the years and in pooled. The application of A_2 (RD of N & K +50% P through SSP) registered a increase of 9.95, 10.15 and 10.05 per cent during 2014-15, 2015-16 and in pooled analysis, respectively available nitrogen content over A_1, respectively. A significant improvement in available N with SSP (phosphorus) and rock phosphate due to increased biological N fixation (kundu *et al*. 1979).

Solubilization of rock phosphate
It is explicit from the data (Table 3) that available nitrogen increased significantly with all the levels of solbilization of rock phosphate during both the years and in pooled also. The data further indicate that the magnitude of increase in nitrogen status of soil was found more under B4 (RP:SW@1:80) compared to B_1 (No SW), B_2 (RP:SW@1:10) and B_3 (RP:SW@1:40) over control. The maximum available nitrogen in soil recorded under B_4 was higher by 23.30, 23.37 and 23.33 per cent over control during both the years and in pooled analysis, respectively and all the levels differed significantly among them. (Zalawadia *et al*., 1997; Patil *et al*., 2000; Goyal *et al*., 2002; Baskar *et al*., 2003; Sukanya and Meli, 2004) [43, 32, 14, 2, 38] In soils applied with SW and RP+SW may be increased appreciable amount of N.

Available P_2O_5
Levels of phosphorus
Data (Table 3) reflect that application of different levels of phosphorus significantly increased the available phosphorus content in soil after crop harvest during both the years of experimentation and in pooled analysis. However, the level A_4 and A_5 remained at par among them during both the years and in pooled. The application of A_3 (RD of N & K +75% P through SSP) registered a increase of 22.46 and 9.46, 23.83 and 10.43, 23.17 and 10.13 per cent during 2014-15, 2015-16 and in pooled analysis, respectively available phosphorus content over A_1 and A_2, respectively.

Solubilization of rock phosphate
An examination of data in same table further revealed that available phosphorus status of soil increased significantly with increasing levels of rock phosphate in both the years as well as in pooled. The maximum (28.71, 29.02 and 28.87 kg/ha) available phosphorus content was noted under B_4 (RP:SW@1:80). The increase in available phosphorus content due to addition of B_4 over control (B_1), B_2 (RP:SW@1:10), B_3 (RP:SW@1:40) was 4.02, 10.25 and 18.93 per cent in year 2014-15, 4.35, 9.18 and 15.11 per cent in 2015-16 and 4.19, 9.73 and 16.98 per cent during pooled analysis, respectively.

Available K_2O
Levels of phosphorus
An examination of data in table 3 further revealed that available potassium status of soil increased significantly with increasing levels of phosphorus in both the years as well as in

pooled analysis. The maximum value (165.35, 169.41 and 167.38 kg/ha) available potassium content was noted under A_3 (100% RD of N & K +75% P through SSP). The increase in available potassium content due to addition of A_3 (100% RD of N & K + 75% P through SSP) over A_1 (control) and A_2 (100% RD of N & K +50% P through SSP) was 12.00 and 1.62, 11.99 and 1.90, 12.00 and 1.76 per cent during both the years and in pooled analysis, respectively.

Solubilization of rock phosphate

The perusal of data given in Table 3 shows that subsequent addition of rock phosphate significantly increased the available potassium during both the years as well as in pooled analysis. Significantly highest available potassium recorded at B_4 (RP:SW@1:80) which was higher by 4.18, 9.02 and 16.58 per cent in 2014-15, 3.72, 8.28 and 14.84 per cent in 2015-16 and 3.95, 8.65 and 15.70 per cent during pooled analysis over B_3, B_2 and B_1, respectively and all the levels differed significantly among them. Pathak *et al*. (1998) [31] has found that application of spent wash in soil appreciable increase in available K status ultimately increase the concentration of K in plant tissues. Spent wash is a very rich source of K. Dongale and Savant (1978) [11] Jadhav and Savant (1975) [16], Devarajan *et al*. (1994) [10] and Zalawadia and Raman (1994) [42]. Likewise, Kulkarni *et al*. (1987) [22] have classified spent wash high K content. PROM is prepared from high grade rock phosphate and organic matter (Kumawat *et al*. 2013) [23] solubilizing K from K-bearing minerals.

Available S

Levels of phosphorus

Data (Table 3) reflect that application of different levels of phosphorus significantly increased the available sulphur content in soil after crop harvest during both the years of experimentation and in pooled analysis. However, the level A_3, A_4 and A_5 remained at par among them during both the years and in pooled. The application of A_2 (RD of N & K +50% P through SSP) registered a increase of 23.92, 24.28 and 24.12 per cent during 2014-15, 2015-16 and in pooled analysis, respectively available sulphur content over A_1 (control), respectively.

Solubilization of rock phosphate

It is explicit from the data (Table 3) that available sulphur increased significantly with all the levels of solbilization of rock phosphate during both the years and in pooled also. The data further indicate that the magnitude of increase in sulphur status of soil was found more under B_4 (RP:SW@1:80) compared to B_1 (No SW), B_2 (RP:SW@1:10) and B_3 (RP:SW@1:40). The maximum available sulphur in soil recorded under B_4 was higher by 23.11, 19.68 and 21.30 per cent over control (B_1) during both the years and in pooled analysis, respectively and all the levels differed significantly among them.

Summary

Levels of Phosphorus

On pooled basis, the nitrogen, phosphorus, potassium and sulphur content in soil increased significantly upto 100% N&K + 75% P through SSP over lower level.

Solubilization of Rock Phosphate

Application of Solubilization of rock phosphate RP:SW@1:80 significantly higher EC (dSm^{-1}), OC (%) as compared to remaining levels of rock phosphate and control but recorded significantly lower pH as compared to remaining levels of rock phosphate and control.

Solubilization of rock phosphate at RP:SW@1:80 recorded significantly higher available N, P, K and S in soil as compared to remaining levels of rock phosphate and control.

Table 1: Physico-chemical properties of the initial soil

Properties	Value	Method followed
A. Mechanical properties		
a. Soil separates (%)		
Sand	57.68	Hydrometer method (Bouyoucos,1962
Silt	14.00	Hydrometer method (Bouyoucos,1962
Clay	28.32	Hydrometer method (Bouyoucos,1962
Textural class	**Sandy clay loam**	
B. Physical properties		
B_1. Bulk density(Mg m^{-3})	1.34	Pycnometer (Black, 1965)
B_2. Partical density (Mg m^{-3})	2.68	Pycnometer (Black, 1965)
B_3.WHC (%)	42.54	Keen-Rackzowski box (Black, 1965)
C. Electro-chemical		
C_1. Soil pH (1:2.5)	7.86	Glass electrode digital pH meter (Chopra and Kanwar, 1982)
C_2. Electrical conductivity (dSm^{-1}) (1:2.5)	0.14	Using EC meter (Sparks, 1996)
C_3. Organic Carbon, (%)	0.47	Walkley and Black (1934)
C_4. Available Nitrogen (Kg ha^{-1})	154.6	Alkaline permanganate method (Subbiah and Asija, 1956)
C_5. Available P_2O_5 (Kg ha^{-1})	17.2	Olsen's colorimetric method (Olsen *et al*., 1954)
C_6. Available K_2O (Kg ha^{-1})	156.7	Flame photometric method (Jackson, 1973)
C_7. Available S (Kg ha^{-1})	14.48	Turbiditymetric method (Chesin and Yein, 1952)

Table 2: Effect of levels of Phosphorus and Rock Phosphate solubilizing by Spent Wash on pH, EC and Organic Carbon in post-harvest soil

Treatments	pH			EC (dSm^{-1})			OC (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Main plot									
Control (Absolute)	7.72	7.68	7.70	0.29	0.32	0.30	0.37	0.37	0.37
100% RD of N & K +50% P through SSP	7.70	7.67	7.69	0.30	0.34	0.32	0.39	0.39	0.39
100% RD of N & K +75% P through SSP	7.69	7.66	7.68	0.30	0.34	0.32	0.39	0.40	0.40
100% RD of N & K +75% P through RP	7.67	7.62	7.65	0.31	0.35	0.33	0.40	0.40	0.40
100% RD of N & K +100% P through RP	7.64	7.60	7.62	0.31	0.35	0.33	0.40	0.41	0.41
SEm±	0.16	0.18	0.12	0.01	0.01	0.01	0.01	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	7.20	8.26	7.75	9.51	9.93	9.76	9.00	9.67	9.35
Sub plot									
No SW	7.87	7.84	7.86	0.21	0.25	0.23	0.32	0.34	0.33
RP:SW @ 1:10	7.73	7.69	7.71	0.31	0.32	0.32	0.37	0.38	0.38
RP:SW @ 1:40	7.64	7.59	7.62	0.34	0.39	0.37	0.43	0.43	0.43
RP:SW@ 1:80	7.51	7.47	7.49	0.35	0.40	0.38	0.44	0.44	0.44
SEm±	0.12	0.12	0.10	0.01	0.01	0.01	0.01	0.01	0.01
CD (p=0.05)	0.34	0.35	0.27	0.02	0.02	0.01	0.02	0.02	0.02
CV (%)	5.96	6.69	7.49	8.50	7.68	9.52	8.09	8.55	9.63

Table 3: Effect of levels of Phosphorus and Rock Phosphate solubilizing by Spent Wash on N, P, K and S in post-harvest soil

Treatments	N ($kg\ ha^{-1}$)			P ($kg\ ha^{-1}$)			K ($kg\ ha^{-1}$)			S ($kg\ ha^{-1}$)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Main plot												
Control (Absolute)	195.72	196.70	196.21	23.37	23.42	23.39	147.64	151.27	149.45	14.84	16.27	15.55
100% RD of N & K +50% P through SSP	215.19	216.66	215.93	26.06	26.26	26.16	162.71	166.25	164.48	18.39	20.22	19.30
100% RD of N & K +75% P through SSP	219.34	220.89	220.11	28.62	29.00	28.81	165.35	169.41	167.38	18.53	20.36	19.44
100% RD of N & K +75% P through RP	216.21	217.70	216.95	27.46	28.42	27.94	162.78	168.81	165.80	18.21	19.82	19.02
100% RD of N & K +100% P through RP	219.18	220.54	219.86	27.59	28.68	28.14	163.54	168.94	166.24	18.33	20.10	19.22
SEm±	5.73	6.16	4.21	0.77	0.84	0.57	4.14	4.21	2.95	0.58	0.55	0.40
CD (p=0.05)	18.69	19.41	12.41	2.50	2.63	1.67	13.50	13.26	8.71	1.89	1.74	1.18
CV (%)	9.32	9.95	9.64	9.99	10.66	10.34	8.94	8.84	8.89	11.35	9.89	10.59
Sub plot												
No SW	191.01	192.66	191.84	24.14	25.21	24.68	147.36	152.86	150.11	15.75	17.48	16.62
RP:SW @ 1:10	205.50	206.54	206.02	26.04	26.58	26.31	157.58	162.11	159.85	17.19	18.97	18.08
RP:SW @ 1:40	220.48	221.12	220.80	27.60	27.81	27.71	164.89	169.24	167.07	18.31	20.05	19.18
RP:SW@ 1:80	235.51	237.68	236.60	28.71	29.02	28.87	171.79	175.54	173.67	19.39	20.92	20.16
SEm±	4.92	4.94	3.78	0.38	0.41	0.36	2.35	2.21	1.98	0.36	0.29	0.28
CD (p=0.05)	14.20	14.21	10.59	1.09	1.18	1.01	6.78	6.36	5.54	1.05	0.84	0.78
CV (%)	8.93	9.78	10.61	5.47	6.42	8.01	5.67	5.69	7.30	7.96	6.37	9.00

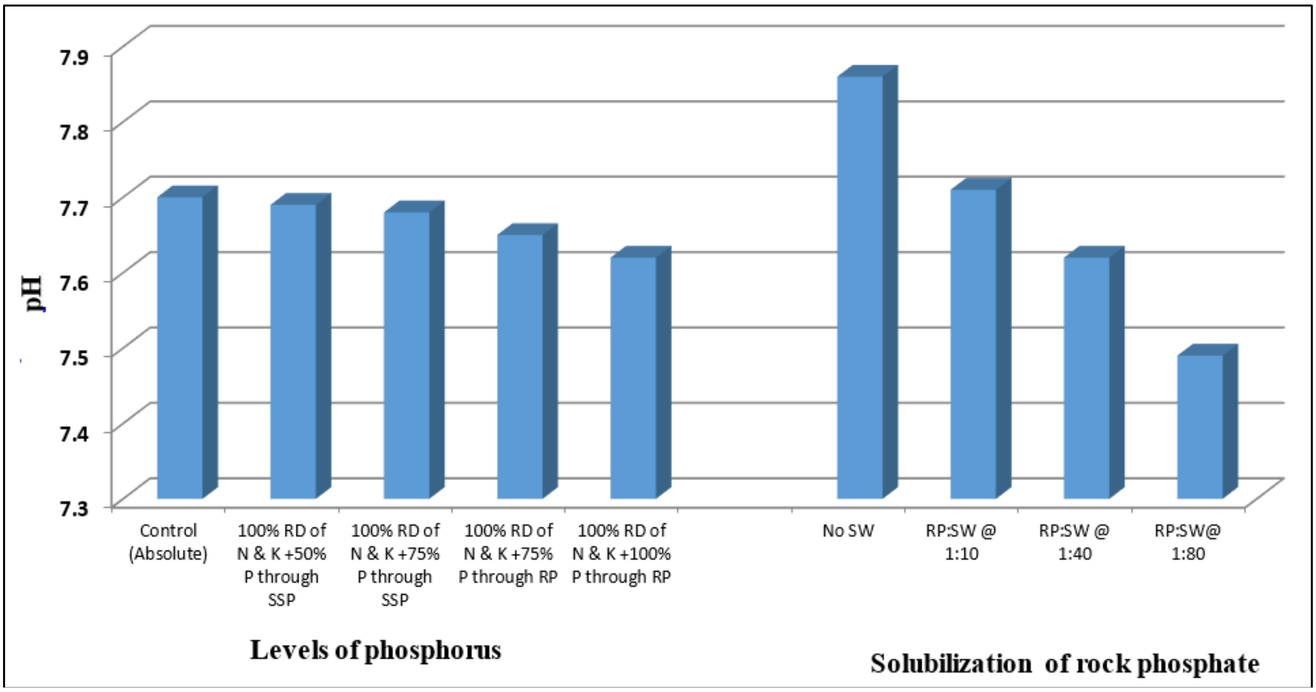

Fig 1: Effect of levels of Phosphorus and Rock Phosphate solubilizing by Spent Wash on pH in post-harvest soil (Pooled mean)

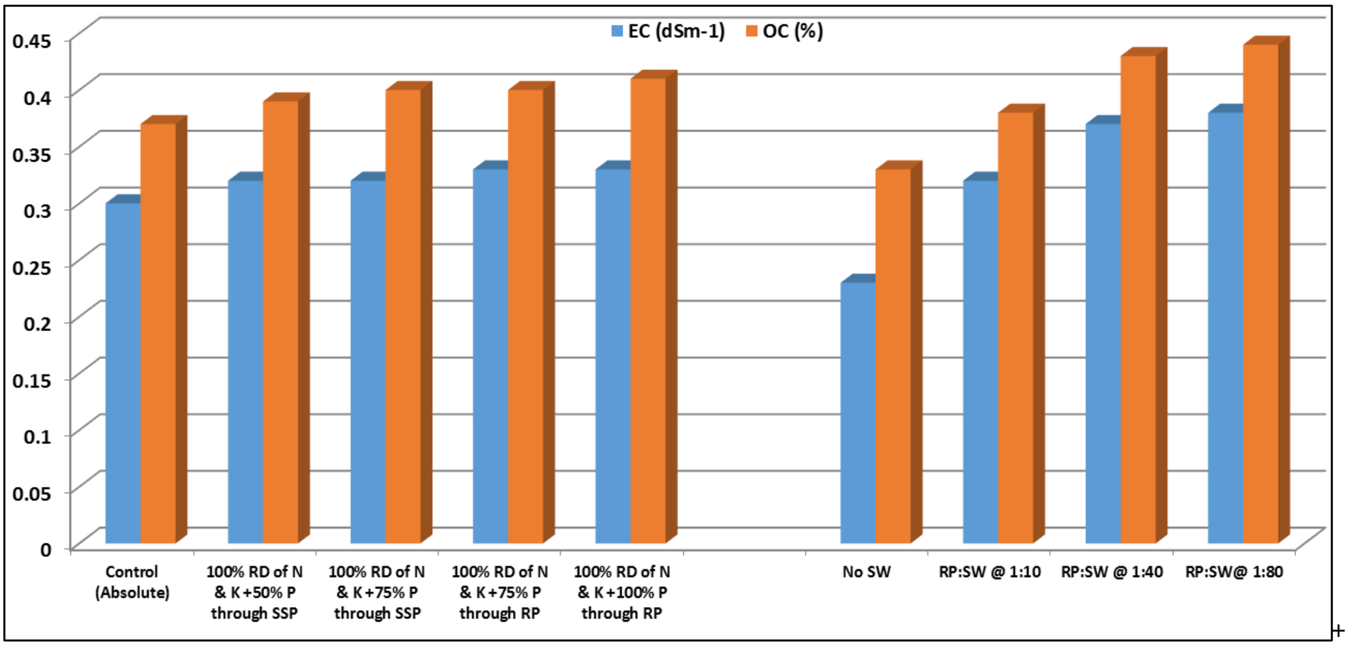

Fig 2: Effect of levels of Phosphorus and Rock Phosphate solubilizing by Spent Wash on EC and OC in post-harvest soil (Pooled mean)

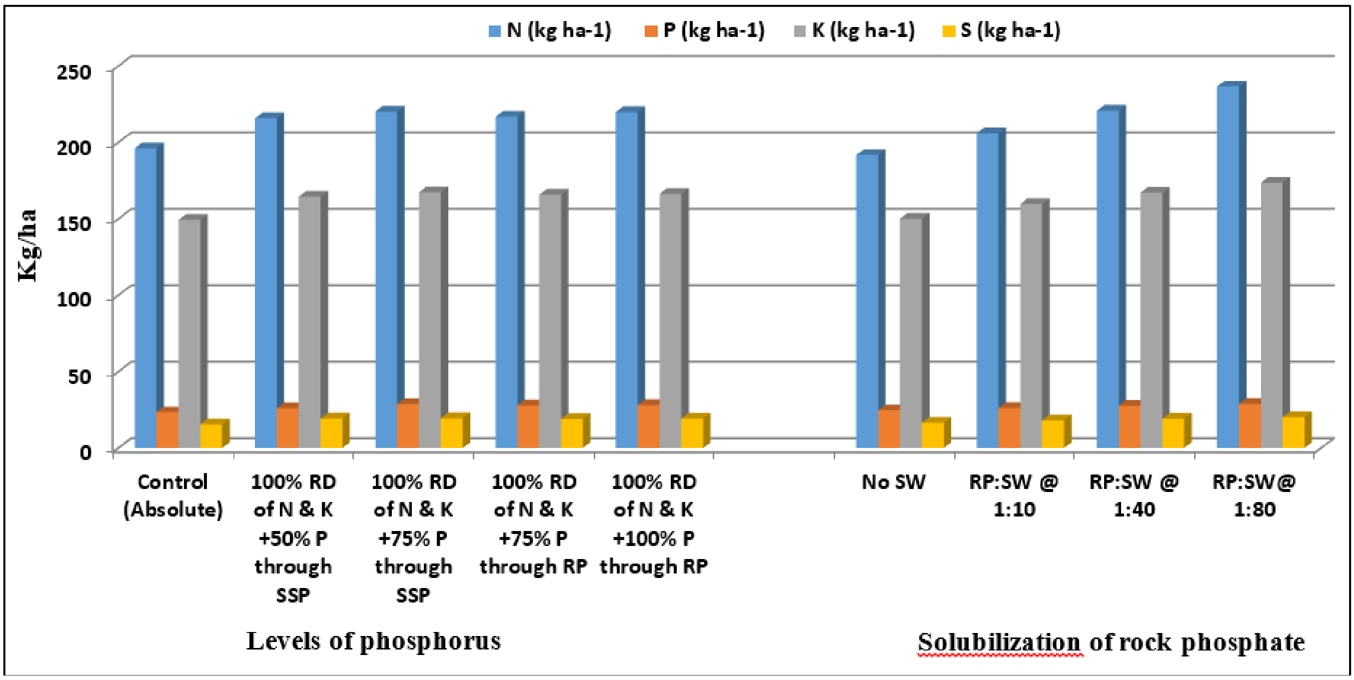

Fig 3: Effect of levels of Phosphorus and Rock Phosphate solubilizing by Spent Wash on N, P, K and S in post-harvest soil (Pooled mean)

Conclusion

Based on the results of present study, it may be concluded that phosphorus level i.e. 100% N&K + 75% P through SSP and application of rock phosphate @ RP:SW@1:80 proved to be the most economic proportion for realising higher Nurtrients as compared to other factors tried. The results emanated from present investigation have clearly established potential role of phosphorus and solubilization of rock phosphate in improving productivity of wheat. In long term the effect of solubilization rock phosphate may be visualized and doses of fertilizer (N&P) may be reduced to mitigate the ill effect of chemical fertilizers on soil health. Thus farmers of the zone may be encouraged to use rock phosphate in conjugation with fertilizers (N & P) to sustain the productivity of wheat crop.

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