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Effect of Phosphorus Levels and Phosphorus-Solubilization Rock Phosphate by Spent Wash on Growth and Productivity of Wheat

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was conducted 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 combinations of twenty treatment were tested in split plot design with three replications. Wheat HUW-468(variety) was sown seed of 100 kg ha^{-1} in rows spaced at 22.5 cm. Results revealed indicate that solubilization of rock phosphate remained at par with RP:SW@1:80 but recorded significantly higher plant height (cm), Total number of tillers/m row length, Chlorophyll content (SPAD), Test weight (gram), Grain yield, Straw yield and Biological yield (kg/ha) 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. Results revealed that application of 100% N&K + 75% P through SSP found significantly superior over the other level.

Keywords: Rock phosphate; SSP; spent wash; yield; wheat.

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1. INTRODUCTION

Wheat (*Triticum aestivum* (L.)) is main second most important cereals crop in India next to rice (*Oryza sativa* L.). It is widely grown different agro climatic zone and contributing about 35% of the food grain production. The annually 670 million tons wheat production in world. In the world After China India have 27.7 million hectares area and 77.6 million tonnes production of wheat. The major productivity of wheat has been observed in the states of Haryana, Punjab and Uttar Pradesh but in recent years higher area coverage is reported from MP. Uttar Pradesh has highest production (35.03%) of nation and also large area. In Uttar Pradesh has wheat production is 24.5 million tonnes, productivity of 2.7 tonnes/ha and area is 9.2 million ha. Wheat consumption shoot up further to 780 million tonnes in 2020. as against present area of 305.97 lac ha and production of 98.38 million tonnes [1]. There is clearly show that Uttar Pradesh as well as in the country productivity is very poor. In most agricultural soils Phosphorus (P) is second limiting plant nutrients in crop production after Nitrogen, [2]. Phosphorus is major nutrients largely required for the growth and development of crop. It have main role of photosynthesis, stimulating root growth and development, energy storage and transfer process. In wheat phosphorus initiate formation of seed and earlier maturity. Application of phosphorus fertilizer increased yield and yield attributes [3,4].Therefore, phosphorus is applied for supply of sufficient of soluble P for attain optimum productivity. Applied soluble forms of P by the phosphorus fertilizers rapidly become fixed in to soil by chemical adsorption and precipitation and unavailable to plants. In soil immobilized organic P fractions are soil organic matters [5]. P is major plant nutrient elements for enhance crop growth and yield. 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 in acid soils as Fe-P and Al-P and in alkaline as Ca-P. In soil soluble P ranges from 0.05 to 10 ppm, out of which only a small part is available to plant [6]. Mainly P in soil moves by Diffusion and the rate of diffusion is very slow (10-12 to 10-15 m^2 sec^{-1}). But uptake of P by crops is very high, than depleted of P around the roots zone. For maintain optimum P concentration in the root zone, becomes necessary to regularly use phosphatic fertilizers. Like N and K, P is also required in large amounts by crops, therefore, a high amount of phosphatic fertilizers is required for sustaining the crop production for growing population of the country. The major problem in decreased of production are reduce soil organic carbon status, nutrient mining, imbalanced use of fertilization, burning of crop residue leading to nutrient and organic carbon loss, lower down the water table and late sowing under rice/sugarcane-wheat and after potato in western Uttar Pradesh. Poor productivity may be ascribed to the poor efficiency and high fixation phosphorus in soil and low availability for crop. Increase the productivity of wheat can also be by the integrated and balanced use of fertilizers, improve variety and advance agronomic practices. Phosphorus play a vital role in root growth, tillering, energy transfer and storage, photosynthesis, enhancing earlier maturity and seed formation. P has also vital role in sustaining and improve fertility, particularly under intensive system of agriculture. Apply of P and K reduce lodging tendency and support tillering in wheat, improves photosynthesis resulting high grains [7] reported that adequate P application increase of 20% grain yield. Increased P applications than Nitrogen uptake could be increased. Chaturvedi [8] reported that optimum dose for growth, plant height, grains $spike^{-1}$, tillers, test weight, grain and straw yields was 28.5 kg P ha^{-1}. Jiang *et al.* [9] observed that higher tillers, leaf area index, ear bearing tillers and dry matter accumulation was 108 kg P ha^{-1} for. Khalid *et al.* [10] reported that obtained maximum productive tillers, grain yield and biological yield in wheat was 45 kg P ha^{-1}. In the above facts the present investigation entitled "Effect of different Phosphorus levels and solubilization of phosphorus by Spent Wash from Rock Phosphate on growth and yield of wheat in an Inceptisol" was conducted at field of Agriculture Research Farm, Institute of Agricultural Science, BHU, Varanasi (U.P.) during rabi seasons 2014-15 and 2015-16. with following objectives: To find out the effect of different Phosphorus levels and solubilization of phosphorus by Spent Wash from Rock Phosphate on growth and yield of wheat in an Inceptisol. To assess the effect of rock phosphate and spent wash on growth and yield by wheat.

2. MATERIALS AND METHODS

Field Experiment was conducted at Agriculture Research farm Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.). Which is located between $25^0$18' North latitude and 80^0 36' East longitude. Climatic condition of

the farm is semi-arid to sub humid and moisture deficit index between 20-40. In the Varanasi onset of monsoon is the 3rd week of June to end of September or somewhere this region up to the 1st week of October. In winter season Showers of rain are often. 1100 mm is the annual rainfall of Varanasi. In this region the maximum temperature ranged between 20^0 - 42^0C and minimum temperature ranged between 9^0-28^0 C, respectively. Hottest months are May and June and temperature ranged between 39^0 to 42^0 C. November and January are coldest month and minimum temperature varying between 9^0-10^0C. The relative humidity is varying from 68% to 82% and in dry season goes down to 30%.

2.1 Sources

2.1.1 Rock phosphate

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

2.1.2 Spent wash

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

2.1.3 Fertilizer application

Urea used as a sources of nitrogen and potash (K) sources is murate of potash (MOP) used. At the sowing time basal application of full dose of phosphorus and potassium and half dose of nitrogen use and thoroughly mix in the soil and remaining half dose of nitrogen divide in two equal portion and apply in to two splits

2.2 Treatments Details

The experiments making twenty treatment combinations 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 in sub-plots four levels of solubilization of rock phosphate treatments (control, RP:SW@1:10, RP:SW@1:40 and RP:SW@1:80) thereby they were tested in split plot design with three replications.

2.3 Analysis of Experiment Data

The experimental data were statistically analyzed to the Split Plot Design (SPD). The critical differences were calculated whereas "F" test was found significant and to draw the valid differences among the treatments [11].

3. RESULTS

3.1 Plant Height

Plant height (Table 1) of wheat revealed that increasing levels of phosphorus significantly increased the plant height. However, level of phosphorus 100% Recommended dose of N & K +50% P through rock phosphate and 100% Recommended dose of N & K +75% P through rock phosphate were remained at par. Plant height data up to the indicated that application P solubilization of spent wash and also resulted increase in plant height and the plant height due to SSP and RP and P level (SW+RP) are comparable. There was a significant increase in plant height with increase in levels of solubilization of rock phosphate in both the years and in pooled analysis. However, the increase was significant up to RP:SW @ 1:40 in both the years and pooled analysis which was at par with RP:SW@ 1:80 and was higher by 19.05 and 6.71 per cent at 30 DAS, 13.81 and 6.13 per cent at 60 DAS, 11.96 and 5.54 per cent at 90 DAS and 12.38 and 5.56 per cent at harvest during both the years and as well as pooled analysis over control and RP:SW @ 1:10, respectively.

3.1.1 Number of tillers per meter row

Application of 100% RD of N & K +75% P through SSP (Table 2) increased the total tillers to the extent of 36.72 and 10.87 per cent at 30 DAS, 21.76 and 9.61 per cent at 60 DAS, 21.74 and 9.88 per cent at 90 DAS and 20.21 and 9.12 per cent at harvest during pooled analysis, respectively over to control and 100% RD of N & K +50% P through SSP. Solubilization of rock phosphate RP:SW@1:40 significantly increased the total tiller to the extent of 14.11 and 6.58 per cent at 30 DAS, 12.07 and 5.84 per cent at 60 DAS, 14.43 and 6.55 per cent at 90 DAS and 13.95 and 6.84 per cent at harvest in pooled analysis, respectively as compared to No SW and RP:SW @ 1:10. No additional increase in total number of tiller was recorded om 1:80 RP:SW.

Table 1. Effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on plant height in wheat

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Main plot												
A_1 Control (Absolute)	24.71	25.28	25.00	59.48	60.28	59.88	88.6	88.6	88.6	88.55	89.19	88.87
A_2 100% RD of N & K +50% P through SSP	27.41	28.01	27.71	68.38	68.90	68.64	98.9	99.1	99.0	99.83	100.10	99.96
A_3 100% RD of N & K +75% P through SSP	30.48	31.09	30.78	75.86	76.98	76.42	107.9	109.1	108.5	109.54	110.74	110.14
A_4 100% RD of N & K +75% P through RP	28.91	30.37	29.64	72.93	73.67	73.30	105.4	105.7	105.6	105.30	106.13	105.72
A_5 100% RD of N & K +100% P through RP	29.50	30.50	30.00	75.85	76.69	76.27	107.8	108.6	108.2	109.07	110.15	109.61
SEm±	0.79	0.85	0.58	1.95	2.17	1.46	2.7	3.1	2.0	2.86	3.24	2.16
CD (p=0.05)	2.59	2.67	1.71	6.38	6.82	4.30	8.7	9.7	6.0	9.32	10.22	6.38
CV (%)	9.76	10.11	9.94	9.61	10.52	10.08	9.1	10.4	9.8	9.67	10.88	10.30
Sub plot												
B_1 No SW	25.60	25.41	25.51	64.71	66.16	65.44	95.1	95.6	95.3	95.34	96.15	95.75
B_2 RP:SW @ 1:10	27.89	29.02	28.46	69.67	70.69	70.18	100.9	101.3	101.1	101.44	102.41	101.93
B_3 RP:SW @ 1:40	29.82	30.91	30.37	74.14	74.81	74.48	106.5	106.8	106.7	107.48	107.71	107.60
B_4 RP:SW@ 1:80	29.49	30.86	30.18	73.48	73.56	73.52	104.4	105.1	104.7	105.57	106.78	106.18
SEm±	0.62	0.61	0.48	1.51	1.36	1.15	1.9	1.8	1.5	1.93	1.97	1.60
CD (p=0.05)	1.80	1.74	1.35	4.37	3.92	3.22	5.4	5.3	4.3	5.56	5.66	4.49
CV (%)	8.55	8.86	10.11	8.31	8.12	9.72	7.1	7.6	9.0	7.28	8.09	9.36

Table 2. Effect of levels of phosphorus and P solubilization by spent wash from rock phosphate on number of tillers m^{-1} row in wheat

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Main plot												
A_1 Control (Absolute)	34.45	35.98	35.21	86.77	87.11	86.94	80.56	80.90	80.73	65.91	67.30	66.60
A_2 100% RD of N & K +50% P through SSP	42.67	44.17	43.42	96.21	96.95	96.58	89.14	89.73	89.44	72.76	73.98	73.37
A_3 100% RD of N & K +75% P through SSP	47.38	48.89	48.14	105.52	106.21	105.86	97.66	98.89	98.28	79.52	80.59	80.06
A_4 100% RD of N & K +75% P through RP	46.47	48.07	47.27	102.75	104.36	103.55	96.39	98.45	97.42	78.37	79.06	78.72
A_5 100% RD of N & K +100% P through RP	47.10	48.22	47.66	104.55	105.38	104.96	97.06	98.55	97.80	78.47	79.37	78.92
SEm±	1.22	1.31	0.89	2.79	2.89	2.01	2.70	2.99	2.02	2.12	2.05	1.48
CD (p=0.05)	3.97	4.13	2.64	9.10	9.11	5.92	8.82	9.41	5.94	6.93	6.46	4.35
CV (%)	9.66	10.07	9.87	9.74	10.01	9.88	10.16	11.09	10.65	9.81	9.34	9.57
Sub plot												
B_1 No SW	40.24	41.81	41.03	92.36	93.44	92.90	84.55	85.65	85.10	69.19	70.15	69.67
B_2 RP:SW @ 1:10	43.15	44.71	43.93	97.98	98.76	98.37	90.90	91.87	91.39	73.67	74.95	74.31
B_3 RP:SW @ 1:40	46.05	47.59	46.82	103.56	104.65	104.11	96.76	97.99	97.38	78.81	79.96	79.39
B_4 RP:SW@ 1:80	45.01	46.15	45.58	102.74	103.15	102.95	96.44	97.71	97.08	78.36	79.18	78.77
SEm±	1.00	0.99	0.77	1.84	1.79	1.49	1.78	1.76	1.47	1.54	1.72	1.28
CD (p=0.05)	2.89	2.85	2.16	5.32	5.14	4.17	5.13	5.06	4.11	4.46	4.95	3.57
CV (%)	8.90	9.32	10.45	7.19	7.58	8.98	7.46	8.00	9.49	7.97	9.61	10.13

3.1.2 SPAD values

The maximum SPAD values (Table 3) was found under 100% RD of N & K +75% P through SSP and minimum under Absolute. The application of phosphorus of 100% RD of N & K +50% P through SSP registered 12.38, 11.52 and 11.95 per cent during both the years and in pooled analysis, respectively over control, respectively.The highest SPAD value were recorded under the application of RP:SW @ 1:40 which was higher by 16.70 and 7.66 per cent, 16.40 and 7.55 per cent and 16.57 and 7.62 per cent during 2014-15, 2015-16 and in pooled analysis, respectively over no SW and RP:SW @ 1:10 but it remained statistically at par with RP:SW @ 1:80.

3.1.3 Number of grains per ear

Number of grains per ear (Table 3) significantly increased with increasing levels of phosphorus during both the years as well as in pooled. The application of phosphorus of 100% RD of N & K +75% P through SSP registered 20.18 and 8.22, 19.03 and 8.51, 19.61 and 8.36 per cent higher number of grains per ear over control and Recommended dose of N & K +50% P through SSP, respectively. Data further significantly increase due to RP:SW @ 1:40 over No SW and RP : SW @ 1:10 were to the extent of 13.87 and 6.39, 13.57 and 6.04, 13.70 and 6.20 per cent during both years and in pooled analysis, respectively.

3.2 Test Weight

Level of phosphorus containing 100% RD of N & K +75% P through SSPwas recorded significantly higher test weight (Table 3). However levels of phosphorus 100% RD N & K +50% P through rock phosphate and 100% Recommended dose of N & K +75% P through rock phosphate were at par with each other during both the years and in pooled analysis. Application of 100% RD of N & K +75% P through SSP increased the test weight to the extent of 18.56 and 8.24, 18.86 and 8.53, 18.72 and 8.38 per cent during both the years and in pooled analysis, respectively over to control and 100% RD of N & K +50% P through SSP. Application of rock phosphate RP:SW @ 1:40significantly increased the test weight to the extent of 13.06 and 6.66, 14.95 and 6.05, 14.01 and 6.33 per cent during both the years and in pooled analysis, respectively as compared to No SW and RP:SW @ 1:10. But it remained statistically at par with RP:SW @ 1:80.

3.3 Grain Yield

It is apparent from the data (Table 4) that the grain yield of wheat increased significantly with application of phosphorus of 100% RD of N & K +75% P through SSP during both the years and in pooled analysis. The application of 100% RD of N & K +75% P through SSP increased the grain yield by 39.80 and 15.70, 37.60 and 14.04, 38.70 and 14.59 per cent during both the years and in pooled analysis, respectively over control and 100% RD of N & K +50% P through SSP. Rock phosphate application of RP:SW @ 1:40 gave significantly highest (53.64, 54.87 and 54.26 q ha^{-1}) grain yield during 2014-15, 2015-16 and in pooled, respectively as compared to preceding rock phosphate levels. The application of solubilization rock phosphate of RP:SW @ 1:40 increased grain yield by 26.03 and 5.01, 26.75 and 4.83, 26.42 and 4.93 per cent during both the years and in pooled analysis over No SW and RP:SW@1:10, respectively. However, remained statistically at par with RP:SW@1:80.

3.3.1 Interactive effect of level of phosphorus and solubilization of rock phosphate on grain yield(A x B)

Interactive effect of phosphorus and solubilization of rock phosphate on grain yield was found significant in the year 2014-15, 2015-16 and in pooled analysis (Table 4a). The critical examination of the data given in Table-4a indicate that under all the levels of phosphorus, grain yield increased significantly with increasing application of rock phosphate and spent wash ratio. The data further indicate that the extent of increase in grain yield with increasing solubilization of rock phosphate was less with higher level of phosphorus as compared to lower levels. Under 100% RD of N & K +75% P through SSP, the application of RP:SW @ 1:40 increased the grain yield to the extent of 52.26, 21.97 and 50.78 and 20.15, 51.51 and 21.04 per cent during both the year and in pooled analysis, respectively over (100% RD N & K +50% P through SSP + RP:SW @ 1:40) and (control + no SW). Although the highest value of grain yield was recorded under (100% RD of N & K +75% P through SSP + RP:SW @ 1:40).

3.4 Straw Yield

The phosphorus levels applied @ 100% RD of N & K +75% P through SSP increased the straw yield by 40.59 and 17.88, 38.94 and 17.29, 39.74 and 17.57 per cent during both the years and in

Table 3. Effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on Chlorophyll content (SPAD value), Number of grain ear^{-1} and Test weight in wheat

Treatments	SPAD value at 60 DAS			Number of grains ear^{-1}			Test weight (g)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Main plot									
A_1 Control (Absolute)	30.78	31.00	30.89	44.05	45.30	44.67	33.68	34.26	33.97
A_2 100% RD of N & K +50% P through SSP	34.59	34.57	34.58	48.92	49.69	49.31	36.89	37.52	37.21
A_3 100% RD of N & K +75% P through SSP	36.29	36.40	36.35	52.94	53.92	53.43	39.93	40.72	40.33
A_4 100% RD of N & K +75% P through RP	35.78	35.79	35.79	51.40	52.56	51.98	39.33	39.77	39.55
A_5 100% RD of N & K +100% P through RP	36.16	36.31	36.24	52.69	53.77	53.23	39.50	40.25	39.88
SEm±	0.96	1.12	0.74	1.25	1.34	0.92	0.93	1.02	0.69
CD (p=0.05)	3.13	3.52	2.17	4.01	4.21	2.70	3.03	3.21	2.03
CV (%)	9.57	11.12	10.38	8.67	9.06	8.87	8.49	9.15	8.83
Sub plot									
B_1 No SW	31.55	31.71	31.63	46.22	47.17	46.70	35.15	35.25	35.20
B_2 RP:SW @ 1:10	34.20	34.32	34.26	49.47	50.52	50.00	37.26	38.21	37.74
B_3 RP:SW @ 1:40	36.82	36.91	36.87	52.63	53.57	53.10	39.74	40.52	40.13
B_4 RP:SW@ 1:80	36.32	36.31	36.32	51.67	52.93	52.30	39.32	40.05	39.69
SEm±	0.89	0.90	0.68	1.09	1.04	0.82	0.61	0.58	0.50
CD (p=0.05)	2.57	2.58	1.90	3.15	2.99	2.29	1.77	1.67	1.39
CV (%)	9.92	10.92	11.73	8.44	8.64	9.70	6.26	6.40	7.81

Table 4. Effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on yields and HI in wheat

Treatments	Grain yield (q/ha)			Straw yield (q/ha)			Biological yield (q/ha)			Harvest index (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Main plot												
A_1 Control (Absolute)	39.32	40.43	39.87	57.50	58.55	58.03	96.83	98.97	97.90	40.75	40.98	40.86
A_2 100% RD of N & K +50% P through SSP	47.73	48.78	48.26	68.58	69.36	68.97	116.31	118.14	117.22	40.97	41.23	41.10
A_3 100% RD of N & K +75% P through SSP	54.97	55.63	55.30	80.84	81.35	81.09	135.81	136.98	136.40	40.27	40.40	40.33
A_4 100% RD of N & K +75% P through RP	53.57	54.33	53.95	76.38	78.89	77.64	129.95	133.22	131.59	41.19	40.76	40.98
A_5 100% RD of N & K +100% P through RP	54.86	55.58	55.22	78.38	80.20	79.29	133.24	135.77	134.51	41.19	40.96	41.07
SEm±	1.25	1.37	0.93	1.80	1.83	1.28	2.37	2.78	1.83	1.00	1.11	0.75
CD (p=0.05)	4.08	4.32	2.74	5.86	5.78	3.79	7.74	8.76	5.39	NS	NS	NS
CV (%)	8.66	9.32	9.00	8.60	8.62	8.61	6.71	7.73	7.25	8.46	9.44	8.96
Sub plot												
B_1 No SW	42.56	43.29	42.92	65.78	66.78	66.28	108.34	110.07	109.21	39.59	39.64	39.62
B_2 RP:SW @ 1:10	51.08	52.34	51.71	73.15	74.25	73.70	124.23	126.59	125.41	41.09	41.33	41.21
B_3 RP:SW @ 1:40	53.64	54.87	54.26	76.05	77.49	76.77	129.69	132.36	131.03	41.28	41.39	41.33
B_4 RP:SW@ 1:80	53.08	53.29	53.18	74.37	76.15	75.26	127.45	129.44	128.44	41.53	41.10	41.32
SEm±	0.87	0.86	0.70	0.98	1.12	0.90	1.91	1.82	1.48	0.79	0.77	0.61
CD (p=0.05)	2.50	2.46	1.97	2.84	3.22	2.52	5.53	5.23	4.14	NS	NS	NS
CV (%)	6.69	7.13	8.34	5.27	6.45	7.39	6.06	6.20	7.18	7.45	7.98	9.00

Table 4(a). Interaction effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on Grain yield in wheat

Treatments	B_1 No SW	B_2 RP:SW @ 1:10	B_3 RP:SW @ 1:40	B_4 RP:SW@ 1:80
	2014-15			
A_1 Control (Absolute)	37.19	40.12	40.66	39.32
A_2 100% RD of N & K +50% P through SSP	41.12	48.84	50.76	50.19
A_3 100% RD of N & K +75% P through SSP	42.52	54.29	61.91	61.16
A_4 100% RD of N & K +75% P through RP	45.95	55.46	56.65	56.21
A_5 100% RD of N & K +100% P through RP	46.01	56.69	58.20	58.52
SEm±	1.94			
CD (p=0.05)	5.59			
	2015-16			
A_1 Control (Absolute)	39.07	40.98	41.49	40.16
A_2 100% RD of N & K +50% P through SSP	42.21	50.11	52.07	50.74
A_3 100% RD of N & K +75% P through SSP	42.55	56.09	62.56	61.33
A_4 100% RD of N & K +75% P through RP	46.38	56.96	58.23	55.75
A_5 100% RD of N & K +100% P through RP	46.25	57.58	60.02	58.46
SEm±	2.10			
CD (p=0.05)	4.23			
	Pooled			
Control (Absolute)	38.13	40.55	41.08	39.74
A_1 Control (Absolute)	41.66	49.48	51.42	50.47
A_2 100% RD of N & K +50% P through SSP	42.54	55.19	62.24	61.25
A_3 100% RD of N & K +75% P through SSP	46.17	56.21	57.44	55.98
A_4 100% RD of N & K +75% P through RP	46.13	57.14	59.11	58.49
SEm±	1.72			
CD (p=0.05)	4.77			

pooled analysis, respectively over control) and 100% RD of N & K + 50 % P through SSP (Table 4). With the increase in levels of solubilizaton of rock phosphate from no SW to 1:80, a significant increase in straw yield was observed. The application of solubilization of rock phosphate @ RP:SW @ 1:40 increased the straw yield by 15.61 and 3.96 and 16.04 and 4.36, 15.83 and 4.17 per cent during both the years and in pooled analysis over no SW and RP:SW @ 1:10, respectively.

3.4.1 Interactive effect of level of phosphorus and solubilization of rock phosphate on straw yield(A x B)

Irrespective of all the phosphorus levels, all the increasing levels of solbilization of rock phosphate gave significantly higher straw yield over control. Similarly, irrespective of rock phosphate, the application of different levels of phosphorus enhanced the straw yield of wheat over control (Table 4b). The pooled data further indicate that the extent of increase in straw yield with the application of all phosphorus levels was higher with higher levels of rock phosphate as compared to lower levels. The magnitude of increase in straw yield with increasing levels of solubilization of rock phosphate was higher at application of RP:SW @ 1:40. The maximum yield was recorded under application of 100% RD of N & K +75% P through SSP + RP:SW@ 1:40, while minimum under control + No SW during both the years and in pooled analysis.

3.5 Biological Yield

The application of 100% RD of N & K +75% P through SSP increased significantly the biological yield by 40.26 and 16.77, 38.41 and 15.95, 39.33 and 16.36 per cent during both the years and in pooled analysis, respectively over control and 100% RD of N & K +50% P through SSP (Table 4). However, 100% RD of N & K +50% P through rock phosphate and 100% RD of N & K +75% P through rock phosphate were remained at par with each other. Rock phosphate application of RP:SW @ 1:40 gave significantly highest (129.69, 132.36 and 131.03 q ha^{-1}) biological yield during 2014-15, 2015-16 and in pooled, respectively as compared to preceding rock phosphate levels. The application of solubilization rock phosphate of RP:SW @ 1:40 increased biological yield by 19.71 and 4.40, 20.25 and 4.56, 19.98 and 4.48 per cent during both the years and in pooled analysis, over No SWand RP:SW@1:10, respectively. However, remained statistically at par with RP:SW@ 1:80 [12].

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3.5.1 Interactive effect of level of phosphorus and solubilization of rock phosphate on biological yield(A x B)

The interaction effect of combined application of phosphorus levels and solubilization of rock phosphate was also significantly influenced the yield during both the years and in pooled analysis (Table 4c). The combined application was significantly maximum biological yield was recorded as 143.78, 144.99 and 144.39 q ha^{-1} under the treatment 100% RD of N & K +75% P through SSP + RP:SW@ 1:40 during 2014-15, 2015-16 as well as pooled analysis, respectively [12].

3.5.2 Harvest index (%)

Increasing levels of applied phosphorus and solubilization of rock phosphate did not differ significantly in all the levels during both the years and in pooled analysis but showed increasing trend in both the years and in pooled mean.

4. DISCUSSION

4.1 Growth Parameters

Source and sink are related the most significant aspect of inter dependency of structure and function. The sink (number and size of grain) influences the photosynthesis and its rate of transport of photosynthates to storage organs. Evidently, efforts to bring about higher values of sink would hang its relationship that harvest index high. Higher plant population due to phosphorus application increases inter plant competition so that the total dry matter is high with the same amount of grain yield, thus lowering the harvest index.

Apply 100% N&K + 75% P through SSP had significantly increased all growth parameters the due to this treatment over rest of the treatment. Increased supply of phosphorus might have early root initiation and well establishment of the crop thereby increased growth parameters. Phosphorus also helps in cell division and vigorous plant growth. Phosphorus stimulating root growth and development. Thus, the combined application of phosphorus at higher level higher plant height, number of tillers and dry mater at lower levels. So that overall growth parameters with application of phosphorus conformed by Ghosh et al. [13], Singh et al. [14]

Table 4(b). Interaction effect of levels of Phosphorus and P solubilization by spent wash from rock phosphate on straw yield in wheat

Treatments	B_1 No SW	B_2 RP:SW @ 1:10	B_3 RP:SW @ 1:40	B_4 RP:SW@ 1:80
	2014-15			
A_1 Control (Absolute)	47.26	59.99	61.81	60.95
A_2 100% RD of N & K +50% P through SSP	67.27	68.67	70.26	68.12
A_3 100% RD of N & K +75% P through SSP	79.96	80.58	81.99	80.96
A_4 100% RD of N & K +75% P through RP	69.67	74.12	81.87	79.75
A_5 100% RD of N & K +100% P through RP	64.76	82.39	84.32	82.05
SEm±	2.20			
CD (p=0.05)	6.35			
	2015-16			
A_1 Control (Absolute)	48.82	60.28	62.98	62.11
A_2 100% RD of N & K +50% P through SSP	68.58	69.83	70.76	68.25
A_3 100% RD of N & K +75% P through SSP	80.14	81.45	82.43	81.36
A_4 100% RD of N & K +75% P through RP	70.91	75.41	85.12	84.12
A_5 100% RD of N & K +100% P through RP	65.45	84.26	86.16	84.92
SEm±	2.75			
CD (p=0.05)	5.53			
	Pooled			
Control (Absolute)	48.04	60.14	62.40	61.53
A_1 Control (Absolute)	67.93	69.25	70.51	68.19
A_2 100% RD of N & K +50% P through SSP	80.05	81.02	82.15	81.16
A_3 100% RD of N & K +75% P through SSP	70.29	74.77	83.56	81.94
A_4 100% RD of N & K +75% P through RP	65.11	83.33	85.24	83.49
SEm±	2.20			
CD (p=0.05)	6.11			

Table 4(c). Interaction effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on Biological yield in wheat

Treatments	B_1 No SW	B_2 RP:SW @ 1:10	B_3 RP:SW @ 1:40	B_4 RP:SW@ 1:80
	2014-15			
A_1 Control (Absolute)	84.45	100.11	102.47	100.27
A_2 100% RD of N & K +50% P through SSP	108.39	117.51	121.02	118.31
A_3 100% RD of N & K +75% P through SSP	122.48	134.87	143.78	142.12
A_4 100% RD of N & K +75% P through RP	115.62	129.58	138.64	135.96
A_5 100% RD of N & K +100% P through RP	110.77	139.08	142.52	140.57
SEm±	4.28			
CD (p=0.05)	12.37			
	2015-16			
A_1 Control (Absolute)	87.89	101.26	104.47	102.27
A_2 100% RD of N & K +50% P through SSP	110.79	119.94	122.83	118.99
A_3 100% RD of N & K +75% P through SSP	122.69	137.54	144.99	142.69
A_4 100% RD of N & K +75% P through RP	117.29	132.37	143.35	139.87
A_5 100% RD of N & K +100% P through RP	111.70	141.84	146.18	143.38
SEm±	4.46			
CD (p=0.05)	8.99			
	Pooled			
Control (Absolute)	86.17	100.69	103.47	101.27
A_1 Control (Absolute)	109.59	118.73	121.93	118.65
A_2 100% RD of N & K +50% P through SSP	122.59	136.21	144.39	142.41
A_3 100% RD of N & K +75% P through SSP	116.46	130.98	141.00	137.92
A_4 100% RD of N & K +75% P through RP	111.24	140.46	144.35	141.98
SEm±	3.62			
CD (p=0.05)	10.04			

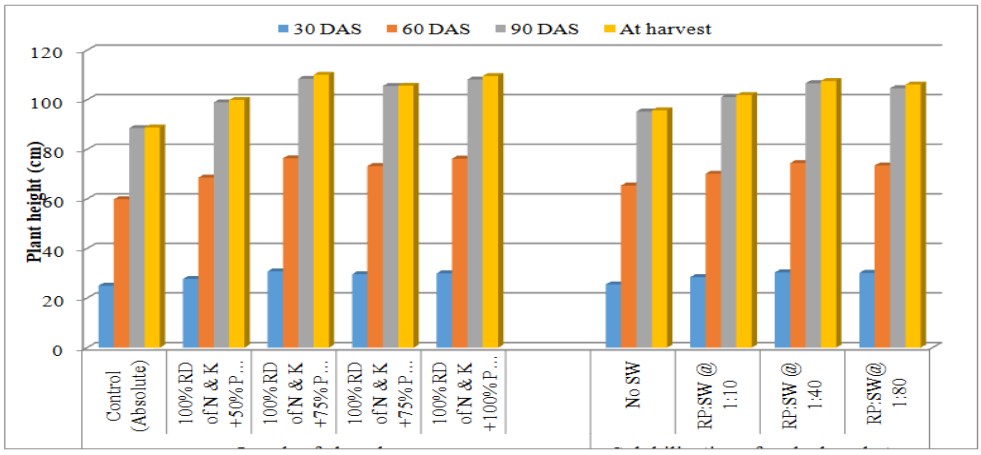

Fig. 1. Effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on plant height in wheat (Pooled mean)

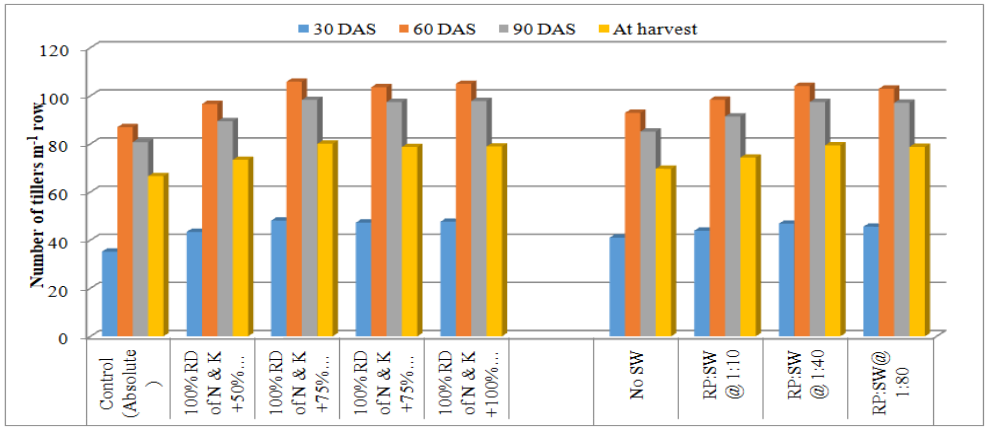

Fig. 2. Effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on Number of tillers m-1 row in wheat (pooled mean)

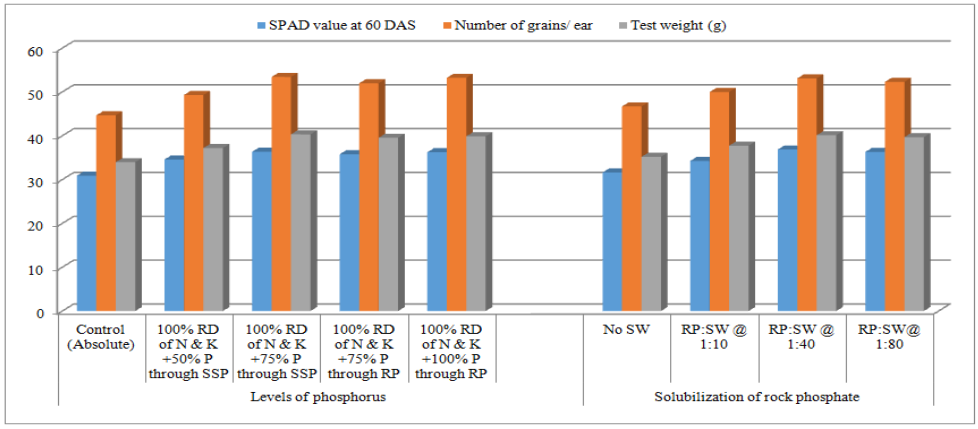

Fig. 3. Effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on Chlorophyll content (SPAD value), Number of grain ear-1 and Test weight in wheat (Pooled mean)

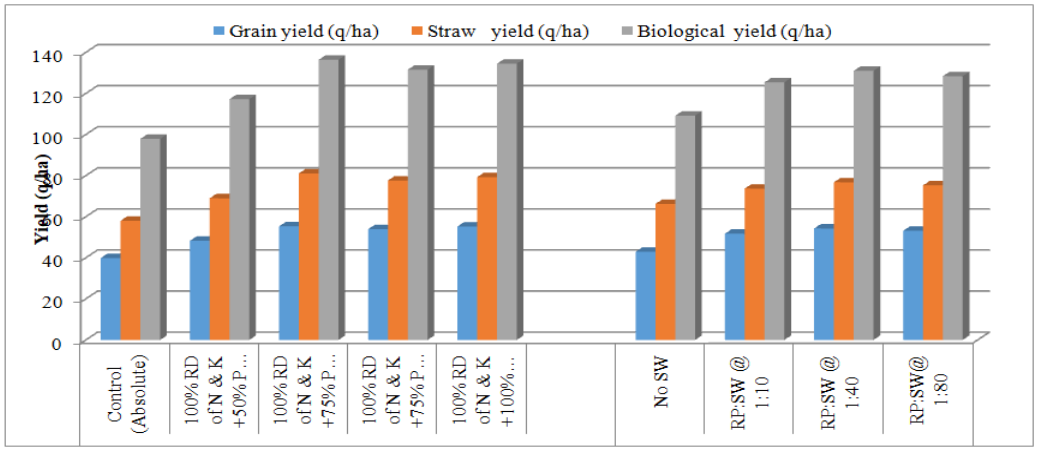

Fig. 4. Effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on yield in wheat (Pooled mean)

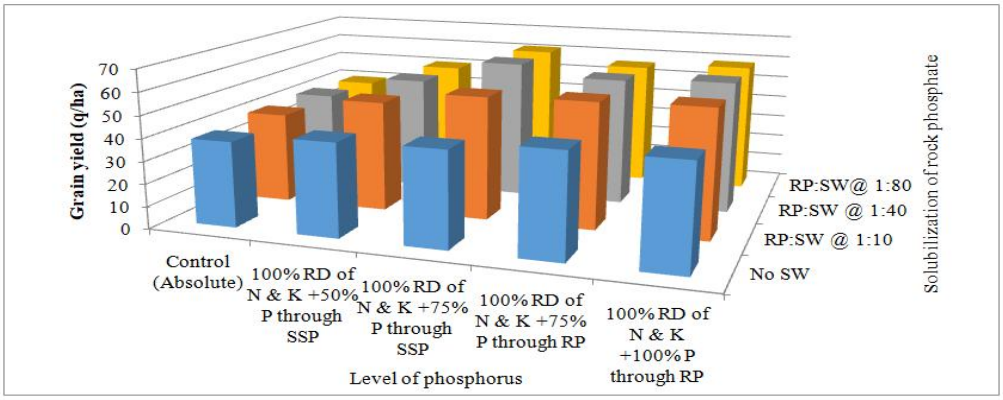

Fig. 4.1. Interaction effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on Grain yield in wheat (Pooled mean)

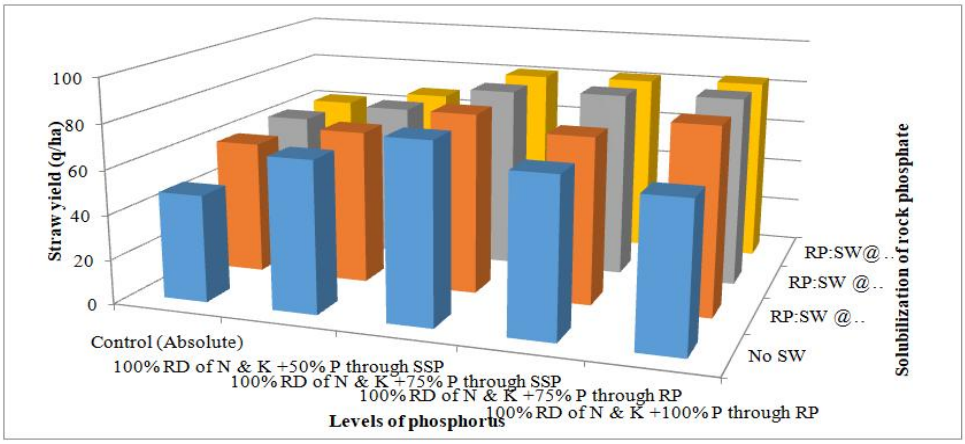

Fig. 4.2. Interaction effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on straw yield in wheat (Pooled mean)

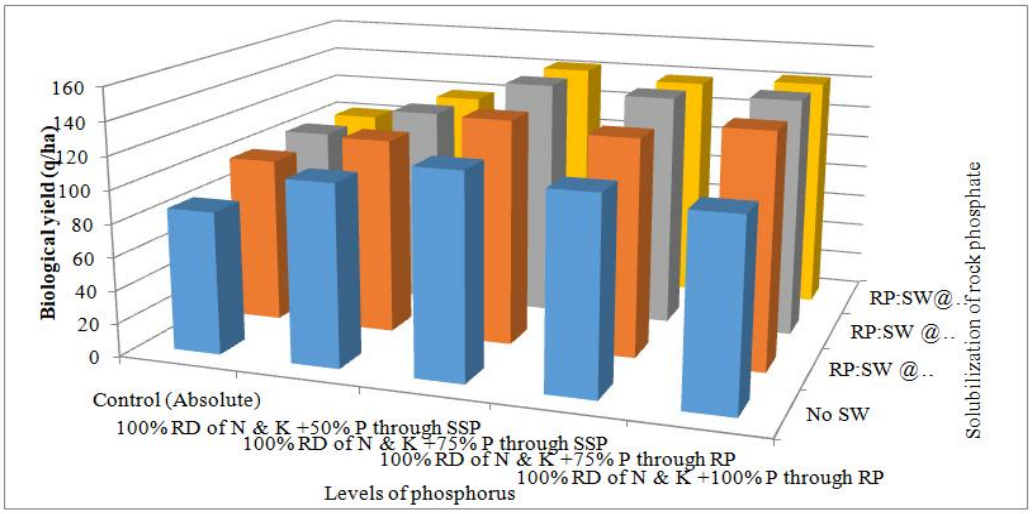

Fig. 4.3. Interaction effect of levels of Phosphorus and P solubilization by Spent Wash from Rock Phosphate on biological yield in wheat (Pooled mean)

and Samra and Dhillon [15] in wheat. Also apply of RP:SW@1:40 Increase in number of effective tillers could be ascribed to enhance phosphorus availability as it take part in cell division and grain development (Abedin et al.,1998 and Pandey et al., 2001) [12].

4.2 Yield and Yield Attributes

Application of phosphorus significantly increased the number of SPAD values at 60 DAS and grains/ear up to 100% N&K + 75% P through SSP. As already discussed in preceeding paragraph increased supply of phosphorus to increase flowering and fruiting, higher photosynthesis activity and its subsequent partitioning in sink. Phosphorus plays an important role in energy transfer and conservation. In the growing stage assimilate is produced to use for growth and development excess storage in storage compounds. Thus adequate supply of phosphorus nutrient to plants in balance proportion improved the yield attributing characters of crop viz., grains/ear and test weight over control and lower levels of nitrogen and phosphorus findings of Pal et al. [16] and Thakur and Sharma [17]. Yield of a crop is a function of many yield components and application of phosphorus significantly increase in grain, straw and biological yield. The biological yield is a sum of grain and straw yield. Thus application of phosphorus significantly increase in biological yield due to increased grain and straw yields. Srivastava et al. [18] and Kumar and Kumar [19] obtained that application of NPK in wheat increased grain, straw and biological yields. Thus results that application of phosphorus increase in grain yield and straw yield. Therefore, phosphorus was most important role in plant metabolism, oxidative disintegration process of carbohydrate, hexose phosphate, meristemic tissues development by cell division and grain filling. Phosphorus increase root development so the help of absorption and utilization of other major and micro nutrients also so finely increase the grain and straw yield. findings of scientists namely Tell and Khattari [20]. Modak [21] and Ravi [22].

5. CONCLUSION

There for 1:40 ratio of RP:SW was considered of taken for field requirmentation. Field requirement results revealed that increase in all the yields attributes (Number of panicles, Test weight, Straw yield and Grain yield) was statistically and at par with increase in thus parameter on application RP:SW in 1:80 ratio. A combination (100% N&K + 75% P through SSP and with RP:SW@1:40) and resulted in maximum mean grain yield is 62.24 q ha^{-1}. The results emanated from present investigation have clearly established potential of spent wash solubilization of rock phosphate and improving productivity of wheat.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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