Indian Journal of Agronomy **67** (4): 417–424 (December 2022)

Research Paper

Integrated nutrient management effects on yield, nutrient uptake and economics of soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system

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Received: November 2021; Revised accepted: November 2022

ABSTRACT

An experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2014–15 and 2015–16 at Research-cum Instructional Farm of the Indira Gandhi Krishi Vishwavidalaya, Raipur, Chhattisgarh, to examine the interactive effects of organic manure and inorganic fertilizers on the yield, nutrient uptake and economics of soybean (*Glycine max* (L.) Merr.)–wheat (*Triticum aestivum* L.) cropping system. Treatments comprised 4 nutrient sources, viz. control, wheat-crop residues @ 5 t/ha, FYM @ 5 t/ha, poultry manure @ 2.5 t/ha in main plots, and 5 levels of fertilizer, viz. control, 50% Recommended dose of fertilizer (RDF), 100% RDF, 50% RDF + Zn @ 5 kg/ha and 100% RDF+ Zn @ 5 kg/ha, to soybean in subplots, and in the case of wheat the residual effect of previous 4 treatments in main plots and 5 nutrient levels, viz. control, 50% RDF, 100% RDF, 50% RDF + Zn @ 5 kg/ha, and 100% RDF + Zn @ 5 kg/ha, were tested in split-plot design with 3 replications. Results revealed that, among different nutrient sources, poultry manure @ 2.5 t/ha significantly resulted in the highest grain (2.20 t/ha and 2.84 t/ha) and straw yield (4.27 t/ha and 6.00 t/ha), net return (72,215 ₹/ha) and benefit : cost ratio (5.49). Among various nutrient levels, application of 100% RDF along with Zn @ 5 kg/ha significantly recorded the highest grain (2.28 t/ha and 2.99 t/ha) and straw yield (4.30 t/ha and 6.14 t/ha) and economic returns (72,370 ₹/ha) as well as improved the available nutrient status (N 220.50 and 212.10 kg/ha, P_2O_5 22.54 and 21.69 kg/ha, K_2O 326.85 and 322.09 kg/ha) after the harvest of soybean (N 220.50, N 22.54 and k20 326.85) and wheat (N 212.10 kg/ha, p 21.62 k20 322009) crops as compared to all other treatments.

***Key words*:** Economics, Nutrient uptake, INM, Soybean wheat cropping system, Yield

Rice–wheat cropping system in India has significantly contributed in enhancing the foodgrain production and achieving the food self-sufficiency and food security. This system now is under threat due to stagnating or declining crop productivity and threatening the issues related to sustainability. Soybean [*Glycine max* (L.) Merr.]–wheat (*Triticum aestivum* L.) system has emerged as a predominant cropping system as a part of crop diversification as well as for maintaining the sustainability of the soils (Verma and Sharma, 2007). Soybean is a legume and wheat is a cereal, they together complimented each other in the cropping system. The farmers prefer soybean as a cash crop followed by wheat as a high-yielding foodgrain crop**.** The productivity of these crops is very low in Chhattisgarh. Imbalance nutrition is one of the important constraints of low soybean productivity in north Indian plains (Singh and Singh, 2018). Sustaining production and productivity of any system is of paramount importance by improving the physical, chemical and biological properties of soil (Karunakaran and Behera, 2015). An application of organic material along with inorganic fertilizers into the soil leads to increase the productivity of the cropping system, enhance the fertilizer-use efficiency and sustain the soil health for longer period (Jat *et al*., 2013). Since relevant information on the effect of organic manures in conjunction with chemical fertilizers on the yield, nutrient uptake and economics of soybean–wheat cropping system is meager especially under the agro-climatic conditions of Chhattisgarh plains, therefore, the present study was planned and carried out to explore the production potential, nutrient uptake and economics of this system as an alternative to rice–wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2014–15 and 2015–16 at Research-cum Instructional Farm of the Indira Gandhi Krishi Vishwavidalaya, Raipur, Chhattisgarh, which is

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located in subtropical region at 21° 4'N, 81° 39'E and 298 m above the mean sea-level**.** The soil of the experimental field was Clayey in texture (sand 21.60%, silt 36.20% and clay 42.20%) having organic carbon contents of 0.46%, with a *p*H of 6.90. The available NPK in the soil was 214.2, 21.50 and 319.2 kg/ha, respectively, which showed that soil was low in nitrogen, medium in phosphorus and high in potassium contents. The treatments comprised 4 nutrient sources, viz. control, wheat-crop residues @ 5 t/ha, FYM @ 5 t/ha, poultry manure @ 2.5 t/ha in the main plots, and 5 levels of recommended doses of fertilizers, viz. recommended doses of fertilizers (RDF: 20, 60 and 20 kg N, P and K/ha), viz. control, 50% RDF, 100% RDF, 50% RDF + Zn @ 5 kg/ha and 100% RDF + Zn @ 5 kg/ha, to soybean in subplots. The organic sources of nutrients were applied 15 days before sowing and incorporated through land preparation in the soil and the nutrient levels of RDF were applied in furrows at the time of sowing. The urea, single superphosphate and muriate of potash were used as sources of N, P and K, respectively, for supplying the levels of RDF. The S content in single superphosphate was made up uniform in all the treatments using gypsum. Soybean (cv. 'JS 9752') was sown during the first fortnight of July each year using a seed rate of 80 kg/ha, spaced 30 cm apart.

After the harvest of soybean, the land was prepared without disturbing the lay-out. wheat (cv. 'Ratan') was seeded during the first fortnight of November, each year using a seed rate of 120 kg/ha, spaced 22.5 cm apart. The residual effect of previous 4 organic sources as main plot treatments and 5 inorganic nutrient levels, viz. control, 50% RDF, 100% RDF, 50% RDF + Zn @ 5 kg/ha, and 100% RDF + Zn @ 5 kg/ha, as subplot treatments in wheat was tested in split-plot design with 3 replications. The half dose of N + full dose of P and K were given basal in furrows and remaining N was applied in 2 equal splits–at maximum tillering and ear-formation stages, as top-dressing. Both the crops were raised with standard agronomic practices except for the treatments.

During the crop-growing seasons of soybean, the weekly mean maximum and minimum temperature was 33.4°C and 22.5°C in 2014 and 34.6°C and 22.1°C in 2015. During the crop-growing season of wheat, the mean maximum and minimum temperature was 25°C and 8°C in 2014 and 27°C and 9°C in 2015, respectively. About 868.0 mm and 611.2 mm rainfall was received during the rainy seasons of 2014 and 2015. During the winter season about 31 mm and 46 mm rainfall was received in 2014 and 2015, respectively.

Both soybean and wheat crops were manually harvested, threshed and the yield was recorded. The soil samples were collected from each plot after harvesting of soybean and wheat crop, at 0–30 cm depth, and analysed using standard procedures. The uptake of N, P and K by crop (grain and straw) was computed from crop yield and nutrient contents of respective treatments. The net returns and benefit : cost (B : C) ratio were computed using the prevailing market rates and prices for the inputs and yields of soybean and wheat. The data recorded were statistically analyzed as per analysis of variance technique for split-plot design and presented as mean data of 2 years.

RESULTS AND DISCUSSION

Grain and straw yield

The maximum grain (2.20 t/ha and 2.84 t/ha) and straw yields (4.27 t/ha and 6.00 t/ha) of soybean and wheat were recorded with the application of poultry manure @ 2.5 t/ha (S_3) which was significantly superior to that of the other treatments (Table 1). The minimum grain and straw yields were harvested from the control (S_0). Among the different nutrient levels, the highest grain (2.28 t/ha and 2.99 t/ha) and straw yields (4.30 t/ha and 6.14 t/ha) of soybean and wheat were obtained from the plots supplied with 100% RDF + Zn @ 5 kg/ha (F_4). The control (F_0) treatment had the minimum yields of both the crops. Rana and Badiyala (2014) also reported that the use of 100% RDF resulted in significantly the highest seed (1.59 t/ha) and straw yield (9.14 t/ha) of soybean as compared to other treatments.

The nutrient sources and nutrient levels interacted significantly in terms of grain and straw yields of both soybean and wheat crops (Table 2). The application of direct and residual effect of poultry manure @ 2.5 t/ha in combination with 100% RDF + Zn @ 5 kg/ha recorded significantly higher grain (2.48 t/ha and 3.39 t/ha) and straw (4.63 t/ha and 6.93 t/ha) yield of soybean and wheat, respectively. It was closely followed by the combination of FYM @ 5 t/ha and 100% RDF + Zn @ 5 kg/ha (S_2F_4) and poultry manure @ 2.5 t/ha and 100% RDF in soybean as well as wheat crops. The lowest values in all these attributes were observed in the combination of controls × control. Likewise, Kumar *et al*., (2006) also reported higher yield of soybean owing to combined application of nutrient sources, micronutrients and 100% RDF by their complementary effect on soil bio-chemical reactions and soil fertility.

System profitability

Both the sources and levels of nutrients had significant effect on the profitability of soybean–wheat cropping system (Table 1). Among all organic sources of nutrients, the highest net returns of 72,215 ₹/ha coupled with broadest benefit : cost (B:C) ratio of 5.49 was obtained owing to the direct and residual effect of poultry manure @ 2.5 t/ha. Application of 100% RDF + Zn @ 5 kg/ha fetched the

Table 1. Effect of sources and levels of nutrients on yield and economics of soybean–wheat cropping system (mean of 2 years data)

Treatment		Yield (t/ha)				System economics	
		Soybean		Wheat			
Soybean	Wheat	Grain	Straw	Grain	Straw	Net returns (₹/ha)	Benefit: cost ratio
Nutrient sources							
S_0, Control	S_0, Control	1.50	3.31	2.01	4.16	39,067	3.94
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	1.86	3.63	2.38	5.01	52,804	4.44
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	1.99	4.00	2.61	5.60	62,081	4.96
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	2.20	4.27	2.84	6.00	72,215	5.49
SEm±		0.11	0.37	0.14	0.15	464	0.02
CD (P=0.05)		0.39	1.27	0.50	0.53	1,607	0.08
Nutrient levels							
F_0, Control	F_0, Control	1.34	3.11	1.70	3.84	33,967	3.91
F_1, 50% RDF	F_1, 50% RDF	1.77	3.72	2.31	4.91	51735	4.57
F_2, 100% RDF	F_2, 100% RDF	2.14	4.10	2.79	5.74	65,874	4.96
F_3, 50% RDF + Zn 5 kg/ha	F_3, 50% RDF + Zn 5 kg/ha	1.90	3.80	2.52	5.32	58,762	4.90
F_4, 100% RDF + Zn 5 kg/ha	F_4, 100% RDF + Zn 5 kg/ha	2.28	4.30	2.99	6.14	72,370	5.20
SEm±		0.21	0.40	0.22	0.41	886	0.04
CD (P=0.05)		0.62	1.17	0.63	1.17	2,553	0.12

RDF, Recommended dose of fertilizer; FYM, farmyard manure

Table 2. Effect of interaction between nutrient sources × nutrient levels on grain and straw yields of soybean and wheat (mean of 2 years data)

Treatment	Yield (t/ha)			
	Soybean		Wheat	
	Grain	Straw	Grain	Straw
S_0F_0	0.97	2.40	1.46	3.30
S_0F_1	1.33	3.23	1.91	3.93
S_0F_2	1.67	3.73	2.26	4.55
S_0F_3	1.59	3.26	2.07	4.28
S_0F_4	1.93	3.92	2.36	4.72
S_1F_0	1.29	2.80	1.57	3.54
S_1F_1	1.66	3.57	2.19	4.58
S_1F_2	2.25	3.94	2.69	5.66
S_1F_3	1.81	3.61	2.43	5.01
S_1F_4	2.28	4.24	3.00	6.27
S_2F_0	1.43	3.58	1.79	4.13
S_2F_1	1.91	3.82	2.45	5.31
S_2F_2	2.26	4.18	2.93	6.13
S_2F_3	1.95	4.05	2.68	5.79
S_2F_4	2.41	4.39	3.20	6.65
S_3F_0	1.67	3.66	1.97	4.39
S_3F_1	2.17	4.26	2.68	5.82
S_3F_2	2.39	4.54	3.26	6.62
S_3F_3	2.28	4.27	2.89	6.21
S_3F_4	2.48	4.63	3.39	6.94
SEm±				
2 SP at same MP	0.43	0.80	0.44	0.82
2 MP at same SP	0.40	0.81	0.42	0.75
CD (P=0.05)				
2 SP at same MP	1.24	2.33	1.27	2.35
2 MP at same SP	1.17	2.43	1.24	2.16

Details of treatment are given in Table 1
SP, Subplots-nutrient levels; MP, main plots-nutrient sources

maximum net returns of ₹72,370 /ha with a widest B : C ratio of 5.20 which was significantly higher than those recorded with the other levels of nutrients. The greater economic returns might be because of higher productivity of both the crops coupled with better market price in spite of higher cost of cultivation that incurred in the aforesaid treatments. The combined use of poultry manure @ 2.5 t/ha along with 100% RDF + Zn @ 5 kg/ha resulted in the maximum net returns of ₹85,425 /ha, with a widest B : C ratio of 5.89. Our results confirm the findings of Gharpinde *et al*., (2014).

Available nutrients status in soil after crop harvesting

Available N : The maximum available N in soil, viz. 215.46 and 207.90 kg/ha, after soybean and wheat harvesting was noticed in treatment receiving direct and residual effect of poultry manure @ 2.5 t/ha (Table 3). The higher values of N content could be owing to the presence of residues after harvesting of crop. The available N was depleted under unfertilized control treatment (S_0) after harvesting of

Table 3. Effect of sources and levels of nutrients on available nutrients status in soil after harvesting of soybean and wheat (mean of 2 year data)

Treatment		Available nutrients status in soil (kg/ha)					
		N		P_2O_5		K_2O	
Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
Nutrient sources							
S_0, Control	S_0, Control	198.24	188.58	20.51	20.01	290.69	302.59
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	202.86	196.14	21.08	20.67	312.70	308.78
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	211.26	202.02	21.65	21.21	318.82	312.78
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	215.46	207.90	22.22	21.56	328.01	320.88
SEm±		1.94	1.43	0.07	0.09	1.24	0.35
CD (P=0.05)		6.02	4.96	0.24	0.31	4.30	1.23
Nutrient levels							
F_0, Control	F_0, Control	187.42	184.80	19.74	19.86	296.41	300.86
F_1, 50 % RDF	F_1, 50% RDF	204.22	191.63	21.05	20.53	312.34	306.13
F_2, 100 % RDF	F_2, 100% RDF	216.30	207.90	22.02	21.39	322.84	319.25
F_3, 50 % RDF + Zn 5kg/ha	F_3, 50% RDF + Zn 5kg/ha	206.32	196.88	21.46	20.83	313.69	307.95
F_4, 100% RDF + Zn 5kg/ha	F_4, 100% RDF + Zn 5kg/ha	220.50	212.10	22.54	21.69	326.85	322.09
SEm±		1.66	1.75	0.11	0.13	1.12	1.17
CD (P=0.05)		4.79	5.03	0.33	0.37	3.23	3.38

Initial status of NPK in soil was 192.40 kg N, 17.60 kg P_2O_5 and 282.54 kg K_2O/ha
RDF, Recommended dose of fertilizer; FYM, farmyard manure

soybean and wheat crops. The residual effect of poultry manure or FYM might have attributed to the mineralization of N in soil and owing to high enzyme activities in the soil amended with organic manure might have increased the transformation of nutrients to available form. Sharma *et al*., (2013) also reported an increase in available N status of soil because of the addition of organic manures.

The available N in soil also varied significantly with successive increase in fertilizer levels. Among the nutrient levels, crop treated with 100% RDF + Zn @ 5 kg/ha (F_4) maintained the greater values of available N in soil (220.50 and 212.40 kg/ha) after the harvesting of soybean and wheat crops, indicating the impact of fertilizer application on enhancement of N pools. The bare minimum value of available nitrogen in soil was recorded under the unfertilized control treatment (F_0) after the harvesting of both soybean and wheat crops. The higher value of available N over the initial value might be because of the nitrogen fixation by soybean crop. The results are in agreement with the work of Gharpinde *et al*., (2014), who observed the maximum amount of available N content is soil after soybean harvesting with the application of 30, 75 and 25 kg of N, P and K/ha. The available N content in soil remained unchanged due to the interaction between sources and levels of nutrients for both soybean and wheat crops.

Available P_2O_5 : Among the nutrient sources, direct and residual effects of poultry manure @ 2.5 t/ha resulted in the maximum amount of available P_2O_5 in soil, viz. 22.22 and 21.56 kg/ha, after harvesting of both crops, which was significantly different to those found due to other sources of nutrients (Table 3). The lowest values of available P_2O_5 were observed in the control plots of both soybean and wheat crops. Organic manures, on decomposition, solubilizes the insoluble organic P fractions through release of organic acids, thus resulting in significant improvement in soil-available P status owing to application of poultry manure and FYM, as also reported by Sharma *et al*., (2013).

Data further showed that, among the different nutrient levels, crop fertilized with 100% RDF + Zn @ 5 kg/ha accounted for higher amount of P_2O_5 contents, viz. 22.54 and 21.69 kg/ha, in soybean and wheat crops, respectively, than the other levels of nutrients. However, an application of 100% RDF + Zn @ 5 kg/ha was statistically on a par with 100% RDF for soybean and wheat crops. The lowest value of available P_2O_5 was recorded under control treatments in soybean and wheat crops. Mere *et al*., (2013) also reported

that, available phosphorus in soil after harvesting of soybean was increased with the increase in the level of RDF. The available P_2O_5 content in soil remained unchanged due to the interaction between sources and levels of nutrients for soybean and wheat crops.

Available K_2O : Among different sources of nutrients, higher amount of K_2O, viz. 328.01 and 320.88 kg/ha was recorded with direct and residual effects of poultry manure @ 2.5 t/ha, which stands at par with that caused by FYM @ 5 t/ha (Table 3). The lowest value of available potassium was observed in the control plot, being identical to crop residues 5 @ t/ha after the harvesting of soybean and wheat crops. The buildup of soil-available K with the addition of poultry manure or FYM may be owing to addition of K through fertilizers, solubilizing action of certain organic acids produced by decomposition of organic manure and its greater capacity to hold K in the available K pool of soil (Ramesh *et al*., 2009).

Among the nutrient levels, 100 % RDF + Zn 5 kg/ha resulted in the highest value of available soil K_2O, viz. 326.85 and 322.09 kg/ha after harvesting of soybean and wheat crops which was comparable with 100% RDF. On the other hand, the lowest value of available K_2O was recorded under the control. Our results are similar to those of Gharpinde *et al*., (2014). The interaction effects between nutrient sources and nutrient levels on the available K_2O in the soil were non-significant for soybean and wheat crops.

Nutrient content in grain and straw

Nitrogen : All the sources of nutrients applied to both soybean and wheat crops, increased the N contents significantly compared to untreated control treatment (Table 4). Among different nutrient sources, direct and residual effects of poultry manure resulted in higher contents N, viz. 6.14 and 2.017% in grains and 2.17 and 0.759% in soybean and wheat straw, respectively. The nitrogen content in soybean and wheat grains noticed under the control treatment was at par with those found under crop-residues treatments. The levels of nutrients also enhanced the N contents in grains and straw of soybean and wheat crops. An application of 100% RDF + Zn @ 5 kg/ha resulted in the highest N contents of 6.14 and 2.046% in grains and 2.39 and 0.790% in the soybean and wheat straw, respectively, compared to the other treatments. The unfertilized control treatment (F_0) showed the lowest values of N contents in both the crops.

Phosphorus : The sources and levels of nutrients caused significant variations in phosphorus contents of grain and straw of both the crops (Table 5). Among the sources of nutrients, the maximum P, viz. 0.257 and 0.552% in grain and 0.134 and 0.209% in straw of soybean and wheat were recorded under direct and residual effect of poultry manure, which were comparable to that found with the application of FYM. The maximum P, viz. 0.262 and 0.562% in grain and 0.135 and 0.198% in straw of soybean and wheat crops were noticed under 100% RDF + Zn @ 5 kg/ha which was found to be significantly higher than the other levels of nutrients.

Potassium : The K contents in grain and straw of both the crops varied significantly with different sources of nutrients (Table 6). The direct and residual effects of poultry manure resulted in the maximum K of 1.14 and 0.787% in grains and 2.87 and 1.059% in soybean and wheat straw which differed significantly from the sources of nutrients. Treatment of 100% RDF + Zn @ 5 kg/ha showed the highest value of K viz. 1.14 and 0.752% in the grains and 2.85 and 1.101% in the straw of soybean and wheat compared to those found with the other nutrient levels. The interaction between nutrient sources and nutrient levels did not caused significant variations in the NPK contents in soybean and wheat crops.

Total nitrogen, phosphorus and potassium uptake by soybean and wheat

Nitrogen uptake : Different sources of nutrients had significant influence on total N uptake by both soybean and wheat crops during both the years (Table 4). Among the nutrient sources, direct and residual effects of poultry manure drew the highest amount of nitrogen, i.e. 224.03 and 233.60 kg N/ha, in soybean and in wheat 102.25 and 104.50 kg N/ha, during 2014–15 and 2015–16, respectively, which was markedly different than those observed with the other sources of nutrients. The lowest value of total nitrogen uptake by soybean and wheat was noticed in the control during both the years. Increase in total N uptake might be owing to higher availability of nitrogen from soil reservoir and additional quantity of N supplied by adding fertilizers which in turn resulted in higher grain yield and N uptake. These results corroborated the findings of Rana and Badiyala (2014).

Among the nutrient levels, each increment in fertility level from control to 100% RDF + Zn @ 5 kg/ha significantly increased the value of total N uptake by soybean and wheat during both the years. The highest value of total N uptake in soybean, viz. 240.70 and 245.71 kg/ha, and 109.16 and 110.74 kg/ha in wheat during 2014–15 and 2015–16, respectively, were recorded with 100% RDF + Zn @ 5 kg/ha which was significantly greater than those recorded with the other levels of nutrients during both the years. On the other hand, the lowest value of total N uptake in soybean and wheat crops was recorded under the control during both the years. Jat *et al*., (2013) also reported the highest amount of N uptake with the application of N : P : K @ 120 : 60 : 60 kg/ha in wheat crops. The interaction

Table 4. Effect of sources and levels of nutrients on mean nitrogen contents and total nitrogen uptake in soybean and wheat (mean of 2 years data)

Treatment		Mean nitrogen content (%)				Total nitrogen uptake (kg/ha)			
		Grain		Straw		2014–15		2015–16	
Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
Nutrient sources									
S_0, Control	S_0, Control	6.02	1.941	1.99	0.691	161.86	70.69	152.87	65.61
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	6.05	1.962	2.02	0.710	183.78	82.42	190.30	83.36
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	6.08	1.996	2.10	0.735	202.74	91.87	209.78	95.83
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	6.14	2.017	2.17	0.759	224.03	102.25	233.60	104.50
SEm±		0.009	0.010	0.02	0.003	1.82	0.47	2.20	0.48
CD (P=0.05)		0.03	0.036	0.07	0.009	6.31	1.61	7.61	1.65
Nutrient levels									
F_0, Control	F_0, Control	5.99	1.891	1.74	0.667	141.06	59.92	129.17	55.86
F_1, 50% RDF	F_1, 50% RDF	6.05	1.951	1.98	0.694	177.70	78.55	184.18	80.12
F_2, 100% RDF	F_2, 100% RDF	6.10	2.022	2.24	0.757	218.01	99.28	227.94	100.94
F_3, 50% RDF + Zn 5 kg/ha	F_3, 50% RDF + Zn 5 kg/ha	6.07	1.986	2.00	0.709	188.04	87.13	196.20	88.98
F_4, 100% RDF + Zn 5 kg/ha	F_4, 100% RDF + Zn 5 kg/ha	6.14	2.046	2.39	0.790	240.70	109.16	245.71	110.74
SEm±		0.01	0.008	0.01	0.005	2.67	0.70	2.94	1.01
CD (P=0.05)		0.03	0.022	0.04	0.014	7.70	2.02	8.48	2.90

RDF, Recommended dose of fertilizer; FYM, Farmyard manure

effects of sources and levels of nutrient on total nitrogen uptake by soybean and wheat remained non-significant during both the years.

Phosphorus uptake : The direct and residual effects of poultry manure 2.5 t/ha significantly resulted in the highest values of total P uptake, amounting to 11.21 and 11.66 kg/ha in soybean and 28.14 and 28.97 kg P/ha in wheat during 2014–15 and 2015–16, respectively (Table 5). The lesser amount of total phosphorus was drawn by soybean and wheat in the control during both the years. The solubilizing action of organic acids produced during decomposition of Poultry manure/FYM might have increased the release of native P, stimulated the microbial growth in soil and favoured root growth which had finally led to increased P uptake by wheat. Similar findings were also reported by Sharma *et al*., (2013).

Nutrient levels enhanced the total phosphorus uptake by soybean and wheat relative to unfertilized control treatment during both the years. The highest amount of phosphorus, viz. 11.58 and 11.99 kg/ha by soybean and 28.95 and 29.52 kg/ha by wheat, was withdrawn during 2014–15 and 2015–16, respectively, when treated with 100% RDF + Zn @ 5 kg/ha. However, the lowest amount of total P was drawn by soybean and wheat crops under the control treatment during both the years. The higher P uptake was owing to more availability of phosphorus with optimum doses and deep penetration of roots must have facilitated in absorbing higher amount of nutrients from the rhizosphere. Similar results were reported by Mere *et al*., (2013). The total phosphorus uptake by soybean and wheat remained unchanged due to the interaction between sources and levels of nutrients during both the years.

Potassium uptake : Both sources and levels of nutrients caused significant variations in the total K uptake by soybean and wheat during both the years (Table 6). The highest values of total K uptake amounting to be 146.65 and 151.94 kg/ha by soybean and 85.59 and 88.67 kg/ha by wheat during 2014–15 and 2015–16, respectively, was recorded under the direct and residual effects of poultry manure. The lowest value of total K uptake by soybean and wheat crop was found under the control during both the years. The increased uptake of K by wheat may be ascribed to the release of K from the K-bearing minerals by complex agents and organic acids produced during decomposition of organic resources. These results confirm those of Sharma *et al*., (2013).

Among the levels of nutrients, the application of 100% RDF + Zn @ 5 kg/ha recorded the highest value of K uptake, i.e. 148.41 and 150.81 kg/ha by soybean and 90.43 and 91.89 kg/ha by wheat, during 2014–15 and 2015–16, respectively. Untreated control treatment resulted in the lowest value of total potassium uptake by soybean and

Table 5. Effect of sources and levels of nutrients on mean phosphorus content and total phosphorus uptake in soybean and wheat (mean of 2 years data)

Treatment		Phosphorus content (%)				Total phosphorus uptake (kg/ha)			
Soybean	Wheat	Grain		Stover		2014–15		2015–16	
		Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
Nutrient sources									
S_0, Control	S_0, Control	0.219	0.489	0.117	0.159	7.68	17.31	7.20	15.86
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	0.241	0.504	0.125	0.167	8.97	20.33	9.27	20.84
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	0.248	0.520	0.129	0.190	10.07	23.89	10.31	25.19
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	0.257	0.552	0.134	0.209	11.21	28.14	11.66	28.97
SEm±		0.001	0.003	0.0003	0.001	0.06	0.20	0.08	0.15
CD (P=0.05)		0.004	0.011	0.0011	0.005	0.20	0.68	0.29	0.53
Nutrient levels									
F_0, Control	F_0, Control	0.213	0.473	0.118	0.159	7.10	14.72	6.31	13.71
F_1, 50% RDF	F_1, 50% RDF	0.236	0.495	0.124	0.175	8.72	19.96	9.09	20.51
F_2, 100% RDF	F_2, 100% RDF	0.254	0.539	0.131	0.191	10.71	25.80	10.96	26.66
F_3, 50% RDF + Zn 5 kg/ha	F_3, 50% RDF + Zn 5 kg/ha	0.244	0.512	0.126	0.184	9.30	22.66	9.69	23.18
F_4, 100% RDF + Zn 5 kg/ha	F_4, 100% RDF + Zn 5 kg/ha	0.262	0.562	0.135	0.198	11.58	28.95	11.99	29.52
SEm±		0.002	0.003	0.001	0.002	0.11	0.19	0.16	0.27
CD (P=0.05)		0.005	0.009	0.003	0.006	0.31	0.54	0.47	0.77

RDF, Recommended dose of fertilizer; FYM, farmyard manure

Table 6. Effect of sources and levels of nutrients on mean potassium content and total potassium uptake of soybean and wheat (mean of 2 years data)

Treatment		Mean potassium content (%)				Total potassium uptake (kg/ha)			
Soybean	Wheat	Grain		Stover		2014–15		2015–16	
		Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
Nutrient sources									
S_0, Control	S_0, Control	0.87	0.580	2.41	0.871	97.07	50.02	90.36	46.45
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	0.94	0.631	2.53	0.967	109.39	63.92	111.83	65.44
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	1.03	0.717	2.69	1.004	126.69	74.65	131.64	77.42
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	1.14	0.787	2.87	1.059	146.65	85.59	151.94	88.67
SEm±		0.006	0.006	0.010	0.008	1.54	0.69	1.27	0.59
CD (P=0.05)		0.02	0.021	0.034	0.028	5.33	2.38	4.39	2.06
Nutrient levels									
F_0, Control	F_0, Control	0.84	0.599	2.31	0.841	87.93	44.66	80.10	40.73
F_1, 50% RDF	F_1, 50% RDF	0.95	0.657	2.49	0.902	108.49	59.03	112.74	61.15
F_2, 100% RDF	F_2, 100% RDF	1.05	0.712	2.77	1.018	134.50	77.36	139.68	80.94
F_3, 50% RDF + Zn 5 kg/ha	F_3, 50% RDF + Zn 5 kg/ha	1.00	0.674	2.68	1.015	120.42	71.24	123.88	72.77
F_4, 100% RDF + Zn 5 kg/ha	F_4, 100% RDF + Zn 5 kg/ha	1.14	0.752	2.85	1.101	148.41	90.43	150.81	91.89
SEm±		0.010	0.009	0.013	0.012	1.53	1.02	1.50	1.28
CD (P=0.05)		0.028	0.027	0.036	0.034	4.40	2.93	4.31	3.69

RDF, Recommended dose of fertilizer; FYM, farmyard manure

wheat during both the years. The K has a role in enzyme activation, photosynthesis and protein synthesis. It regulates stomatal activity, enhances the transport of sugars, water and nutrients and maintains crop quality. The continuous availability of K resulted in more uptake of potassium than the control and lower levels of fertilizers. Rana and Badiyala (2014) also reported similar result. The interaction between sources and levels of nutrients did not cause significant variations in total K uptake of soybean and wheat during the both the years.

On the basis of 2 years study, it can be concluded that direct and residual effects of poultry manure @ 2.5 t/ha among the nutrient sources and 100% recommended dose of fertilizers along with Zn @ 5 kg/ha to soybean and wheat crops recorded significantly higher grain and straw yields as well as nutrient contents, nutrient uptake, net returns and benefit : cost ratio of soybean and wheat crop. The combined use of poultry manure @ 2.5 t/ha and 100% RDF along with Zn @ 5 kg/ha resulted in highest grain and straw yields, profitability, NPK contents and their total uptake in comparison to their sole application in soybean–wheat cropping system. Thus, combined application of 2.5 t/ha of poultry manure to soybean and 100% RDF along with Zn @ 5 kg/ha to both soybean and wheat is necessary for maximum yield and net returns from soybean–wheat cropping system under the agro-climatic conditions of Chhattisgarh plains.

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