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Research Paper

Production potential, economics and energetic as influenced by integrated nutrient management in soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted for 2 consecutive years during 2014–15 and 2015–16 at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, with the objective to evaluate the direct and residual effect of organic and inorganic fertilizers on productivity and economics of soybean [*Glycine max* (L.) Merill]–wheat (*Triticum aestivum* L. emend. Fiori and Paol) cropping system. In soybean, the treatments comprised of 4 nutrient sources, viz. S_0, control; S_1, crop residues (wheat) 5 t/ha; S_2, FYM 5 t/ha; S_3, poultry manure 2.5 t/ha in the main plots and in the sub-plots 5 nutrient levels, viz. F_0, control; F_1, 50% RDF; F_2, RDF; F_3, 50% RDF + Zn 5 kg/ha; and F_4, RDF + Zn 5 kg/ha. In wheat, residual effect of nutrient sources applied to soybean was evaluated in the main plots while in the sub-plots 5 nutrient levels; F_0, control; F_1, 50% RDF; F_2, RDF; F_3, 50% RDF + Zn 5 kg/ha; and F_4, RDF + Zn 5 kg/ha. Experiment was laid out in split plot design with 3 replications for both the crop. Results revealed that among different nutrient sources, poultry manure (2.5 t/ha) registered significantly the highest grain and stover yields and economic parameters (gross returns, net returns and B:C ratio) for both soybean and wheat crops compared to control and rest of the organic treatments. The wheat crop residues (5 t /ha) incurred more cost towards soybean production (20.2×10^3 ₹/ha). Among various nutrient levels, application of RDF along with Zn 5 kg/ha produced significantly the highest grain and stover yields and economic parameters as compared to rest of the treatments. On the basis of yields and economic returns of soybean and wheat in system, annual application of poultry manure @ 2.5 t/ha in soybean and RDF + 5 kg Zn/ha to both soybean and wheat was found to be optimum in order to raise the productivity and profitability of both the crops. However, combined application of poultry manure and RDF along with zinc in soybean–wheat cropping system appears to be a better nutrient management option for yield and profit maximization besides improvement in the fertility of the soil.

Key words : Economics, Energetics, INM, Soybean–wheat cropping system, Yields

Soybean–wheat is the predominant cropping system in India. The success of any cropping system depends upon the appropriate management of resources including balanced use of manures and fertilizers. Rice–wheat cropping systems in India have significantly contributed in enhancing the food grain production and achieving the food self-sufficiency and food security. The rice–wheat production system now is under threat due to stagnating or declining crop productivity and threatening the issues related to sustainability. Both, rice and wheat are heavy feeders and exhaust the soil nutrients to the maximum, resulting in many problems in the traditional rice–wheat cropping system. The soybean–wheat system has emerged as a good alternative both as a part of crop diversification as well as for maintaining the sustainability of the soils (Verma and Sharma, 2007). The long-term use of inorganic fertilizers without organic supplements damages the soil physical, chemical and biological properties and causes environmental pollution. Organic manures act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients turnover and many other changes related to physical, chemical and biological parameters of the soil (Albiach *et al*., 2000).

Soybean with its 40–42% protein and 20–22% oil has already emerged as one of the major oilseed crop in India. In India, soybean is cultivated in 10.84 million ha with a production of 14.67 million tonnes and average productivity of 1,162 kg/ha, which is very low than the world average of 2,670 kg/ha (Anonymous, 2014).

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Wheat is one of the most important cereal crops of the world and in India's second most important food crop, next only to rice, therefore it has pivotal role in ensuring food security of the country. It occupies 30.96 million ha area with production of about 88.94 million tonnes and average productivity of 2,272 kg/ha during 2015–16 (Anonymous, 2016). The rapid increase in the world population demands parallel increase in food production, particularly of wheat. In Chhattisgarh, average productivity of wheat is only 1,455 kg/ha. The major cause of low productivity of the crop in Chhattisgarh is imbalanced fertilizer application or low use of inorganic fertilizer.

Due to intensive cultivation of crops with recommended or imbalance dose of chemical fertilizers alone, the productivity of soil has gone down, and now, time has come to supplement these chemical fertilizers with organics to sustain the fertility and productivity of the soils (Behera *et al*., 2007). Supply of nutrients through bulky organics FYM, poultry manure and crop residues (wheat stover) along with chemical fertilizers can help to maintain the soil nutrient reserves for attaining higher crop yields. The development of the poultry industry in Chhattisgarh has provided considerable quantities of organic waste, poultry litter, which have potential for use in agriculture. Under these circumstances, integration of chemical and organic sources and their proper management have shown promising results not only in sustaining the productivity but have also proved to be effective in maintaining soil health and enhancing nutrient-use efficiency (Thakur *et al*. 2011). Hence, balanced nutrient application is must to harness the productivity of the crops and get maximum profit. As information on these aspects is lacking in soybean–wheat cropping system, a field investigation undertaken under the agro-climatic conditions of Chhattisgarh plains.

MATERIALS AND METHODS

A field experiment was conducted at research cum instructional farm of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during rainy (*kharif*) and winter (*rabi*) seasons of 2014–15 and 2015–16. The soil of the experimental field was clayey in texture having neutral *p*H (6.9), EC (0.13 ds/m) and low in organic carbon (0.46%). Fertility status of soil was categorised as low in available N (214.2 kg/ha), medium in available P (21.50 kg /ha) and high in available K (319.2 kg/ha), respectively. The experiment was laid in split plot design with 3 replications. The treatment to soybean comprised of 4 nutrient sources, viz. S_0, control; S_1, crop residues (wheat) 5 t/ha; S_2, FYM 5 t/ha; S_3, poultry manure 2.5 t/ha in the main plots and 5 nutrient levels; F_0, control; F_1, 50% RDF; F_2, RDF; F_3, 50% RDF + Zn 5 kg/ha; and F_4, RDF + Zn 5 kg/ha in the sub plots. In succeeding wheat crop residual effect of nutrient sources given to soybean was evaluated in the main plots, nutrient levels, viz. F_0, control; F_1, 50% RDF; F_2, RDF; F_3, 50% RDF + Zn 5 kg/ha; and F_4, RDF + Zn 5 kg/ha. The recommended dose of fertilizers for soybean and wheat are 20:60:20 and 120:60:40 kg of N, P_2O_5 and K_2O/ha, respectively and their source of application are urea, single super phosphate and muriate of potash. In soybean the full dose of N, P_2O_5 and K_2O was applied as basal. In wheat as per treatment the full dose of P_2O_5, K_2O and half dose of N was applied as basal and remaining half N was applied in 2 equal splits at maximum tillering and panicle initiation stages during both years of experimentation.

Soybean 'JS 9752' and wheat 'Ratan' was sown in rows 30 and 22.5 cm apart using a seed rate of 80 and 120 kg/ha, respectively. Soybean was sown on 17 July 2014 and 4 July 2015 and wheat on 14 November 2014 and 21 November 2015. The weekly average maximum and minimum temperature during crop seasons of soybean ranged between 25.1°C to 33.4°C and 22.5°C to 28.3°C in 2014 and 30.28°C to 34.6°C and 22.1°C to 26.5°C in 2015 and wheat 25°C to 33.5°C and 8°C to 19.3°C in 2014–15 and 27°C to 35.4°C and 9°C to 20.8°C in 2015–16, respectively. The total rainfall received from sowing to harvest was 868.0 mm and 611.2 mm for soybean during 2014 and 2015, and 30.9 mm and 46 mm for wheat during 2014–15 and 2015–16, respectively.

The wheat crop received four uniform irrigations during both the years of experimentation. The experiment was conducted on the same site without any change in the layout plan. The grain and stover yields of soybean and wheat were recorded from net plot area and converted into tonnes/ha under different treatments. The cost of cultivation and gross returns (₹/ha) for all the treatments was worked out on the basis of the prevailing market price of input and the produce. The net returns (₹/ha) was calculated by substracting the cost of cultivation from the gross returns. The B:C ratio was calculated treatment-wise to assess the economic impact of the treatments by dividing the gross returns with the cost of cultivation. Total productivity of the system in soybean-equivalent yield was calculated using the given formula.

$$\text{SEY of wheat (t/ha)} = \frac{\text{Yield of wheat (t/ha)} \times \text{Price of wheat (₹/t)}}{\text{Price of soybean (₹/t)}}$$

The energy output of different treatments was calculated on the basis of biological yield as given by Mittal *et al.* (1985) and expressed as total energy (MJ/ha). Energy efficiency and output-input ratio were calculated by using the given formula.

$$\text{Energy use efficiency (tMJ} \times 10^3) = \frac{\text{Total produce (Seed + Stover (in t)}}{\text{Energy input (MJ} \times 10^3)}$$

$$\text{Energy output-input ratio} = \frac{\text{Energy output}}{\text{Energy input (MK/ha)}}$$

The data collected from the experimental field and laboratory analysis was subjected to statistical analysis. Standard statistical methods were used (Gomez and Gomez., 1984). The results are presented at 5% level of significance (P=0.05) for making comparison between treatments.

RESULTS AND DISCUSSION

Grain and stover yield

The maximum grain (2.20 t/ha and 2.84 t/ha) and stover (4.27 t/ha and 6.0 t/ha) yields of both soybean and wheat were recorded with the application of direct and residual effect of poultry manure 2.5 t/ha (S_3), which was significantly higher than that of other treatment for both soybean and wheat crops (Table 1). The minimum grain and stover yields of both soybean and wheat crops were harvested from control (S_0) plot in 2 years mean data. Among the different nutrient levels, the highest grain (2.28 t/ha and 2.99 t/ha) and stover (4.30 t/ha and 6.14 t/ha) yields of soybean and wheat is obtained from the plots supplied with 100% RDF + Zn 5 kg/ha (F_4) and minimum under control (F_0) treatment. Rana and Badiyala (2014) also reported that the use of RDF resulted in significantly high seed (1.59 t/ha) and stover (3.14 t/ha) yields of soybean as compared to 50% RDF and the control. This was might be due to variation in variety of crops, soil and climatic conditions.

The nutrient sources and nutrient levels interacted significantly in terms of grain and stover yields of soybean as well as wheat crop. The direct and residual effect of poultry manure (PM) 2.5 t/ha in combination with RDF + Zn 5 kg/ha (S_3F_4) recorded higher grain (2.48 t/ha and 3.39 t/ha) and stover (4.63 t/ha 6.93 t/ha) yield of soybean and wheat crops. It was closely followed by the combination of FYM 5 t/ha × 100% RDF + Zn 5 kg/ha (S_2F_4) and PM 2.5 t/ha × 100% RDF (S_3F_2) for soybean crops and it was closely followed by the combination of FYM 5 t/ha × 100% RDF (S_2F_2) and PM 2.5 t/ha × 100% RDF (S_3F_2) in case of wheat. The lowest values of yield was observed in the combination of controls × control (S_0F_0) among the nutrient sources and nutrient levels in 2 years mean data of both soybean and wheat crops. Kumar *et al.* (2006) also reported higher yield of soybean due to combined application of nutrient sources, micronutrients and RDF by their complementary effect on soil bio-chemical reactions and soil fertility. Similar results have been reported by Shivakumar and Ahalawat (2008). Dwivedi and Thakur (2004) have recorded significantly higher yield attributes

Table 1. Grain and stover/straw yields, system productivity and soybean equivalent yield (SEY) as influenced by sources and levels of nutrients (mean data of 2 years)

Treatment		Yield (t/ha)				System productivity (t/ha)		Soybean equivalent yield (t/ha)
		Soybean		Wheat				
Soybean	Wheat	Grain	Stover	Grain	Straw	Grain	Stover	
Nutrient sources								
S_0, Control	S_0, Control	1.50	3.31	2.01	4.16	3.58	7.46	1.16
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	1.86	3.63	2.38	5.01	4.24	8.64	1.37
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	1.99	4.00	2.61	5.60	4.60	9.61	1.51
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	2.20	4.27	2.84	6.00	5.02	10.27	1.64
SEm±		0.11	0.37	0.14	0.15	0.22	0.39	0.08
CD (P=0.05)		0.39	1.27	0.50	0.53	0.77	1.36	0.29
Nutrient levels								
F_0, Control	F_0, Control	1.34	3.11	1.70	3.84	3.05	6.95	0.98
F_1, 50% RDF	F_1, 50% RDF	1.77	3.72	2.31	4.91	4.09	8.63	1.33
F_2, RDF	F_2, RDF	2.14	4.10	2.79	5.74	4.94	9.84	1.61
F_3, 50% RDF + Zn 5 kg/ha	F_3, 50% RDF + Zn 5 kg/ha	1.90	3.80	2.52	5.32	4.44	9.12	1.45
F_4, RDF + Zn 5 kg/ha	F_4, RDF + Zn 5 kg/ha	2.28	4.30	2.99	6.14	5.27	10.44	1.72
SEm±		0.21	0.40	0.22	0.41	0.41	0.63	0.13
CD (P=0.05)		0.62	1.17	0.63	1.17	1.17	1.82	0.36

of wheat under residual fertility of FYM with recommended dose of fertilizers. This might be due to variation in treatment combinations.

Total system productivity

The total productivity of soybean–wheat system was found to be influenced by different sources of nutrients in 2 years mean data. The maximum productivity in terms of total grain (5.02 t/ha) and stover (10.27 t/ha) yield was observed by the crop undergoing the direct and residual effect of poultry manure 2.5 t/ha, which was significantly higher than that obtained with other sources of nutrients. Whereas, lowest total system productivity was found in control plot (Table 1).

The total productivity of soybean–wheat cropping system was influenced significantly due to different levels of nutrients in two years mean data. The highest productivity in terms of total grain (5.27 t/ha) and stover (10.44 t/ha) yields were obtained from soybean–wheat when fertilized with RDF + Zn @ 5 kg/ha, which was found significantly superior in comparison to all other levels of nutrients (Table 1).

The soybean–wheat cropping system resulted in highest total productivity in terms of total grain (5.85 t/ha) and stover (11.50 t/ha) yields with the conjunctive use of direct and residual effect of poultry manure 2.5 t/ha along with RDF + 5 kg Zn/ha (S_3F_4) in comparison with other treatment combinations. The lowest values in all these attributes were observed in combination of controls × control (S_0F_0) among the nutrient sources and nutrient levels in 2 years mean data of soybean and wheat crops.

Soybean equivalent yield (SEY)

The soybean equivalent yield varied significantly among the different sources of nutrients and the highest SEY of 1.64 t/ha was recorded with the application of PM @ 2.5 t/ha (S_3) being significantly higher than those found in other treatments in 2 years mean data. The lowest SEY was recorded in control (S_0) treatment in 2 years mean data. The higher SEY yield was mainly due to higher yield of wheat. Among the different nutrient levels, crop fertilized with RDF + Zn 5 kg/ha (F_4) resulted in maximum SEY of 1.72 t/ha. On the other hand, the lowest SEY was recorded under untreated control treatment (Table 1).

Furthermore, the combined effect of sources and levels of nutrients on SEY of soybean were significant in 2 years mean data. It is obvious from the data that sources of nutrients at the same or different levels altered the SEY significantly in 2 years mean data. An application of PM @ 2.5 t/ha in conjunction with RDF + Zn 5 kg/ha (S_3F_4) recorded the highest SEY of 1.95 t/ha in 2 years mean data, which appears to be higher than those found with other treatment combinations. The absolute control treatment (S_0F_0) had significantly minimum SEY compared to all other treatment combinations (Table 1). In soybean–wheat cropping system Ramesh *et al.*, (2009) also recorded the highest equivalent yield under integrated nutrient management.

Economics

The highest economics in terms of net return (40.8 × 10^3₹/ha and 31.3 × 10^3₹/ha) and B: C ratio (2.93 and 2.56) among different sources was observed with direct application of PM 2.5 t/ha for soybean and there residual effect in succeeding wheat crops, indicating that it was much benefited by the residual effect. The lowest economic returns were obtained in control plots, which might be due to the poor grain and stover yields (Table 2).

The data further revealed that economic returns increased with increased levels of nutrients compared to unfertilized control treatments. The highest net returns amounting to be 41.0 × 10^3₹/ha and 31.3 × 10^3₹/ha with a widest B: C ratio of 2.79 and 2.41 were recorded in the crop fertilized with RDF + Zn 5 kg/ha (F_4) followed by application of RDF (F_2), being higher over other levels of nutrients for both soybean and wheat crops. Similar findings were also reported by Shivakumar and Ahlawat (2008). On the other hand, the lowest economic returns was found in control plot (F_0) treatment.

In interaction effects among different treatment combinations (Table 2), the PM @ 2.5 t/ha along with RDF + Zn 5 kg/ha (S_3F_4) incurred maximum economics in terms of net returns and B: C ratio followed by (S_3F_2) treatment combinations. Among the various treatment combination control × control (S_0F_0) treatment might have resulted in the lowest economics compared to others treatment combinations in both soybean and wheat crops. Finally it was concluded that the combined application of PM @ 2.5 t/ha along with RDF + Zn 5 kg/ha will be helpful in realizing higher productivity and economic returns from both the crops individually as well as from soybean–wheat cropping system.

Energetics

Among the nutrient sources, the highest total energy output of soybean and wheat (32. 33 and 116.65 MJ/ha, was recorded with application of PM @ 2.5 t/ha (S_3) to soybean and their residual effect on succeeding wheat crop, which may be due to the highest grain and stover yields of both the crops. The lowest value of energy output was obtained in untreated control (S_0) treatment. With regard to nutrient levels, application of RDF + Zn 5 kg/ha (F_4), recorded maximum value of total energy output of soybean and wheat (33.44 and 120.67 MJ/ha) as compared

Table 2. Economics of soybean–wheat cropping system as influenced by sources and levels of nutrients (mean data of 2 years)

Treatment: Soybean	Treatment: Wheat	Cost of cultivation (× 10³ ₹/ha) Soybean	Cost of cultivation (× 10³ ₹/ha) Wheat	Net returns (× 10³ ₹/ha) Soybean	Net returns (× 10³ ₹/ha) Wheat	Benefit : cost ratio Soybean	Benefit : cost ratio Wheat
Nutrient sources							
S_0, Control	S_0, Control	17.6	16.4	22.7	16.3	2.12	1.81
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	20.2	16.4	29.7	23.0	2.30	2.14
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	19.2	16.4	34.6	27.4	2.59	2.36
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	18.7	16.4	40.8	31.3	2.93	2.56
SEm±		–	0.06	0.37	0.01	0.01	
CD (P=0.05)		–	0.19	1.07	0.05	0.04	
Nutrient levels							
F_0, Control	F_0, Control	17.6	16.4	19.3	14.5	2.02	1.89
F_1, 50% RDF	F_1, 50% RDF	19.4	19.1	29.1	22.5	2.40	2.18
F_2, RDF	F_2, RDF	21.1	21.9	37.7	28.1	2.67	2.28
F_3, 50% RDF + Zn 5 kg/ha	F_3, 50% RDF + Zn 5 kg/ha	19.6	19.3	32.6	26.0	2.56	2.35
F_4, RDF + Zn 5 kg/ha	F_4, RDF + Zn 5 kg/ha	21.4	22.2	41.0	31.3	2.79	2.41
SEm±		–	–	0.30	0.78	0.03	0.02
CD (P=0.05)		–	–	0.92	2.31	0.08	0.05

MSP 2014–15: soybean ₹25,600/t, wheat ₹14,500; 2015–16 soybean ₹26,000/t, wheat ₹15,250/t

Table 3. Energy input and output relationship of soybean as influenced by sources and levels of nutrients (mean data of 2 years)

Treatment: Soybean	Treatment: Wheat	Energy input (MJ × 10³) Soybean	Energy input (MJ × 10³) Wheat	Energy output (MJ/ha) Soybean	Energy output (MJ/ha) Wheat	Energy output-input ratio Soybean	Energy output-input ratio Wheat	Energy-use efficiency (MJ × 10³/ha) Soybean	Energy-use efficiency (MJ × 10³/ha) Wheat
Nutrient sources									
S_0, Control,	S_0, Control	4.55	3.93	22.02	81.54	4.84	20.73	1.06	1.57
S_1, Crop residues 5 t/ha	S_1, Residual effect of previous treatment	10.83	3.93	27.30	97.58	2.52	24.81	0.51	1.88
S_2, FYM 5 t/ha	S_2, Residual effect of previous treatment	6.08	3.93	29.28	108.38	4.82	27.55	0.99	2.09
S_3, Poultry manure 2.5 t/ha	S_3, Residual effect of previous treatment	7.33	3.93	32.33	116.65	4.41	29.66	0.88	2.25
Nutrient levels									0.00
F_0, Control	F_0, Control	4.55	3.93	19.74	72.95	4.34	18.54	0.98	1.41
F_1, 50% RDF	F_1, 50% RDF	5.56	8.02	25.96	95.33	4.67	11.89	0.99	0.90
F_2, RDF	F_2, RDF	6.56	12.10	31.50	112.69	4.80	9.31	0.95	0.71
F_3, 50% RDF + Zn 5 kg/ha	F_3, 50% RDF + Zn 5 kg/ha	6.61	9.06	27.99	103.54	4.23	11.43	0.86	0.87
F_4, RDF + Zn 5 kg/ha	F_4, RDF + Zn 5 kg/ha	7.61	13.14	33.44	120.67	4.39	9.18	0.86	0.70

to rest of other treatments. The lowest value of total energy output was under control (F_0) treatment (Table 3).

The highest energy output-input ratio of soybean (4.84) was recorded under untreated control (S_0) treatment owing to the lowest total energy input as compare to nutrient applied treatment. In wheat crop, residual effect of poultry manure @ 2.5 t/ha (S_3) recorded the highest energy output-input ratio (29.66), which may be due to the highest grain and stover yields as compare to rest of the treatments. On the other hand the lowest energy output-input ratio of soybean was recorded with application of crop residues 5 t/ha (S_1) and in wheat under untreated control (S_0) treatment. With regard to nutrient levels, application of RDF (F_2) recorded maximum value of energy output-input ratio (4.80) of soybean. Untreated control (F_0) treatment recorded maximum value of energy output-input ratio (18.54) in succeeding wheat crop in comparison to remaining treatments (Table 3). The lowest value of energy output-input ratio of soybean under application of 50% RDF + Zn 5 kg/ha (F_3) and RDF + Zn 5 kg/ha (F_4) in succeeding wheat crop. The results are in accordance with the findings of Billore and Joshi (2004).

The highest energy-use efficiency of soybean 1.06 t MJ × 10^3/ha was recorded under untreated control treatment, which was owing to the lowest total energy input as compared to nutrient applied treatment. In succeeding wheat crop the highest energy-use efficiency (2.25 t MJ × 10^3/ha) was recorded under residual effect of application of PM @ 2.5 t/ha, which may be due to the highest grain and stover yields. On the other hand, the lowest value of energy-use efficiency of soybean was recorded with application of crop residues 5 t/ha and untreated control treatment in succeeding wheat crop. Similar result was also reported by Billore and Joshi (2004). As regard to nutrient levels, application of 50% RDF recorded maximum value of energy-use efficiency of soybean (0.99 t/MJ × 10^3/ha). In succeeding wheat crop untreated control treatment recorded maximum value of energy-use efficiency (1.41 t/MJ × 10^3/ha) as compared to rest of other treatments which might be due to lower total energy input as compared to nutrient applied treatment. The lowest value of energy-use efficiency of soybean under application of 50% RDF + Zn 5 kg/ha and wheat under application of RDF + Zn 5 kg/ha (Table 3).

Based on the study, it was concluded that highest total productivity net returns and B:C ratio were recorded in soybean–wheat cropping system with the direct and residual effect of poultry manure compared to other sources. Both the crops in system when fertilized with RDF + Zn @ 5 kg/ha recorded the highest total productivity, net returns and B:C ratio among all the levels of nutrients. The conjunctive use of poultry manure and RDF + 5 kg Zn/ha resulted in the highest total productivity and profitability in comparison to their sole application.

REFERENCES

Anonymous. 2014. Annual Report of the All India Coordinated Research Project on Soybean (2014-15). National Research Centre for Soybean, Indore, Madhya Pradesh. Pp. 7–9.

Anonymous. 2016. Annual Report 2015–16, Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare, Government of India. Krishi Bhawan, New Delhi. Pp 3–4.

Albiach, R., Canet, R., Pomares, F. and Ingelmo, F. 2000. Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bio-research Technology* **75**: 43–48.

Behera, U.K., Sharma, A.R. and Pandey, H.N. 2007. Sustaining productivity of wheat-soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant and Soil* **297**(1/2): 185–199.

Billore, S.D. and Joshi, O.P. 2004. Production potential and economic feasibility of soybean, (*Glycine max* (L.) Merrill)-based cropping systems. *Journal of Oilseeds Research* **21**(1): 55–57.

Dwivedi, D.K. and Thakur, S.S. 2004. Effect of organic and inorganic sources of nutrients on chemical properties of soil under rice–wheat cropping system. *RAU Journal of Research* **14**(1): 5–8

Gomez, K.A. and Gomez, A.A. 1984. *Statistical procedures for agricultural research*. A Willey Inter Science Publications, New York. pp 76–83.

Kumar, Y.K.D., Ananda, M.R., Rehaman, H.M.A., Vishwanath, A.P. and Vital, N. 2006. Nutrient uptake, availability and yield of soybean as influenced by integrated nutrient management. *Environment and Ecology* **24**(4): 1,056–1,058.

Mittal, V.K., Mittal, J.P. and Dhawan, K.C. 1985. Research digest on energy requirements in Agriculture sector (1971-82) *ICAR/AICRP/ERAS/85*(1) Ludhiana, pp. 159–163.

Rana, R. and Badiyala, D. 2014. Effect of integrated nutrient management on seed yield, quality and nutrient uptake of soybean (*Glycine max*) under mid hill conditions of Himachal Pradesh. *Indian Journal of Agronomy* **59**(4): 641–645.

Ramesh, P., Panwar, N.R., Singh, A.B. and Ramana, S. 2009. Production potential, nutrient uptake, soil fertility and economics of soybean (*Glycine max*)-based cropping systems under organic, chemical and integrated nutrient management practices. *Indian Journal of Agronomy* **54**(3): 278–283.

Shivakumar, B.G. and Ahlawat, I.P.S. 2008 Integrated nutrient management in soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **53**(4): 273–278

Thakur, R., Sawarkar, S.D., Vaishya, U.K. and Singh, M. 2011. Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean–wheat intensive cropping of a vertisol. *Journal of the Indian Society of Soil Science* **59**(1): 74–81.

Verma, S. and Sharma, P.K. 2007. Effect of long-term manuring and fertilizer on carbon pools, soil structure and sustainability under different cropping systems in wet temperate zone of north-west Himalayas. *Biology and Fertility of Soils* **44**(1): 235–240.