Indian Journal of Agronomy **53**(4): 273–278 (December 2008)

Integrated nutrient management in soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system

B.G. SHIVAKUMAR* AND I.P.S. AHLAWAT

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012

Received: June 2008

ABSTRACT

A field experiment was carried out during 2001-03 at Indian Agricultural Research Institute, New Delhi to study the impact of nutrient management practices on the growth, yield and economics of soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system. The treatments consisted of combinations of 4 nutrient sources in main plots and 3 nutrient levels in subplots in soybean in rainy season. A general crop of wheat was grown during the following winter season to study the residual effect of treatments imposed on the previous soybean. The results indicated that application of 5 t/ha each of crop residues (CR) and farmyard manure (FYM) along with 5 kg zinc/ha among the nutrient sources and 100% recommended dose of fertilizer (RDF) among the nutrient levels recorded significantly higher growth and yield parameters and yield (1.62 t/ha) of soybean. The succeeding crop of wheat too showed a similar trend. The net returns were higher with 5 t/ha of FYM in soybean (Rs 8,154) and 5 t/ha each of CR and FYM alongwith 5 kg Zn/ha in succeeding wheat (Rs 12,577), as well as in soybean-wheat cropping system (Rs 20,334). The benefit:cost (B:C) ratio was higher with 100% RDF among nutrient levels (0.89) and with 5 t/ha CR (0.81) among the nutrient sources in soybean, whereas the 100% RDF among nutrient levels (0.73) and FYM @ 5 t/ha+ CR @ 5 t/ha + 5 kg Zn/ha among sources given to soybean recorded higher B:C ratio (0.72) in wheat. The organic carbon and the available N, P, K and Zn were higher with 5 t/ha each of CR and FYM along with 5 kg zinc/ha among the nutrient sources, and 100% RDF among nutrient levels after the completion of 3 years of experimentation. It was concluded that combined application of 5 t/ha each of CR and FYM along with 5 kg/ha zinc is necessary for getting higher yield and net returns from soybean-wheat cropping system.

Key words: Economics, Nutrient sources, Recommended dose of fertilizer (RDF), Soil-fertility, Soybean, Wheat

Soybean [*Glycine max* (L.) Merr.] – wheat (*Triticum aestivum* L. emend. Fiori. & Paol.) cropping system has a great potential in the northern plains zone of India, comprising Punjab, Haryana, western Uttar Pradesh, Delhi, parts of Rajasthan, Madhya Pradesh etc. With many problems coming to fore 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). As soybean is a legume and wheat is a cereal, together they complement each other in the cropping system. However, both these crops require better nutrient-management practices to express their full potential. The optimum dose of nutrients and their sources play an important role in increasing the productivity of these crops. Due to prolonged cultivation of crops with recommended dose of inorganic fertilizers alone, the productivity of soils has gone down, and time has come to supplement these inorganic fertilizers with organics and micronutrients to sustain the fertility and productivity of the soils (Behera *et al.*, 2007). Integration of inorganic and organic sources of nutrients along with bio-fertilizers is found to give higher productivity and monetary returns in soybean (Singh and Rai, 2004; Bhattacharyya *et al.*, 2008). Further the organic sources unlike inorganic ones have substantial residual effect on the succeeding crops (Duraisami and Mani, 2001). Keeping these points in view a field investigation was carried out to workout suitable nutrient management practices for higher productivity and monetary returns in soybean-wheat cropping system.

*__Corresponding author__ (Email: bgskumar@yahoo.com)

MATERIALS AND METHODS

A field experiment was carried out during 2000-01 to 2002-03 at the research farm of Indian Agricultural Research Institute, New Delhi. The weather during the experimental period was normal except for lower rainfall in the second year (2001-02). The soil was alluvial sandy loam, slightly alkaline (pH 7.4), analysing medium in organic C (0.51%), low in available N (298 kg/ha) and medium in P (14 kg/ha) and K (286 kg/ha), with DTPA-extractable Zn of 0.44 ppm.

The treatments consisted of 4 nutrient sources, viz. the control, wheat crop residue @ 5 t/ha, farmyard manure @ 5 t/ha and combination of 5 t/ha each of crop residue (CR) and farmyard manure (FYM) along with 5 kg zinc/ha in the main plots; and 3 levels of recommended dose of fertilizers (RDF) (30-33-33.2 kg N-P-K/ha) viz. 0, 50 and 100% in subplots in soybean. Twelve treatment combinations were tried in split-plot design, replicated thrice. The nutrient sources, viz. wheat residue (0.84% N, 0.06% P and 1.44% K), farmyard manure (0.51% N, 0.20% P, 0.19% K) and zinc (as $ZnSO_4.7H_2O$; 21% Zn) as per the treatments, were applied 15 days before sowing and incorporated through land preparation in the soil; and the nutrient levels of recommended dose of fertilizer were applied broadcast and incorporated into the soil during final seed bed preparation. Urea, single superphosphate and muriate of potash were used as sources of N, P and K respectively for supplying the levels RDF. The sulphur content in single superphosphate was made up uniform in all the treatments using gypsum ($CaSO_4$ $5H_2O$; 18% S).

Soybean ('Pusa 22') was sown @ 75 kg/ha in 45 cm rows during the first fortnight of July in all the 3 years of experimentation. The seeds were treated with cultures of rhizobium (*Bradyrhizobium japonicum*) and phosphate-solubilizing bacteria (PSB) (*Pseudomonas striata*) before sowing. After emergence of seedlings, these were thinned manually to maintain a plant population of 0.45 million/ha. The crop was irrigated by surface flooding as and when dry spells occurred. On an average 3 irrigations were given during the entire crop growing period in different years of experimentation. Two manual weedings were carried out at 30 and 50 days after sowing (DAS) and inter-cultivation was done by running a plough between the rows twice after each manual weeding to facilitate proper aeration of the root zone and to overcome compaction during manual weeding. There were no incidents of severe insect pests or diseases during any of these years. However, one spray of dimethoate (@ 2 ml/litre water) solution was undertaken as preventive measure to control white-flies acting as vector for yellow mosaic virus (YMV) during the peak vegetative period (45 DAS). The crop was raised with standard agronomic practices except for the treatments. All the growth and yield parameters were recorded at physiological maturity (110 DAS), whereas observations on the nodule numbers and their biomass were recorded at 60 DAS and the crop was manually harvested, threshed and seed yields were recorded.

After the harvest of soybean, the land was disked and levelled without disturbing the lay-out. The recommended dose of fertilizer of wheat (120-26.4-33.2 kg N-P-K /ha) in the form of urea, diammonium phosphate and muriate of potash was given uniformly to all the plots. Wheat ('HD 2285') was sown in 22.5 cm rows using a seed rate of 100 kg/ha in the second fortnight of November in all the years, and the crop was raised with normal agronomic practices. All the growth and yield parameters were recorded at physiological maturity (120 DAS). The crop was manually harvested, threshed and the yield was recorded.

The soil samples were collected from each plot after the harvest of wheat, after 3 years of cropping system, at 0-30 cm depth and analysed using standard procedures. The net return and benefit : cost (B : C) ratio were computed using the prevailing market rates and prices for the inputs and the seed of soybean and wheat. The data recorded were analysed as per analysis of variance technique for split-plot design and presented as mean data of 3 years.

RESULSTS AND DISCUSSION

Performance of soybean

The growth attributes, viz. plant height, number of branches/plant, dry-matter accumulation and number of nodules and their dry weight in soybean were maximum with the combined application of 5 t/ha each of crop residues, farmyard manure and 5 kg/ha zinc. The least values of these attributes were noted with the control among the nutrient sources. The 100% RDF application recorded significantly higher plant height, number of branches and dry-matter accumulation than the rest of the treatments among the nutrient levels, whereas the number of nodules and their dry weight, being on par with 50% RDF, were significantly superior to the control (Table 1). This performance may be attributed to improved soil fertility and microflora activity in the rhizosphere with the application of organic sources of nutrients and RDF.

The number of pods/plant, number of seeds/pod and the pod yields/plant were significantly higher with the combined application of 5 t/ha each of crop residues, farmyard manure and 5 kg/ha of zinc compared with the rest of the nutrient sources. It was followed by individual application of farmyard manure and crop residue, respectively. The least values were observed with the control. Further, the application of 100% RDF recorded significantly higher values of these yield attributes than 50% RDF, which in turn was significantly superior to the control among the fertility levels. Though the 100-seed weight was higher with the combined application of 5 t/ha each of crop residue, farmyard manure and 5 kg/ha zinc among nutrient sources and 100% RDF among the nutrient levels, it was found statistically on par with that of other treatments. The increased growth attributes due to these treatments might have improved the yield parameters of soybean.

Combined application of 5 t/ha each of crop residues, FYM and 5 kg/ha of zinc recorded significantly higher seed yield (1.48 t/ha), stover yield (4.06 t/ha) and harvest index (36.4%). It was closely followed by application of 5 t/ha FYM alone. Application of 100% RDF recorded significantly higher seed yield (1.55 t/ha), stover yield (4.35 t/ha) and harvest index (35.5). As there was ideal condition for soil microflora due to application of crop residues and FYM along with zinc, and increased availability of nutrients with 100% RDF, there was improvement in both growth and yield attributes, which in turn might have increased the yield of soybean.

The nutrient sources along with zinc and nutrient levels showed significant interaction effects among them. The combined application of 5 t/ha each of crop residues, FYM and 5 kg/ha of zinc in combination with 100% RDF recorded significantly higher plant height, dry-matter accumulation, pods/plant, seeds/pod, seed yield (1.62 t/ha) (Fig. 1) and stover yield (4.65 t/ha). It was closely followed by the combination 5 t/ha FYM and 100% RDF, which recorded higher values in all these except dry-matter accumulation and pods/plant, wherein the application of 5 t/ha each of crop residues, FYM and 5 kg/ha of zinc in combination with 50% RDF recorded higher values. The lowest values in all these attributes were observed in the combination of controls among the nutrient sources and nutrient levels. Likewise Kumar *et al.* (2006) also reported higher yield of soybean due to combined application of nutrient sources, micronutrients and 100% RDF by their complementary effect on soil bio-chemical reactions and soil fertility.

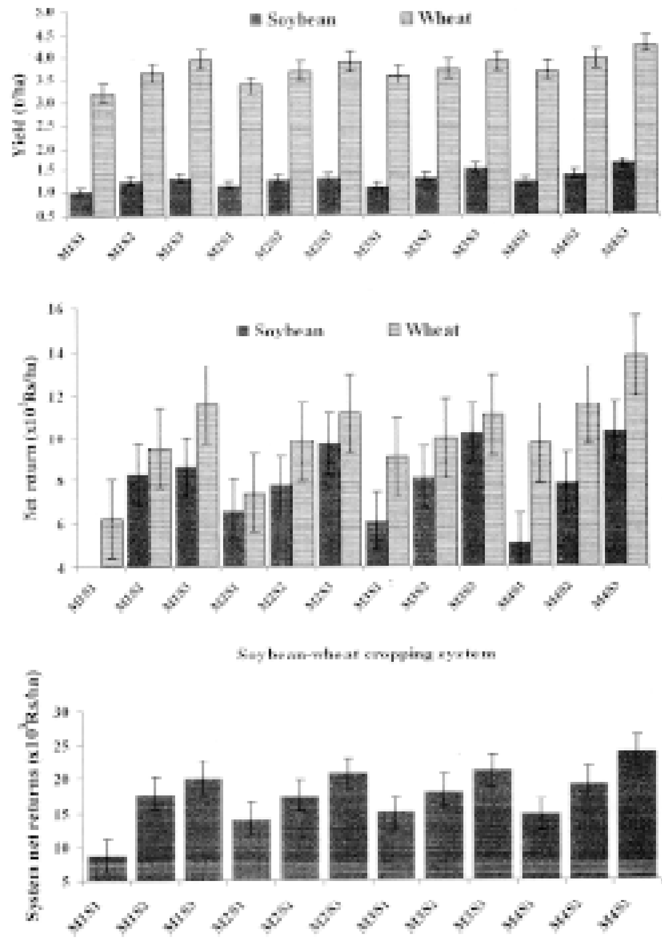

Fig. 1. Interaction effect of nutrient sources and nutrient levels on grain yield and net returns of soybean-wheat cropping system. M_1=Control, M_2=CR @ 5 t/ha, M_3=FYM @ 5 t/ha, M_4=CR 5 t/ha +FYM 5 t/ha + Zn 5 kg/ha; S_1=Control, S_2=50% RDF, S_3=100% RDF

Residual effect on wheat

The growth attributes (plant height, number of tillers

Table 1. Effect of nutrient-management practices on growth and yield attributes, yield and harvest index of soybean (mean data of 3 years)

Treatment	Plant height (cm)	Nodules/ plant	Nodule dry weight (mg/plant)	Pods/ plant	Seeds/ pod	Pod yield (g/plant)	100 seed weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Nutrient sources										
Control	59.7	28.8	300.8	37.2	1.90	5.60	9.05	1.12	3.49	31.9
CR 5 t/ha	60.7	33.4	333.0	41.3	2.00	5.93	9.22	1.33	3.88	34.3
FYM 5 t/ha	60.9	44.2	351.7	42.2	2.10	6.16	9.42	1.42	4.03	35.1
CR+FYM+Zn 5 kg/ha	62.2	44.3	364.0	52.1	2.30	6.37	9.43	1.48	4.06	36.4
SEm±	0.42	0.34	2.22	0.85	0.03	0.05	0.32	0.03	0.08	0.32
CD (P=0.05)	1.47	1.19	7.70	2.95	0.12	0.19	NS	0.09	0.28	1.12
Nutrient levels										
Control	58.5	35.7	326.8	37.2	1.90	5.69	9.21	1.10	3.27	33.4
50% RDF	61.5	38.0	341.3	42.4	2.10	6.03	9.33	1.37	3.98	34.4
100% RDF	62.7	39.4	344.1	50.0	2.20	6.34	9.31	1.55	4.35	35.5
SEm±	0.34	1.02	3.38	0.77	0.03	0.09	0.23	0.02	0.07	0.24
CD (P=0.05)	0.98	2.94	9.79	2.24	0.10	0.26	NS	0.07	0.20	0.70

CR=Crop residues; FYM=farmyard manure; RDF=recommended dose of fertilizers and dry-matter accumulation), yield attributes (number of ears, ear weight, 1,000-seed weight); seed yield and straw yield were significantly higher with 5 t/ha each of crop residues, FYM and 5 kg/ha zinc among the nutrient sources applied to previous soybean. These were, however at par with application of 5 t/ha FYM alone in all the yield attributes. Similarly, 100% RDF applied to the previous soybean recorded significantly higher growth and yield attributes, and yield of wheat among the different nutrient levels. The least values were observed with the control. Harvest index was not significantly influenced by either nutrient sources or nutrient levels applied to the previous soybean (Table 2). The nutrient sources due to slow and gradual decomposition show residual effect and thus might have improved the performance of wheat after soybean. Further, the application of 100% RDF might have resulted in better supply of nutrients to the previous crop and after meeting its requirement some quantity might have been made available to the succeeding crop of wheat. Upadhyay (2003) also observed such residual effects of organic as well as inorganic sources of nutrients.

Nutrient sources and levels applied to soybean on wheat showed significant residual effect. The combined application of 5 t/ha each of crop residues, FYM and 5 kg/ha zinc in combination with 100% RDF to soybean recorded significantly higher ear weight and seed yield (4.26 t/ha) (Fig. 1). Deshmukh *et al.* (2005) also reported that 100% RDF along with 2.5 t FYM/ha and drainage in soybean and soil mulch in chickpea recorded the highest yield in soybean-chickpea cropping system, indicating that addition of organics along with 100% RDF is necessary for higher productivity of soybean.

Soil fertility

There was some degree of variation in the organic C content, available N, P, K and DTPA-extractable Zn compared with the initial status in the soil after 3 years of soybean-wheat cropping system. All the treatments improved the organic C content over the years, but that of the available N, P, K and Zn decreased in the control among the sources and increased with other treatments (Table 3). Among the treatments, the combined application of 5 t/ha each of crop residues, FYM and 5 kg/ha zinc recorded significantly higher organic carbon content and the available N, P and Zn in the soil after completion of soybean-wheat system compared with 5 t/ha crop residues and the control among nutrient sources. It also recorded significantly higher available K after soybean-wheat system among all the treatments of nutrient sources. Similarly, 100% RDF to soybean recorded significantly higher organic carbon, available N and P in the soil after soybean-wheat system compared with 50% RDF and the control. Both 50% and 100% RDF to soybean, being at par, recorded significantly higher available K and Zn in the soil compared with the control. Abraham and Lal (2003) too reported that the percentage of organic carbon and available status of P and K in the soil increased due to the integration of organic and inorganic sources of nutrients in soybean-Indian mustard-fodder cowpea in north eastern plains zone of India. Walia and Kler (2007) also observed positive balance of available P with the combination of organic sources of nutrients in soybean-wheat cropping system.

Economics

The highest net returns (Rs 8,154/ha) among sources

Table 2. Residual effect of nutrient-management practices in preceding soybean on growth and yield attributes, yield and harvest index of wheat (mean data of 3 years)

Treatment	Plant height (cm)	Ears/ m row	1000-seed weight (g)	Seed yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Nutrient sources						
Control	93.7	75.6	47.9	3.60	8.51	42.2
CR 5 t/ha	94.8	77.0	48.4	3.65	8.58	42.6
FYM 5 t/ha	96.2	79.7	50.1	3.73	8.70	43.0
CR+FYM+Zn 5 kg/ha	98.8	80.0	50.4	3.96	9.19	43.1
SEm±	0.52	0.48	0.27	0.03	0.10	2.55
CD (P=0.05)	1.81	1.64	0.93	0.12	0.36	NS
Nutrient levels						
Control	87.7	74.5	46.4	3.46	8.50	40.7
50% RDF	94.9	77.5	49.4	3.76	8.68	43.3
100% RDF	105.0	82.4	51.9	3.99	9.05	44.1
SEm±	0.66	0.80	0.49	0.03	0.10	2.05
CD (P=0.05)	1.93	2.30	1.41	0.10	0.28	NS

CR=Crop residues; FYM=farmyard manure; RDF=recommended dose of fertilizers was observed with FYM @ 5 t/ha, followed by crop residues @ 5 t/ha. The application of 5 t/ha each of CR, FYM and 5 kg Zn/ha recorded lower net returns owing to higher input costs. However, all the nutrient sources were significantly superior to the control. The highest B:C ratio was however observed with the CR @ 5 t/ha (0.81). The lowest benefit:cost (B:C) ratio was observed with 5 t/ha each of CR, FYM and 5 kg/ha zinc. This may be attributed to non-matching economic returns due to this treatment, although the net returns were higher than in the control. Among the nutrient levels, 100% RDF recorded significantly higher net returns and B:C ratio (0.89), due to better response to the applied fertilizers.

The highest net return and B:C ratio in succeeding wheat were observed with 5 t/ha each of FYM, CR and 5 kg Zn/ha among nutrient sources, indicating that it was much benefited by the residual effect. The 100% RDF being at par with 50% RDF recorded significantly higher net returns, while B:C ratio was significantly superior among the nutrient levels with 100% RDF. Joshi and Billore (2004) also reported similar findings.

The net return from soybean-wheat cropping system was significantly higher with application of 5 t/ha each of CR, FYM and 5 kg/ha zinc to previous soybean among the nutrient sources except FYM 5t/ha. Again, significantly higher net return from the system was observed with 100% RDF applied to soybean among different nutrient levels, followed by 50% RDF and the control. Further, there was a significant interaction effect between the best treatments in nutrient sources and nutrient levels, record-

Table 3. Effect of nutrient management practices in soybean on organic C, available N, P, K and Zn status in the soil after 3 cycles of soybean-wheat cropping system

Treatment	Organic C (%)	Available nutrients (kg/ha) N	P	K	Zn (ppm)
Nutrient sources					
Control	0.51	296.9	13.0	281.0	0.42
CR 5 t/ha	0.54	311.3	13.3	290.1	0.46
FYM 5 t/ha	0.59	314.6	13.4	295.1	0.47
CR+FYM+Zn	0.62	317.9	13.8	311.9	0.58
SEm±	0.02	1.4	0.13	3.0	0.01
CD (P=0.05)	0.06	4.9	0.45	10.5	0.04
Nutrient levels					
Control	0.55	304.3	13.2	286.7	0.46
50% RDF	0.56	310.1	13.3	296.0	0.49
100% RDF	0.60	316.1	13.7	300.9	0.50
SEm±	0.01	1.2	0.11	2.9	0.01
CD (P=0.05)	0.03	3.5	0.32	8.4	0.02

Table 4. Effect of nutrient-management practices on cost of cultivation and monetary returns (x10^3 Rs/ha) from soybean-wheat cropping system (mean data of 3 years)

Treatment	Soybean			Wheat			System net returns
	Cost of cultivation	Net returns	B : C ratio	Cost of cultivation	Net returns	B : C ratio	
Nutrient source							
Control	8.66	6.49	0.73	16.13	9.04	0.56	15.54
CR 5 t/ha	9.86	8.06	0.81	16.13	9.43	0.58	17.49
FYM 5 t/ha	10.86	8.15	0.74	16.13	10.00	0.62	18.16
CR+FYM+Zn	12.06	7.76	0.64	16.13	11.58	0.72	19.33
SEm ±		0.33	0.03		0.23	0.01	0.51
CD (P=0.05)		1.15	0.11		0.80	0.05	1.76
Nutrient level							
Control	9.70	5.09	0.52	16.13	8.08	0.50	13.17
50% RDF	10.36	8.04	0.79	16.13	10.16	0.63	18.21
100% RDF	11.02	9.72	0.89	16.13	11.80	0.73	21.52
SEm ±		0.32	0.03		0.24	0.01	0.41
CD (P=0.05)		0.92	0.10		0.68	0.04	1.18

ing the highest net returns (Rs. 23,973) from the soybean-wheat cropping system (Fig. 1). Deshmukh *et al.* (2005) too reported higher monetary returns in soybean-chickpea cropping system due to combined application of organics and 100% RDF.

It was concluded that the combined application of 5 t/ha each of CR, FYM and 5 kg/ha zinc along with 100% RDF to soybean will be helpful in realizing higher productivity and net returns from both the crops individually as well as from soybean–wheat cropping system. These treatments also help in maintaining higher available status of N, P, K and Zn besides higher organic C content.

REFERENCES

Abraham, T. and Lal, R.B. 2003. Strategies for INM technology in sustainable edapho-cultivar management for a legume based (soybean-mustard-fodder cowpea) cropping system for the inceptisols in the NEPZ. *Crop Research, Hisar* **26**(1): 33-41.

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.

Bhattacharyya, R., Kundu, S., Ved Prakash and Gupta, H.S. 2008. Sustainability under combined application of mineral and organic fertilizers in a rainfed soybean–wheat system of the Indian Himalayas. *European Journal of Agronomy* **28**(1): 33-46.

Deshmukh, K.K., Saraiya, A.B. and Dubey, D.P. 2005. Effect of integrated nutrient management on productivity trends, economics and soil fertility in soybean–chickpea cropping system. *JNKVV Research Journal* **39**(2): 29-32.

Duraisami, V.P. and Mani, A.K. 2001. Residual effect of inorganic nitrogen, composted coir-pith and biofertilizer on yield and uptake of soybean in an inceptisol. *Madras Agricultural Journal* **88**(4/6): 277-280.

Joshi, O.P. and Billore, S.D. 2004. Fertilizer management in soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* **74**(8): 430-432.

Kumar, Y.K.D., Ananda, M.R., Rehaman, H.M.A., Vishwanath, A.P. and Vittal, Navi. 2006. Nutrient uptake, availability and yield of soybean as influenced by integrated nutrient management. *Environment and Ecology* **24**(4): 1056-1058.

Singh, Ranjit and Rai, R.K. 2004. Yield attributes, yield and quality of soybean (*Glycine max*) as influenced by integrated nutrient management. *Indian Journal of Agronomy* **49**(4): 271-274.

Upadhyay, V.B. 2003. Fertilizer management in soybean (*Glycine max* L.)–wheat (*Triticum aestivum* L.) cropping system in Malwa Plateau of Madhya Pradesh. *Journal of Oilseeds Research* **20**(2): 278-279.

Verma, S. and Sharma, P.K. 2007. Effect of long-term manuring and fertilizers 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.

Walia, S.S. and Kler, D.S. 2007. Ecological studies on organic verses inorganic nutrient sources under diversified cropping systems. *Indian Journal of Fertilisers* **3**(7): 55-62, 74.