



## Performance of soybean (*Glycine max*)-based cropping sequences under organic, inorganic and integrated nutrient supply systems in a *Vertisols*

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### ABSTRACT

Experiments were conducted at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during 2004–05 to 2008–09 (five years) with the objective to develop efficient crop and soil management options for organic farming and their after effects on productivity and sustainability of 4 soybean [*Glycine max* (L.) Merr.] based cropping systems with wheat [*Triticum aestivum* (L.) emend. Fiori & Paol], berseem (*Trifolium alexandrinum*), mustard [*Brassica juncea* (L.) Czern & Coss.] and chickpea [*Cicer arietinum* (L.)] under organic, inorganic and integrated nutrient supply system. In the first year of study, inorganic nutrient supply system (INS) recorded markedly higher yield in all the cropping systems. However, from the second year onwards, integrated plant nutrient supply system (IPNS) produced higher yield in all the four cropping systems studied and found better than INS. Production in all the four cropping systems with organic manuring alone (ONS) was significantly lower than with INS, although the differences decreased as the cropping systems progressed over years. Organic farming system can be profitable only if a price premium of 20% or above is provided. From the view point of soil fertility, IPNS was the best followed by organic nutrient supply system (ONS), while the application of chemical fertilizer alone (INS) recorded the lowest values of available N, P and K and bacterial count.

**Key words:** Organic farming, Soybean-based systems, Sustainability, Total productivity

Soybean is an important *kharif* crop in Chhattisgarh under upland soil conditions, where rice is not grown on *Vertisols*. It occupies an area of 1.12 lakh ha and has a productivity of 1200 kg/ha. It can be an ideal option for using farm derived organic sources to reduce not only the expenditure on fertilizers in soybean based cropping system but also for raising a produce with a premium price, which is important for small farm holders whose income is not enough to feed his family. Being a leguminous crop it deals to build-up of soil fertility as well. Organic farming is not new to Indian farming community. Organic farming has been successfully practiced by the farmers in rainfed, tribal areas of Chhattisgarh. This has been mostly by default due to constraints of fertilizers, herbicides, pesticides and other agricultural chemicals. Even today, the farmers do not have enough funds to purchase chemical fertilizers and other agricultural chemicals. Organic cultivation of soybean, therefore seems promising especially in the state by gaining interest and price premium on organic foods (Prasad, 2005, Mahapatra *et al.*, 2009). Even in

the modern agriculture recycling of organic wastes as manure for sustaining soil health is considered important and integrated nutrient supply system (IPNS) is receiving considerable attention (Blaise and Prasad, 2005; Urkurkar *et al.*, 2010) but persuasive confirmation of maintaining the comparable crop yield under organic farming is not adequate. Therefore, a long-term study was initiated to compare inorganic and IPNS vis-a-vis organic farming in soybean based cropping systems.

### MATERIALS AND METHODS

Experiments were carried out at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during crop years 2004–05 to 2008–09 to evaluate different soybean based cropping sequences under full organic, integrated nutrient supply system (IPNS) and inorganic nutrient supply system. The soil was *Vertisol* with pH 7.7 and medium in organic C (6.4 g/kg). It was low in alkaline permanganate oxidizable available N (237kg/ha), medium in Olsen's available P (23 kg/ha) and high in 1M ammonium acetate exchangeable K (274 kg/ha). Initial microbial population was  $0.73 \times 10^5$ /g soil during summer 2004. The 3 nutrient supply systems as per respective crops *i.e.* 100% organic (1/3 of recommended N each from enriched compost (EC),

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cow dung manure (CDM) and neem cake (NC), 100% inorganic (from chemical fertilizer) and integrated (50% organic and 50% inorganic) and 4 cropping systems *viz.* soybean–wheat, soybean–berseem, soybean–mustard and soybean–chickpea were studied in the strip plot design with three replications having nutrient sources in vertical strips and cropping systems in horizontal strips. During *rabi* season, wheat ‘GW-273’, berseem ‘JB-1’, mustard ‘Pusa bold’ and chickpea ‘JG-74’ were grown after soybean ‘JS-335’ in *kharif*. Quantity of organic manures was determined on the basis of recommended doses of each crop *viz.* soybean–30:60:30, berseem–20:50:00, wheat–100:60:40, chickpea–20:50:00 and mustard–80:50:30 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O/ha. Nitrogen, P and K content (%) of different organic manures on dry weight basis were 0.5, 0.37 and 0.80 in CDM; 5.0, 1.0 and 1.25 in NC and 0.5, 0.5 and 0.75 in EC, respectively. The grain/seed yield of wheat, mustard and chickpea and fresh biomass of berseem was recorded. Soil samples at the end of each cycle were collected and analyzed for organic carbon, available N, available P and available K by following standard procedures. The total rainfall received during *kharif* (July to October) was 690, 1290, 930, 746 and 735 mm and during *rabi* (November to March) was 115, 159, 22, 44 and only 2.2 mm in 2004–05, 2005–06, 2006–07, 2007–08 and 2008–09 respectively. The experiment was conducted under assured irrigation facilities and need based irrigations were applied to soybean and *rabi* crops as per recommended practice. The cost of cultivation was calculated for 2008–09 only because organic farming requires a certain period for establishing the crop yields.

## RESULTS AND DISCUSSION

### Seed yield of soybean

In the first year of study soybean yield (1.6 t/ha with organic nutrient supply (ONS) was 23.3% lesser than that obtained with inorganic nutrient supply system (INS) (2.09 t/ha) and the difference was significant. Even integrated plant nutrient supply system (IPNS) recorded 8.7% lower soybean seed yield (1.91 t/ha) as compared to INS and the difference was significant (Table 1). This was due

to slow release of plant nutrients from organic sources. These differences in soybean yield declined as the cropping systems continued and during the sixth year, the yield difference between different nutrient supply systems were not significant. These results show that for soybean a yield stabilizing factor of about 5–6 years is required for practicing organic farming. As regards IPNS; it was at par with INS from the fourth year onwards, although not significant system seed yields were better with IPNS than INS. These results show the importance of organic manures in making farming more sustainable (Prasad and Mishra, 2001). Combined application of farmyard manure with chemical fertilizers was also found beneficial on grain yield of soybean by Chaturvedi and Chandel (2005).

### Seed yield of *rabi* crops

*Wheat*: Wheat yield also gradually increased with organic manures (ONS) and the gap between organic and inorganic sources of nutrients, which was 26.5% during 2004–05 narrowed down to only 7.7% during 2008–09 as compared to INS (Table 2). Mader *et al.*, (2002) also found 20 percent reduction in yields when a rotation including wheat, potato and forage was grown organically at Switzerland. On the contrary, in IPNS the wheat yield was lesser than that in INS only in the first year but increased by 22.6, 14.6, 8.6 and 9.4 % in second, third, fourth and fifth year, respectively. Nutrient release from organic sources was low which failed to fulfill the higher nitrogen requirements of wheat and reflected in lower yields due to inequity between plant nutrient demand and supply particularly initial stage of conversion from conventional to organic management system. In fifth year of experiment, maximum yield was recorded with integrated (2.27 t/ha) followed by inorganic (2.07 t/ha) and organic (1.91 t/ha).

*Berseem*: Green fodder production in berseem also followed the same trend as in wheat (Table 2). In ONS the reduction in green fodder yield declined from 25.7% in the first year to 9.1% in the fifth year. The green fodder yield in IPNS was significantly more than INS in second (18.6%), fourth (20.9%) and fifth (6.02%) year.

*Mustard*: The seed yield of mustard with organic ma-

**Table 1.** Seed yield (t/ha) of soybean and percent change under organic and IPNS over inorganic fertilizers

Nutrient source	Seed yield (t/ha)					
	2004	2005	2006	2007	2008	2009
Organic	1.6(–23.3)	2.38(–18.2)	2.79(+6.8)	2.45(–2.4)	1.62(–8.0)	1.56(–3.0)
Inorganic	2.09	2.91	2.61	2.51	1.76	1.60
IPNS	1.91(–8.7)	2.63(–9.6)	2.72(+4.2)	2.60(+3.6)	1.80(+2.0)	1.63(1.4)
SEm±	0.03	0.04	0.03	0.06	0.04	0.02
CD (P=0.05)	0.09	0.13	0.10	NS	0.11	0.06

Figure in parenthesis indicate the % change over inorganic

tures (ONS) was 29.7, 21.1, 12.6, 6.6 and 21.4% lesser than INS during first, second, third, fourth and fifth year. Again IPNS produced significantly more mustard than INS from the second year onwards. Organic nitrogen applied as manure is slowly available over a long period of time compared to chemical fertilizers and this limits the plant growth resulting in lower yields in ONS (Ramesh *et al.*, 2009).

**Chickpea:** The relative efficiency of ONS, INS and IPNS in production of grain in chickpea followed the same trend as in mustard.

### System productivity

The total productivity of cropping system was calculated based on total yield of *kharif* and *rabi* crops converted into soybean equivalent yield. Among the four cropping systems soybean–berseem recorded the highest total productivity, while soybean–wheat was next to it. Soybean–mustard recorded the lowest total productivity. As regards to nutrient supply system, IPNS recorded the highest total productivity (3.10 t/ha), followed by INS (3.0 t/ha). The lowest productivity (2.77 t/ha) was recorded in organic farming (ONS).

### Economic analysis

Due to higher market prices and premium prices as assigned to organic produce, soybean–berseem system fetched the highest total net return (₹53.3 × 10<sup>3</sup>/ha) as well as B:C ratio (1.97) (Table 3). Similarly, despite of less total productivity, soybean–chickpea produced higher income (₹44.9 × 10<sup>3</sup>/ha) and comparable benefit per rupee invested

(1.91) under organic nutrient. While, due to higher fertility levels under inorganic and integrated nutrient sources, where premium prices was not assigned, soybean–wheat and soybean–berseem was found to be more beneficial in terms of higher total net return as compared to other cropping systems. Total benefit: cost ratio was the highest (2.08) in soybean–berseem cropping system with inorganic nutrient supply.

### Soil properties

Intensive cropping and nature, source and amount of other inputs applied to the soil not only influenced the growth rate of the crops but also influenced the physico-chemical properties of native soil. The nature and magnitude of change brought about in soils, generally, depends upon the initial soil conditions, its clay content and depth. Bulk density in general, increased with soil depth and growth period of crops. Bulk density remained lower in organic source of nutrients (ONS) as compared with inorganic and IPNS in all the years, whereas no difference was observed amongst various crops (Fig. 1). The decrease in bulk density under organic source of nutrient was due to more pulverized condition and loosening of soils to a greater depth. The values of final infiltration rate measured at flowering stage of crop were maximum in IPNS and ONS as compared to INS in all the years (Fig. 1). The data pertaining to organic carbon content showed that it was slightly higher in ONS and IPNS as compared to INS in all the years (Fig. 2). On completion of fifth cycle (2008–09), the effect was more pronounced irrespective of various crops. This also points out that if fertilizer use is integrated

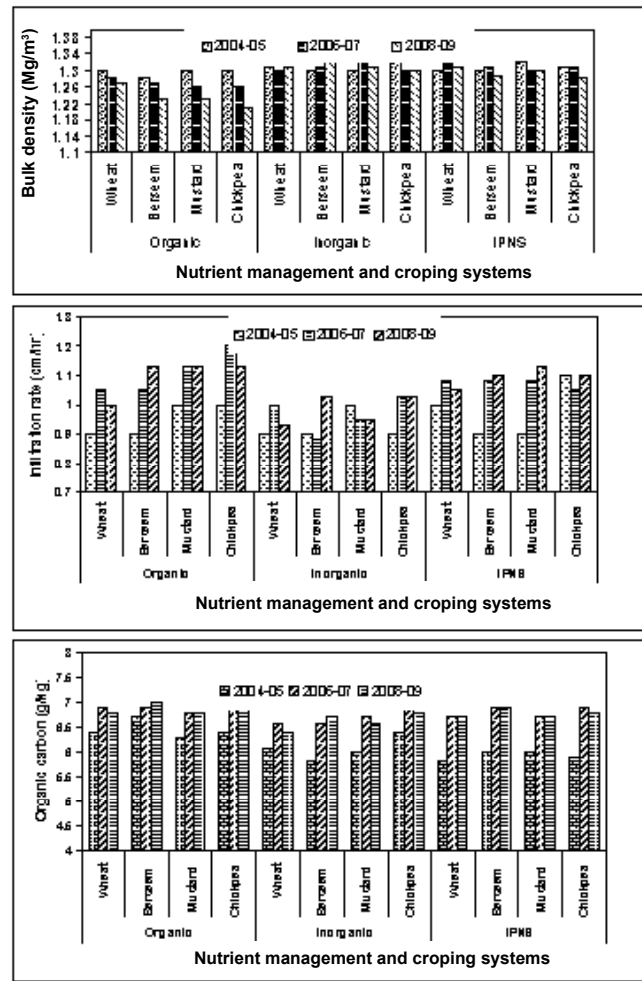
**Table 2.** Grain/Seed/green fodder yield of *rabi* crops and percent change in yield over inorganic source of nutrients

	Grain/seed yield (t/ha)					Grain/green fodder yield (t/ha)				
	2004–05	2005–06	2006–07	2007–08	2008–09	2004–05	2005–06	2006–07	2007–08	2008–09
	<i>Wheat</i>					<i>Berseem</i>				
Organic	1.75	2.18	2.20	2.15	1.91	15.6	59.9	13.4	24.7	36.8
	(-26.5)	(-11.7)	(-13.0)	(-9.2)	(-7.7)	(-25.7)	(12.5)	(-8.6)	(15.5)	(-9.10)
Inorganic	2.38	2.47	2.53	2.37	2.07	21.0	53.2	14.7	23.2	40.5
IPNS	2.08	3.03	2.90	2.58	2.26	19.8	63.0	9.1	28.0	43.0
	(-12.6)	(22.6)	(14.6)	(8.6)	(9.4)	(-5.5)	(18.6)	(-3.7)	(20.9)	(6.02)
SEm±	0.11	0.14	0.02	0.70	0.05	0.10	0.90	0.13	3.5	0.70
CD (P=0.05)	0.31	0.43	0.06	0.21	0.17	0.31	2.69	0.37	10.7	1.91
	<i>Mustard</i>					<i>Chickpea</i>				
Organic	0.64	1.05	1.32	1.10	0.62	0.77	1.48	1.09	0.61	0.96
	(-29.7)	(-21.1)	(-12.6)	(-6.6)	(-21.4)	(-29.4)	(7.2)	(16.0)	(1.66)	(-2.34)
Inorganic	0.91	1.33	1.51	1.17	0.78	1.09	1.38	0.94	0.60	0.98
IPNS	0.81	1.52	1.73	1.26	0.82	0.93	1.38	1.26	0.65	1.11
	(-11.0)	(14.3)	(14.6)	(+7.1)	(4.2)	(-14.7)	(0.0)	(34.0)	(8.3)	(13.6)
SEm±	0.03	0.13	0.05	0.03	0.03	0.11	0.10	0.02	0.04	0.10
CD (P=0.05)	0.09	0.43	0.15	0.08	0.08	0.31	0.30	0.06	0.12	0.31

**Table 3.** Economic analysis of different soybean-based cropping system (2008–09)

Main plot	Sub-plot cropping system	Total productivity (Soybean equivalent) (t/ha)			Gross returns ( $\times 10^3$ ₹/ha)			Cost of cultivation ( $\times 10^3$ ₹/ha)			Net returns ( $\times 10^3$ ₹/ha)			Benefit cost ratio		
		Kharif	Rabi	Total	1	2	Total	3	4	Total	1-4	2-5	Total	Kharif	Rabi	Total
Organic	Soybean-Wheat	1.62	1.24	2.87	40.6	37.9	78.5	13.4	23.3	36.7	27.2	14.6	41.8	2.02	0.63	1.14
	Soybean-Berseem	1.74	1.47	3.21	43.4	36.8	80.3	13.4	13.6	27.0	30.0	23.3	53.3	2.23	1.72	1.97
	Soybean-Mustard	1.5	0.77	2.27	37.4	19.3	56.8	13.4	19.2	32.7	24.0	0.1	24.1	1.79	0.01	0.74
Inorganic	Soybean-Chickpea	1.78	0.96	2.74	44.5	23.9	68.5	13.4	10.1	23.5	31.1	13.8	44.9	2.32	1.37	1.91
	Soybean-Wheat	1.76	1.35	3.11	35.3	34.1	69.4	10.7	12.7	23.4	24.6	21.4	46.0	2.29	1.69	1.97
	Soybean-Berseem	1.69	1.87	3.56	33.9	32.2	66.1	10.7	10.8	21.5	23.2	21.5	44.7	2.16	2.00	2.08
IPNS	Soybean-Mustard	1.52	0.98	2.49	30.3	19.6	49.9	10.7	10.5	21.2	19.6	9.1	28.7	1.83	0.87	1.35
	Soybean-Chickpea	1.72	1.11	2.83	34.4	22.2	56.5	10.7	8.6	19.3	23.7	13.6	37.2	2.21	1.58	1.93
	Soybean-Wheat	1.8	1.47	3.27	36.0	37.0	73.0	12.1	18.6	30.7	23.9	18.4	42.3	1.98	0.99	1.38
Soybean-Berseem	Soybean-Berseem	1.86	1.76	3.63	37.3	30.4	67.7	12.1	12.0	24.1	25.2	18.4	43.6	2.09	1.53	1.81
	Soybean-Mustard	1.65	1.02	2.68	33.1	20.4	53.5	12.1	13.7	25.8	21.0	6.7	27.7	1.74	0.49	1.07
	Soybean-Chickpea	1.84	0.98	2.82	36.8	14.7	51.6	12.1	9.7	21.8	24.8	5.1	29.8	2.05	0.53	1.37

Market Price (₹/t) taken for 2008–09: Soybean-₹20,000; Wheat-₹13,000; Berseem fodder-₹875; Mustard-₹25,000; Chickpea-₹20,000; Wheat straw-₹1,000; Organic grain/seed/green fodder were valued at a price premium of 25%



**Fig. 1.** Bulk density, infiltration rate and organic carbon under different nutrient management and cropping systems

with manures, there will be considerable improvement in soil health. An increase in organic C in soil due to application of organic manures is well documented by Prasad and Misra (2001). Available NPK and bacterial count was highest under IPNS and lowest with INS; the ONS being in between (Table 4). As regards cropping systems, available nutrient (NPK) content in soil, it was the highest after soybean-chickpea and the lowest for soybean-wheat.

It can be concluded that adoption of a balanced approach will safeguard the higher productivity and returns from money spent, not only on nutrients but also on the entire farming enterprise. The yields of integrated treatment in all the crops were constantly superior over organic. Yield decrease during conversion period by using organic nutrient sources is occurred but then improves afterwards. Legume-legume cropping system was found more beneficial on bacterial population than legume-oilseed followed by legume-cereal cropping system over oilseed system. However, weeds can be a severe problem under organic treatment in all the crops.

**Table 4.** Available nutrient status in soil and bacterial count at the end of 5<sup>th</sup> crop cycle as affected by nutrient packages and cropping systems (2008–09)

Treatment	Available nutrient status (kg/ha)			Bacterial count × soil
	N	P	K	
10 <sup>5</sup> /g				
<i>Nutrient management</i>				
Organic	253	13.0	265	3.91
Inorganic	261	15.5	283	2.45
IPNS	264	15.5	296	5.21
SEm±	2	0.20	3	–
CD (P=0.05)	7	0.68	12	–
<i>Cropping system</i>				
Soybean–Wheat	249	13.8	262	2.68
Soybean–Berseem	264	14.1	280	4.97
Soybean–Mustard	258	15.3	287	2.81
Soybean–Chickpea	267	15.8	296	4.97
SEm±	2	0.23	4	–
CD (P=0.05)	7	1.10	18	–
<i>Nutrient management × Cropping system</i>				
SEm±	4	0.60	10	–
CD (P=0.05)	15	1.25	23	–
Initial	237	13	274	0.73

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