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RESEARCH ARTICLE

Crop management through organic and inorganic inputs in Soybean (*Glycine max* (L.) Merill) based cropping systems

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Abstract

A field experiment was conducted during 2010-11 to 2013-14 at Agharkar Research Institute, Pune, Maharashtra to study the effect of organic and inorganic inputs on productivity of soybean [*Glycine max* (L.) Merill] based cropping systems. Two cropping systems *viz*., soybean-wheat and soybean-chickpea along with three crop management practices *viz.*, organic, inorganic and integrated were evaluated in strip plot design with four replications. In *kharif* season, soybean seed yield was at par in soybean-wheat system (2718 kg ha^{-1}) with soybean-chickpea (2662 kg ha^{-1}) cropping system. Amongst the management practices, organic practice gave significantly higher soybean seed yield (2850 kg ha^{-1}) than inorganic (2592 kg ha^{-1}) and integrated (2629 kg ha^{-1}) practice of crop management. However, in *rabi* wheat (4017 kg ha^{-1}) recorded significantly higher yield than chickpea (1065 kg ha^{-1}). Inorganic management (2829 kg ha^{-1}) recorded significantly highest yield followed by integrated (2698 kg ha^{-1}) and organic practice (2097 kg ha^{-1}) during season. Soybean equivalent yield (SEY) was significantly higher in soybean-wheat cropping system (2595 kg ha^{-1}) than soybean-chickpea (1304 kg ha^{-1}). Inorganic practice showed significantly higher SEY (2129 kg ha^{-1}) than other two management practices. System net returns were higher in soybean-wheat system (Rs. 86964 ha^{-1}) and in inorganic practice (Rs. 97176 ha^{-1}) than in soybean-chickpea cropping system (Rs. 57872 ha^{-1}) and rest of the two management practices. Soybean-wheat cropping system with inorganic practice recorded higher system productivity (5573 kg ha^{-1}).

INTRODUCTION

Soybean [*Glycine max* (L.) Merill] based cropping systems are important for sustaining agricultural production and also maintain soil fertility with an ecological balance. Sustainability aims at balanced use of all available resources to achieve maximum production with minimum exploitation of natural resources. Soybean grown both as an oil seed and grain legume, fixes atmospheric nitrogen in soil and makes it available to partially fulfill the nitrogen requirement of succeeding crop. Soybean-wheat cropping system in rotation gives higher yield, greater income and maintains soil fertility. The soybean-wheat cropping system reduces dependency on chemical fertilizers and helps in monetary saving. Most of the farmers grow soybean without fertilizer application and also realize the carry-over effect of the legume crop on the succeeding wheat crop (Behera *et al*. 2007). Grain legumes play an important role in improving soil fertility and increasing the yield of succeeding crops. Inorganic fertilizers used to increase crop production without organic supplements cause severe damage to soil properties and adversely affect the soil environment by polluting it. Organic manures help to increase biological activity of soil microbes and improve soil structure, water holding capacity and other physico-chemical properties of soil (Devi *et al*. 2013). Dasog *et al*. (2011) reported that the success of any cropping system depends upon the appropriate management of resources including balanced use of manures and fertilizers. Imbalanced application of nutrients to crops leads to loss of productivity due to exhaustion of macro and micro nutrients (Bhandari *et al*. 2002 and Kundu *et al.* 2007). The present study mainly aims at finding the impact of soybean based cropping systems and crop management practices on seed yield and other yield attributes.

Materials and methods

A field experiment was conducted during *kharif* and *rabi* seasons of four consecutive years 2010-11, 2011-12, 2012-13 and 2013-14 at the Research farm of Agharkar Research Institute, Pune, Maharashtra (India). The site of experiment is situated at 18^{o}14' N latitude, 75^{o}21' E longitude and an altitude of 548.6 m above mean sea level. Total rainfall during the *kharif* seasons of 2010, 2011, 2012 and 2013 from July to November (during the crop growth period) was 361.8, 297.3, 222.2 and 409.8 mm, respectively. Soil of the experimental plot belongs to the order vertisols with slightly alkaline pH 7.5 and medium in organic carbon (0.42 %). The available N (298 kg ha^{-1}) and available P_2O_5 (18.87 kg ha^{-1}) were medium and the available K_2O (331 kg ha^{-1}) was high.

The experiment comprised two cropping systems *viz.,* soybean-wheat and soybean-chickpea and three management practices *viz.*, organic, inorganic and integrated was laid out in the strip plot design with four replications. The net plot size was 9.0 m x 3.6 m. Same plots were used for the same cropping system and management practice in each of the four years. In *kharif,* soybean was grown followed by wheat and chickpea in *rabi* season.

In the organic management practice, well decomposed farmyard manure (FYM) was applied before sowing of crop based on nitrogen equivalent basis @ 10 t ha^{-1} and nutrient requirement of each crop. The FYM consisted 0.58, 0.26 and 0.52% of N, P and K respectively. Phosphorus requirement of the crops were supplemented through rock phosphate. Seed inoculation with biofertilizer cultures of *Bradyrhizobium japonicum* (5 g kg^{-1} of seed) and phosphate solubilizing micro-organism (5 g $kg^{-1}$of seed) was done. Seeds were also treated with *Trichoderma viridae* (5 g $kg^{-1}$of seed) before sowing. Pest control was achieved through bio-pesticides *viz.*, neem extract @ 1.2 l ha^{-1} and HaNPV [Trade name: HELIO-KILL, Manufacturer: Mahatma Phule Agricultural University Rahuri, Maharshtra (India)] @ 2.5 l.e. l ha^{-1}. Weed free condition in the plots were maintained by hand weeding.

For the inorganic practice, nutrients were supplied through inorganic fertilizers as per recommended doses (RDF) for soybean 20:80:20, wheat 120:60:40 and chickpea 25:50:30 NPK kg ha^{-1}. Seed treatment with Carbendazim 50 WP [Trade name: BAVISTIN, Manufacturer: BASF Corporation, Missouri (USA)] @ 3 g kg^{-1} of seed for soybean and gram while, Thiram @ 3 g kg^{-1} of wheat seed was done without inoculation with bioinoculants. Weeds were controlled by pre emergence spray of recommended herbicide Pendimethalin [Trade name: STOMP XTRA, Manufacturer: BASF Corporation, Missouri (USA)] @ 1.5 l ha^{-1} and pests with the spray of Quinalphos 25 EC [Trade name: EKALUX 25, Manufacturer: Syngenta India Limited Pune, Maharastra (India)] @ 1.5 l ha^{-1}. For integrated practice, FYM @ 5 t ha^{-1} and 50% RDF were applied. Seeds were inoculated with *Bradyrhizobium japonicum* and phosphate solubilizing micro-organism culture before sowing. Weeds were controlled through pre emergence spray of Pendimethalin @ 1.5 l ha^{-1} followed by one hand weeding whereas, plant protection were carried through integrated pest management practices whenever the incidence of pest and disease was noticed.

Soybean crop was sown in the first week of July during all the *kharif* seasons. Before sowing, land was brought to good tilth to facilitate good germination and favorable conditions for crop stand. FYM and rock phosphate were mixed well and applied in soil before sowing as per the treatment. NPK fertilizers were applied through di-ammonium phosphate, single super phosphate and muriate of potash as a basal dose as per treatments. Seeds of soybean cv. JS 335 were sown manually in rows 45 cm apart with 5-7 cm between plants within rows. All cultivation practices were carried out to raise good crop. Crop was manually harvested at physiological maturity stage in the second week of October.

After harvesting the soybean, plots were harrowed twice to facilitate ease in sowing of the *rabi* crops. Wheat (cv. GW 322) and Chickpea (cv. Vishal) were manually sown at the rate of 100 and 110 kg ha^{-1}, respectively. All sources of nutrients (organic, inorganic and integrated) as per the treatments and RDF of respective crop were applied before sowing, except half the quantity of N was applied through urea as a top dressing to wheat 21 days after sowing at crown root initiation stage. All cultivation practices were carried out to raise good crop. After attaining the physiological maturity, the crop was harvested manually.

Data on growth, yield contributing characters and seed yield (kg ha^{-1}) was recorded. Economic yields of the component crops were converted to soybean-equivalent yield (SEY), by considering prevailing market prices of the crops. System productivity was calculated by adding the SEY of the component crops.

$$\text{Soybean equivalent yield} = \frac{\text{Yield of } rabi \text{ crop X Market price of } rabi \text{ crop}}{\text{Market price of soybean}}$$

Pooled analysis of the data for four years was carried out using standard analysis of variance suggested by Gomez and Gomez (1984).

Results and discussion

Effect of cropping system and management practice on soybean yield

Growth, yield attributes and yield of soybean were not significantly affected by cropping systems. However, soybean yield in soybean-wheat (2718 kg ha^{-1}) cropping system was numerically higher than soybean-chickpea (2662 kg ha^{-1}) cropping system (Table 1). Legume followed by cereal crops is considered to be helpful in soil ameliorating benefits and attaining the sustainability (Gangwar and Prasad, 2005). Billore *et al.* (2013) also reported that soybean yields were more sustainable when grown before wheat rather than chickpea in rotation.

Management practice had significantly influenced the growth and yield attributes *viz.,* number of pods per plant and seed yield (Table 1). Crop management through organic inputs produced significantly higher number of pods per plant and seed yield (2850 kg ha^{-1}) than inorganic (2592 kg ha^{-1}) and integrated (2629 kg ha^{-1}) practice. Crop with organic sources showed about 9.95% increase in yield over inorganically managed crop. Increase in yield might be due to increased biological nitrogen fixation and solubilization of more amount of P by phosphate solubilizing bacteria and organic manure (FYM) also acts as a substrate for microorganisms and improved soil condition favorable for availability of nutrients to crop throughout the growth period (Prajapat *et al.*, 2014). Gallani *et al.* (2013) have reported increase in yield of soybean due to application of organic sources of nutrients. Interaction of the cropping system and management practices had no significant effect on growth, yield attributes and soybean seed yield.

Effect of cropping system and management practice on yield of *rabi* crops

Data for seed yield of *rabi* crops given in Table 2 showed that among cropping systems, wheat (4017 kg ha^{-1}) yield was higher in soybean-wheat system than soybean-chickpea system (1065 kg ha^{-1}). Wheat yielded higher because the residual effect of preceding legume crop on succeeding crops in sequence is evident and easily availability of nitrogen at critical growth stages. Similarly, the increase in wheat yield in soybean-wheat cropping system was reported by (Dixit *et al.* 1993 and Dwivedi *et al.* 1998).

Inorganic practice (4607 kg ha^{-1}) yielded significantly higher wheat yield than integrated practice (4208 kg ha^{-1}) and organic practice (3236 kg ha^{-1}). Low productivity of wheat under organic practice may be due to low availability of nitrogen at various growth stages, which should be more for cereals and also might be due to slow mineralization and unavailability of required nutrients, resulted in setback to crop growth at early stage of its development and thus influenced the crop productivity (Gallani *et al.* 2013). Chickpea yield was significantly highest with integrated practice (1188 kg ha^{-1}) over inorganic (1050 kg ha^{-1}) and organic practice (958 kg ha^{-1}). Significantly higher chickpea yield with the application of 50% recommended dose of fertilizer and 50% FYM was reported by Prajapat *et al*, (2014).

Interaction of cropping system and management practices (Table 3) showed significantly the highest wheat yield in soybean-wheat with inorganic practice (4607 kg ha^{-1}) and it was at par with soybean-wheat with integrated practice (4208 kg ha^{-1}).

Soybean equivalent yield was significantly influenced by cropping system and management practices. Soybean-wheat cropping system (2595 kg ha^{-1}) produced significantly higher soybean equivalent yield than soybean-chickpea cropping system (1304 kg ha^{-1}) (Table 2). As regards to management practice, inorganic practice recorded the highest soybean equivalent yield (2129 kg ha^{-1}) followed by integrated practice (2090 kg ha^{-1}). For interaction components, soybean-wheat cropping system with inorganic practice (2974 kg ha^{-1}) recorded significantly the highest SEY followed by integrated practice (2718 kg ha^{-1}) (Table 4). This might be due to the fertilizer responsiveness of wheat.

System productivity

System productivity was considered in terms of total productivity of the system calculated based on yield of *kharif* and *rabi* crops converted into soybean equivalent yield (Table 4). Soybean-wheat cropping system with inorganic management practice (5573 kg ha^{-1}) recorded the highest total productivity followed by soybean-wheat cropping system with integrated practice (5345 kg ha^{-1}).

System economics

Soybean-wheat system gave higher gross and net monetary returns for the whole cropping system period. Increased wheat yield under soybean-wheat system resulted higher net returns over soybean-chickpea system during all years under study. Inorganically managed wheat crop produced the highest net returns over soybean-chickpea system and rest of the two management practices. Use of alone organic and integration of organic and inorganic sources increased the cost of cultivation as FYM was costlier than inorganic fertilizers, therefore reduced the system net returns (Prajapat *et al*, 2014).

Table 1. Growth, yield contributing characters and yield of *kharif* soybean as affected by cropping systems and management practices

Treatment	Plant height (cm)	Pods Plant^{-1}	Branches Plant^{-1}	Seed Index (g)	Harvest index (%)	Seed Yield (kg ha^{-1})
Cropping systems (C)						
Soybean-Wheat	51.20	33.38	2.88	13.54	48.31	2718
Soybean-Chickpea	49.54	33.06	2.91	13.51	48.62	2662
SEm$\pm$	1.09	0.36	0.03	0.04	0.22	36.15
CD at 5%	NS	NS	NS	NS	NS	NS
Management practices (M)						
Organic practice	51.11	34.85	3.08	13.56	48.77	2850
Inorganic practice	48.04	31.74	2.90	13.40	49.14	2592
Integrated practice	51.96	33.08	2.69	13.60	47.18	2629
SEm$\pm$	1.11	0.60	0.12	0.08	0.63	15.82
CD at 5%	NS	1.69	NS	NS	NS	44.66
Interaction (C x M)						
SEm$\pm$	3.02	1.63	0.21	0.44	1.71	88.65
CD at 5 %	NS	NS	NS	NS	NS	NS

Table 2. *Rabi* crop yield, SEY and economics of cropping system as affected by cropping systems and management practices

Treatment	Wheat yield (kg ha^{-1})	Chickpea yield (kg ha^{-1})	SEY (kg ha^{-1})	System net returns (Rs ha^{-1})	
				S-W	S-C
Cropping systems (C)					
Soybean-Wheat	4017	-	2595	86964	-
Soybean-Chickpea	-	1065	1304	-	57872
SEm±	-	-	54.28	-	-
CD at 5%	-	-	244	-	-
Management practices (M)					
Organic practice	3236	958	1630	74882	56494
Inorganic practice	4607	1050	2129	97176	55775
Integrated practice	4208	1188	2090	88834	61347
SEm±	85.81	24.40	30.27	-	-
CD at 5%	245	70.46	85.4	-	-

Table 3. *Rabi* crop yield (kg ha^{-1}) as influenced by interaction between cropping system and management practices

Treatments	**Cropping systems (C)**		
Management practices (M)	Soybean-Wheat	Soybean-Chickpea	Mean
Organic practice	3236	958	2097
Inorganic practice	4607	1050	2829
Integrated practice	4208	1188	2698
Mean	4017	1065	
SEm±		177.50	
CD at 5 %		500.97	

Table 4. Soybean yield, soybean equivalent yield and system productivity as affected by cropping systems and management practices (Pooled)

Treatments		Soybean yield ($kg\ ha^{-1}$)					Soybean Equivalent Yield ($kg\ ha^{-1}$)					System productivity ($kg\ ha^{-1}$)
Cropping systems and management practices		**2010**	**2011**	**2012**	**2013**	**Mean**	**2010**	**2011**	**2012**	**2013**	**Mean**	**Mean**
Soybean-Wheat	Organic practice	3294	2930	2610	2611	2861	2146	2603	2284	1330	2091	4952
	Inorganic practice	2971	2804	2110	2510	2599	2910	3636	3162	2190	2974	5573
	Integrated practice	3108	2675	2367	2356	2627	2495	3306	3062	2010	2718	5345
Soybean-Chickpea	Organic practice	3112	3022	2620	2576	2832	1165	1867	669	972	1168	4000
	Inorganic practice	2758	2984	2661	2557	2740	1336	1486	851	1464	1284	4024
	Integrated practice	2976	2727	2333	2488	2631	1923	1575	1016	1371	1471	4102
	CD at 5 %	NS	NS	NS	NS		241.00	361.79	250.52	162.38	374.87	

Conclusion

From the studies it was seen that the organic management practice helps in sustainable and higher yield in soybean. Soybean crop management with organic sources is more productive while wheat cultivation using inorganic sources is more productive and remunerative. Residual fertility of soybean is beneficial for growing wheat after harvest of soybean. For getting highest yield and maximum returns from soybean-wheat cropping system, throughout the year organic practice for soybean followed by inorganic practice for wheat should be followed.

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