Indian Journal of Agronomy **60** (2): 212–216 (June 2015)

Research Paper

Seed yield, economics, sustainability and soil fertility as influenced by long-term nutrient management in soybean (*Glycine max*)–sunflower (*Helianthus annuus*) cropping system in Vertisols

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Received : April 2014; Revised accepted : May 2015

ABTRACT

A field experiment was conducted during 1999–2011, on fixed site at Latur, to assess the nutrient requirement of soybean [*Glycine max* (*L*.) Merr.]–sunflower (*Helianthus annuus* L.) cropping system with different combinations of organic and inorganic nutrient management in Vertisols. Twelve treatment combinations were applied on cropping system basis for rainy (*kharif*) season soybean followed by winter (*rabi*) sunflower. Application of 100% recommended NPK + FYM 5 t/ha to *kharif* soybean and 100% recommended NPK to *rabi* sunflower recorded higher seed yield of soybean (2.33 t/ha), sunflower (1.44 kg/ha) and total system productivity in terms of sunflower-equivalent yield (3.33 t/ha). This combination also showed higher production efficiency (16.7 kg/ha/day) sustainable-yield index (0.50), and net monetary returns (₹41.1 × 10^3/ha), and was statistically similar to the application of 150% NPK to both the crops in sequence. Application of FYM 5 t/ha continuously over the period of 13 years along with 100% NPK to *kharif* soybean and 100% NPK to *rabi* sunflower in sequence improved the soil fertility in terms of organic carbon, available nitrogen, phosphorus and potassium.

***Key words* :** Crop productivity, Cropping system, Nutrient management, Soil fertility, Soybean, Sunflower, System productivity, Vertisols

India is one of the largest oilseeds-producing country with largest area under oilseeds sharing 14% of country's gross cropped area, accounting for 1.4% of the gross domestic product and 8% of the value of all the agriculture products. However, the production falls far short of consumption (Sudhakara Babu and Hegde, 2011). The average productivity of oilseeds in India is around 1.0 t/ha, which was far below that of the world (1.9 t/ha) (Damodaram and Hegde, 2010), mainly due to their cultivation under rainfed condition low input use and poor crop management. The factor productivity of oilseeds is decreasing, indicating the need for higher input supply for maintaining the same level of production. Sustainability of the enhanced oilseeds production is as important as enhancing the production.

Soybean is major rainy season crop of Marathwada region of Maharashtra in Vertisols. However, in soybean-based cropping system hardly 10–15 days time is available between harvesting of soybean and timely sowing of winter crop. Sunflower has been proved to be highly promising for round-the-year cultivation under different agro-climatic regions owing to its thermo-photo-insensitivity and can fits well in crop rotation any time. Soybean is sown from the first fortnight of June to first fortnight of July depending upon onset of monsoon. Being a legume crop, soybean fixes atmospheric nitrogen in the soil to an extent of 65 to 100 kg/ha through symbiotic association with *Rhizobium* bacteria (Rao, 2007). Under such a situation, soybean–sunflower cropping system is the best cropping system.

Oilseeds are energy–rich crops and need higher nutrition for realizing high productivity of seed and oil. Integrated nutrient management aims at a judicious combination of inorganic and organic sources for meeting the nutrient needs of crop and cropping system and is of great interest for sustaining high productivity in today's agriculture (Blaise and Prasad, 2005; Hegde, 1998). Addition of organic matter to the soil provides several mechanisms for improved agronomic efficiency, particularly increased retention of soil nutrients and water and better synchroniza-

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tion of nutrient supply with crop demand, and it also improves soil health through increased soil biodiversity and carbon stock.

In intensive cropping system, which has high turnover of nutrients, poor recycling of organic sources and application of high-analysis fertilizer causes deficiency of several micronutrients in soil and also leads to environmental pollution (Kumar, 2008). It is recognized that neither chemical fertilizer nor organic manure alone can be used for sustainable crop production. At present, when sustainability of the crop and soil productivity is the burning issue, the integrated use of organics and inorganics in cropping system need to be emphasized to use nutrient and energy efficiently than conventional management system (Mader *et al*., 2002; Blaise and Prasad, 2005). In view of limited information available on nutrient management in soybean–sunflower cropping system, a fixed plot field experiment was conducted over 13 consecutive years to assess the nutrient requirement in soybean–sunflower cropping systems for sustainable production.

MATERIALS AND METHODS

A field experiment was conducted continuously on fixed site from 1999 to 2011 with soybean–sunflower cropping system with various combinations of organic and inorganic nutrient management at AICRP on Sunflower, Oilseeds Research Station, Latur (18° 05'–18° 75' and 76° 25'–77° 25' 540.63 m sea-level, with sub-tropical climate). The soil was medium black with initial soil fertility of slightly alkaline (pH 7.65), low in organic carbon (0.42%), available nitrogen (122.5 kg/ha), available phosphorus (9.81 kg/ha) and high in available potassium (410 kg/ha). The experiment was laid out in a randomized block design with 12 treatment combinations for rainy season (*kharif*) soybean followed by winter (*rabi*) sunflower cropping system (Table 1). The individual plot size was 5.4 m × 4.8 m with firm bunds and irrigation/drainage channels around. Ploughing and land preparation was done with mould board plough and cultivator without mixing of soil across plots. Data were recorded in net plot (4.5 m × 4.2 m for soybean and 4.2 m × 4.2 m for sunflower) avoiding any possible border effects.

The recommended dose of NPK for soybean was 30:60:30 kg N:P_2O_5:K_2O/ha and for sunflower 60:30:30 kg N:P_2O_5:K_2O/ha. The sources of nutrient were diammonium phosphate (DAP), urea and muriate of potash. Sulphur was applied through gypsum and boron through borax. All the nutrients were applied through soil. Full dose of N, P and K were applied as basal to soybean, while half dose of N and full dose of P and K were applied as basal to sunflower and remaining nitrogen was applied 30 days after sowing (DAS). Soybean 'MAUS 81' and sunflower hybrid 'KBSH 44' were raised during *kharif* and *rabi,* respectively with recommended package of practices. Farmyard manure (FYM) was incorporated 15 days before sowing. The general range of sowing dates was from the last week of June to the first week of July for *kharif* soybean and the first fortnight of November for *rabi* sunflower. The spacing followed for soybean was 45 cm × 5 cm and for sunflower it was 60 cm × 30 cm. The crops were grown under protective irrigation. In this paper, we discuss seed yield of *kharif* soybean and system productivity in terms of sunflower-equivalent yield and sustainable yield index, soil fertility and economics.

Rainfall received during 4 rainy months (June to September) of the crop season was recorded during each year from 1999 to 2011. Total crop seasonal rainfall showed a wide range of distribution from the minimum 423 mm during 2002 to the maximum 921 mm in 2010 with mean of 673 mm and coefficient of variation 23%. The monthly rainfall ranges from 37 mm (2008) to 209 mm (2007) in June, 57 mm (2009) to 337 mm (2004) in July, 59 mm (2004) to 366 mm (2010) in August and 22 mm (2001) to 448 mm (2008) in September. The coefficient of variation was 50% in June, 62% in July, 45% in August and 67% in September. The mean monthly rainfall received during 13 years varied from 102 mm during June to 216 mm during August. The rainfall received in August was more (216 mm) with least variation (45%) than other months rainfall in the season. The mean monthly minimum and maximum temperature was recorded during each year from 1999 to 2000. The mean minimum temperature was low (11.6°C) in December, while it was higher (23.7°C) in May. The coefficient of variation was ranged from 7.9% in June to 15.8% in September. The mean maximum temperature recorded over 13 years varied from 39.3°C in May to 29.3°C in December. The coefficient of variation of maximum temperature was ranged from 2.6% in April to 6.7% in July. The coefficient of variation of minimum temperature was higher than the coefficient of variation of maximum temperature.

The nutrient management in cropping system was evaluated based on sustainable yield index (SYI) as described by Singh *et al.* (1990). Using mean sunflower-equivalent yield (Y_{mean}) of treatments over 13 years, standard deviation (ó) and maximum equivalent yield (Y_{max}) obtained among all the 156 values of the experiment, calculated as:

$$SYI=(Y_{mean}–ó)/Y_{max}$$

A treatment with maximum sustainable yield index was selected for attaining a maximum and sustainable equivalent yield under all the nutrient management in soybean–sunflower cropping system. Data on various variables were analysed by analysis of variance (Panse and

Sukhatme, 1967) and pooled analysis for 13 years were carried out as per Cochran and Cox (1957).

RESULTS AND DISCUSSION

Seed yield of soybean and sunflower

The pooled seed yield of soybean and sunflower varied significantly due to various combinations of organic and inorganic nutrient treatments (Table 1). Application of 100% NPK + FYM @ 5 t/ha to *kharif* soybean and 100% NPK to *rabi* sunflower resulted in significantly higher seed yield of soybean and sunflower, being at par with application of 150% NPK to both the crops in sequence. The higher seed yield owing to inorganic source alone and in combination with organic sources along with FYM might have increased because of sustained nutrient supply and also as result of better utilization of applied nutrients through improved microbial activity that involves in nutrient transformation and fixation. Ravankar *et al.* (1995) also reported similar findings. Under continuous cropping, the application of FYM @ 5 t/ha/year along with optimal dose of fertilizer in soybean–sunflower cropping system was found beneficial in enhancing crop productivity. These findings indicate superiority of optimal dose of fertilizer with organic manure to super-optimal dose of fertilizer. Thus, the balanced use of fertilizer in combination with organic manure is necessary for sustaining soil fertility and productivity of crops (Thakur *et al*., 2011). The seed yield of soybean and sunflower was influenced significantly over the year from 1999 to 2011 (Figs. 1 and 2) due to various combinations of organic and inorganic nutrient treatments. Application 100% NPK + FYM @ 5 t/ha to *kharif* soybean crop and 100% NPK to *rabi* sunflower crop recorded significantly higher seed yield of soybean and sunflower over the years. The variation in yield over the years might be due to seasonal variation.

System productivity, system economics and production efficiency

The pooled system productivity in terms of sunflower

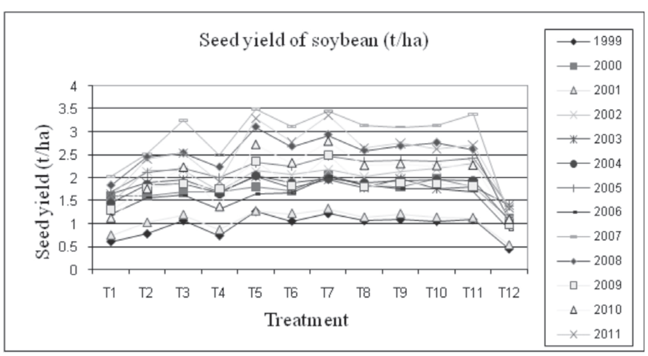

Fig. 1. Yield of soybean as influenced by different organic and inorganic nutrients treatments from 1999 to 2011. (Details of treatments are given in Table 1)

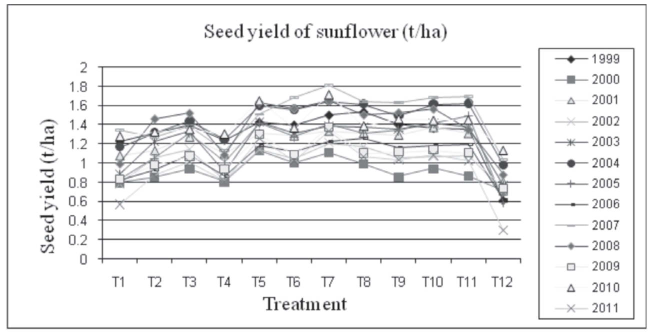

Fig. 2. Yield of sunflower as influenced by different organic and inorganic nutrients treatments from 1999 to 2011. (Details of treatments are given in Table 1)

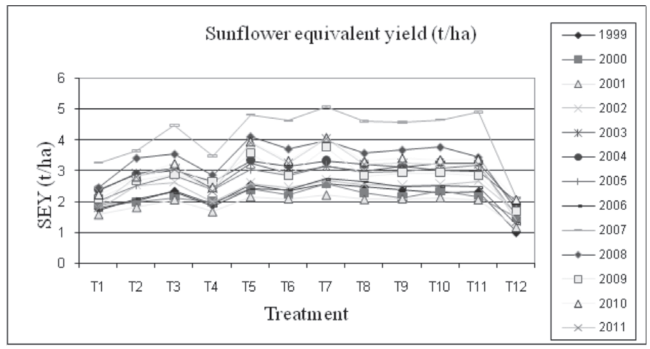

Fig. 3. Sunflower equivalent yield (SEY) as influenced by different organic and inorganic nutrients treatments from 1999 to 2011. (Details of treatments are given in Table 1)

equivalent yield (SEY) was computed (Table 1), which revealed that the system productivity was significantly affected due to different nutrient management and recorded higher with the application of 100% recommended NPK + FYM 5 t/ha to *kharif* soybean and 100% NPK to *rabi* sunflower, followed by application of 150% NPK to both the crops in sequence. The system productivity in terms of sunflower-equivalent yield (SEY) over the years from 1999 to 2011 (Fig.3) showed significantly higher sunflower-equivalent yield with the application of 100% recommended NPK + FYM 5 t/ha to *kharif* soybean crop and 100% NPK to *rabi* sunflower crop, followed by application of 150% NPK to both the crops in the sequence.

The pooled data on system economics (Table 1) showed significantly higher gross and net monetary returns and benefit: cost ratio with the application of 100% recommended NPK + FYM @ 5 t/ha to preceding *kharif* soybean crop and 100% NPK to succeeding *rabi* sunflower crop . However, this combination was statistically similar to the application of 150% recommended NPK to both the crops in the sequence. The production efficiency of 16.7 kg/ha/day was recorded with integrated use of organic and inorganic nutrients, i.e. application of 100% recommended NPK + FYM @ 5 t/ha to *kharif* soybean crop and 100% recommended NPK to *rabi* sunflower crop (Table 1). It might be owing to better residual effect of FYM 5 t/ha continuously for 13 years attributed to release of macro- and micro-nutrients during mineralization and carbon which supplies energy to microbes for their activities and favours decomposition and organic matter also act as source of energy for soil micro-flora which brings about chelation of micronutrient cations (Patel *et al*., 2007).

Sustainable yield index (SYI)

Using mean sunflower-equivalent yield (SEY) and deviation of each treatment over 13 years and maximum SEY of 5.07 t/ha from *kharif* soybean (100% recommended NPK + FYM @ 5 t/ha)–*rabi* sunflower (100% recommended NPK) treatment, sustainable yield indices were derived from each treatment (Table 1). The SYI varied from 0.25 in no-manures/fertilizer treatment to the highest of 0.50 in integrated use of organic and inorganic nutrients, i.e. application of 100% recommended NPK + FYM @ 5 t/ha to *kharif* soybean crop and 100% recommended NPK to succeeding *rabi* sunflower crop .

Soil-fertility status

The changes in organic carbon and availability of major nutrients during the years (Table 2) revealed that there was a significant increase in organic carbon and available nitrogen, phosphorous and potassium contents in soil as compared to initial and no-fertilizer plot values due to the continuous application of 100% recommended NPK + FYM @ 5 t/ha to *kharif* soybean crop and 100% recommended NPK to succeeding *rabi* sunflower in soybean–sunflower cropping system. It might be due to high C : N ratio of FYM, resulting in organic carbon built up in soil and higher available N, P and K might have increased the activity of microorganisms leading to greater mineralization of applied and inherent nutrients. It was also evident that application of phosphorus in conjunction with nitrogen improved the available nitrogen status of the soil as compared to the application of N or P alone, confirming the findings of Sheeba and Chellamuthu (1996). Among the inorganic fertilizers, continuous application of N and NP had depressive effect on the available K content of the soil which might be due to nutrient imbalance in soil (Bharadwaj *at al.,* 1982).

From the results it may be inferred that integrated approach for nutrient management proved most efficient to sustainable productivity of soybean–sunflower cropping system, with maximum built up of

Table 1. Mean seed yield (t/ha), economics and sustainable yield index (SYI) as influenced by different nutrients treatments in soybean–sunflower cropping system (pooled 1999–2011)

Treatment		Seed yield (t/ha)			Economics (₹/ha)			SYI	Production efficiency (kg/ha/day)
Soybean (*Kharif*)	Sunflower (*Rabi*)	Soybean	Sunflower	SEY (t/ha)	Gross returns (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio		
P	N	1.41	0.97	2.11	37.58	20.56	1.21	0.33	10.5
NP	NP	1.84	1.14	2.62	47.65	30.30	1.75	0.41	13.1
NPK	NPK	2.02	1.25	2.89	52.48	33.90	1.82	0.45	14.5
50% NPK	50% NPK	1.65	1.02	2.36	42.58	25.47	1.49	0.37	11.8
150% NPK	150% NPK	2.27	1.38	3.24	59.66	39.53	1.96	0.49	16.2
NPK + sunflower crop residue incorporation	NPK	2.03	1.29	2.93	53.47	34.57	1.83	0.45	14.7
NPK + FYM @ 5 t/ha	NPK	2.33	1.44	3.33	61.40	41.09	2.02	0.50	16.7
NPK	NPK + S @ 20 kg/ha through gypsum	2.03	1.33	2.98	53.96	35.14	1.87	0.46	14.9
NPK	NPK + S + B @ 1 kg/ha in alternate year	2.08	1.29	2.98	54.22	35.29	1.86	0.46	14.9
NPK	NPK + S + B + $ZnSO_4$ @ 20 kg/ha	2.07	1.33	3.01	54.61	35.55	1.87	0.46	15.0
NPK	NPK + S + $ZnSO_4$ @ 20 kg/ha	2.08	1.30	2.99	54.35	35.40	1.87	0.45	14.9
No fertilizers manure	No fertilizers/manure	1.07	0.76	1.63	29.14	13.81	0.90	0.25	8.2
SEm±		0.04	0.02	0.04	0.76	0.76	0.03	–	–
CD (P=0.05)		0.10	0.06	0.11	2.11	2.11	0.10	–	–

Rates (/kg) of soybean and sunflower were 8.3, 7.1, 10.0, 11.0, 14.4, 13.5, 11.0, 1 2.2, 18.0, 16.0, 21.0, 21.0, 22.5 and 9.5, 10.0, 15.1, 16.1, 16.0, 16.0, 15.7, 16.6, 19.0, 20.0, 22.0, 25.0, 28.0 in 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, respectively.

Table 2. Soil status after harvesting as influenced by different nutrients treatments (2011)

Soybean/Sunflower	Available nutrients (kg/ha)			OC
	N	P	K	(%)
P/N	106.5	9.7	400.3	0.57
NP/NP	127.9	10.6	402.6	0.54
NPK/NPK	145.5	12.3	430.8	0.58
50% NPK/50% NPK	109.3	10.5	410.7	0.51
150% NPK/150% NPK	160.6	13.7	460.4	0.56
NPK + sunflower crop residue incorporation/NPK	163.5	13.5	455.2	0.69
NPK + FYM @ 5 t/ha/NPK	172.6	14.4	466.1	0.89
NPK/NPK + S @ 20 kg/ha through gypsum	128.6	11.1	423.8	0.58
NPK/NPK + S + B @ 1 kg/ha in alternate year	141.4	11.7	428.5	0.59
NPK/NPK + S + B + limiting micronutrient $ZnSO_4$ @ 20 kg/ha	158.5	12.7	439.5	0.54
NPK/NPK + S + limiting micronutrient $ZnSO_4$ @ 20 kg/ha	152.5	12.6	435.5	0.56
No-manures/fertilizers/no-manures/fertilizers	104.8	7.7	390.5	0.44
Initial	122.5	9.8	410.0	0.42

available N, P, K and organic carbon. It also proved superiority of optimal dose of fertilizer with organic manure to super-optimal dose of only fertilizer. Thus, adopting integrated approach of nutrient management, the system productivity of soybean–sunflower cropping system can be economically increased with improved soil health.

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