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Productivity, economics and soil fertility of soybean - safflower cropping system in response to nutrient management practices

P. Padmavathi*, I.Y.L.N Murthy and M. Suresh[1]

Directorate of Oilseeds Research,
Rajendranagar, Hyderabad-500 030, India.
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ABSTRACT

A field experiment was conducted to study the effect of nutrient management practices on the performance of soybean - safflower sequence in Vertisols. The safflower equivalent yield (2418 kg/ha^{-1}); gross returns (Rs. 53196/ha^{-1}); net returns (Rs 33734/ha^{-1}) and B:C ratio (2.8) were significantly superior either with the application of NPK to the system + 5 t FYM/ ha to safflower; or NPK to the system + soybean residues to safflower; or NPK to the system + both crop residues. Similar trend was also observed with respect to soil health indicators *viz.*, soil respiration (108 μg C/g soil/10 days), microbial biomass C (284 μg C/g soil), microbial biomass N (41.9 μg N/g soil), mineral N (13.8 μg N/g soil) and net N mineralization (5.4 μg N/g soil/ 10 days). Significant improvement was observed in terms of PGPR and *Trichoderma* sp were found when NPK + crop residues were applied to the system.

Key words: Safflower, Soil biological activity, Soil microbial count, Soybean, System productivity.

INTRODUCTION

Soybean-safflower cropping system productivity and profitability was superior to that of greengram-safflower and maize-safflower cropping systems in Vertisols under rainfed conditions of Deccan plateau (Padmavathi *et al.*, 2012). In India, safflower is grown during post rainy season under receding soil moisture conditions in an area of 1.53lakh ha (2012-13) by the resource poor farmers with an average productivity of 640 kg/ha (FAOSTAT 2014). Continuous use of imbalanced and inadequate dose of fertilizers can have adverse effect on crop productivity and soil health on long-term basis (Dwivedi and Dwivedi, 2007). Applying mineral fertilizers in balanced amounts and in an integrated manner by combining bulky organic manures and crop residues can ensure sustainable production at higher productivity and higher quality level of the oilseed crops (Pasricha, 2010). Hence, the present investigation was carried out to study the effect of individual nutrients, their combinations, with and without FYM or crop residues incorporation on soybean-safflower system productivity, economics and soil microbial and biological activity.

MATERIALS AND METHODS

A fixed plot field experiment was conducted during 2009-12 at ICRISAT-DOR research farm of the Directorate of Oilseeds Research, Hyderabad, Telangana on Vertisols under rainfed conditions. The experimental site is located at 17^0 35' N longitude, 78^0 15' E latitude and at an altitude of 545 m. The eco-region is characterized as semi-arid tropical (SAT) climate and the soil has been classified as deep Vertisols with pH 8.4, EC 0.19 ds/m, low in organic carbon (0.40%) and available nitrogen 2.33 mg/g soil, available Olsen P 0.23 ppm and available potassium 884 kg/ha at the initiation of the experiment. The mean water holding capacity of the soil was 0.150 g/gsoil. Soybean-safflower cropping system was tested for three years. Soybean cv JS335 was sown with the onset of monsoon from last week of June to first week of July. Safflower cv Manjira was sown on zero tilled plots immediately after the harvest of soybean crop during the first fortnight of October. Safflower was harvested during the month of February. Both the crops were cultivated on broad bed and furrows (BBF) of 1.2 m broad bed and 0.3 m furrow. Four rows of soybean and three rows of safflower were sown on each BBF with recommended intra-row plant spacing.

The experiment was conducted in fixed plot with 12 treatments replicated thrice. Experiment was laid out in randomized block design with the plot size of 48 m^2. The treatments comprised: T_1-No fertilizer to both the crops, T_2- No fertilizer to soybean and recommended fertilizer to safflower (40:25:25 kg N:P_2O_5:K_2O kg/ha), T_3- 5t FYM/ha to soybean and recommended fertilizer to safflower, T_4- recommended fertilizer to soybean (20:60:20 kg N:P_2O_5:K_2O/ha) and N alone (40 kg/ha) to safflower, T_5- recommended fertilizer to soybean and N:P (40:25 kg/ha)

*Corresponding author's e-mail: padmavathi91164@gmail.com.
[1]Agricultural Research Station, Tanpur (Angrau), Telangana.

to safflower, T_6-recommended fertilizer to both the crops, T_7-recommended fertilizer to both the crops (P was applied through SSP), T_8-recommended fertilizer to soybean and 50% $N:P_2O_5:K_2O$ (20: 12.5: 12.5) + 5 t FYM/ha to safflower, T_9- recommended fertilizer to soybean and recommended NPK + 5 t FYM/ha to safflower, T_{10}-recommended NPK to soybean and recommended NPK + soybean residues to safflower, T_{11}-recommended NPK + safflower residues to soybean and recommended NPK + soybean residues to safflower, T_{12}-recommended NPK to soybean and 50% NPK + seed treatment with *Azotobacter* (25 g/kg seed) and PSB soil application (1 kg/ha). Except in T_7 in all other treatments P was applied in the form of Diammonium phosphate (DAP).

The amount of rainfall received during cropping season (June to February) was 995, 1121 and 525 mm in 2009-10, 2010-11 and 2011-12 respectively. Nearly one month dry spell in the month of July affected the growth and development of soybean in 2009. Comparisons among different treatments were made by converting yield of two crops into safflower equivalent yield on prevailing market price basis. The equivalent yield was calculated as under.

Safflower equivalent yield (kg/ha) =

$$\frac{\text{Seed yield of soybean (kg/ha) x Price of soybean (Rs/kg)}}{\text{Price of safflower (Rs/kg)}}$$

The soil samples (0-20 cm) were collected during the 3rd year cropping cycle of soybean-safflower cropping system (at flowering stage of soybean and at elongation stage of safflower) for the analysis of soil biological and microbiological properties by adopting standard analytical methods. Mineral N and net N mineralization were estimated using the method Jackson (1973). Soil respiration was estimated according to the method suggested by Anderson (1982). Microbial biomass-C (MBC) and –N (MBN) were estimated by using chloroform fumigation incubation method as described in Horwath and Paul (1994). Soil microbiological properties and microbial counts were estimated by using standard methods described by Jones and Mollison (1948) and Skinner *et al.*, (1952).

Seed yield was estimated from net plot size of 24 m^2. Microbial count was done using standard procedures. Soil microbiological properties were also estimated by following standard procedures. Statistical analysis of the data was carried out using analysis of the variance.

RESULTS AND DISCUSSION

In the first year, uneven distribution of rainfall (one month dry spell in the month of July, 2009) affected the soybean growth and crop was failed. Similarly, in the third year, safflower growth was severely affected due to very less amount of rainfall (521 mm as against 750 mm rainfall of long term average). Under rainfed Vertisols, it is not the total rainfall, but the distribution of rainfall is equally important for successful crop production. Accordingly the results and discussion were presented.

Soybean seed yield: Across two years, application of recommended dose of NPK + safflower residues to soybean and NPK + soybean residues to safflower (T_{11}) recorded significantly superior seed yield (2139 kg/ha) whereas it was statistically on par with T_{10}, T_9, T_8, T_{12} and T_7. Seed yield was significantly low with the treatments of no application of fertilizer to both the crops (T_1) in the system (1440 kg/ha) and no fertilizer to soybean and NPK to safflower (T_2) (1401 kg/ha). Integration of organic and inorganic fertilizer (T_{11}) enhanced the seed yield of soybean over control (T_1) and recommended NPK (T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{12}) (Table 1). Inclusion of either FYM or safflower crop residues enhanced the productivity of greengram-safflower, soybean-safflower and maize-safflower (Padmavathi *et al.*, 2012).

Safflower seed yield: Across three years, application of NPK to soybean and NPK + 5 t FYM/ha to safflower (T_9) recorded high seed yield (1226 kg/ha). This is statistically on par with T_{11}, T_{10}, T_3 and T_6. The lowest seed yield was recorded with the application of no fertilizer to both the crops (T_1) and NPK to soybean and 50% NPK + *Azotobacter* + PSB to safflower (T_{12}) (Table 1). Inclusion of FYM in addition to NPK enhanced the seed yield of safflower (Arbad *et al.*, 2012).

Higher seed yield in both soybean and safflower with high fertilizer input was due to readily available plant nutrients leading to greater photosynthetic activity in comparison with low doses of fertilizers. The application of FYM or crop residues facilitates N availability during entire crop growth period due to slow mineralization of organic N from organic manures in soybean-safflower sequence. Enhancement of safflower yield due to adoption of integrated nutrient management practices was also reported by Suresh *et al.*, (2012).

Safflower equivalent yield: To compare the cropping system productivity, the yield of soybean seed was converted into safflower equivalent yield considering the market value of both the crops in the system. Across three years, it was observed that the application of NPK to soybean and NPK + 5 t FYM/ha to safflower (T_9) recorded substantially higher safflower equivalent yield (2418 kg/ha) (Table 2) which was on par with that of T_{10}, T_{11}, T_8, T_7, T_6, T_5 and T_3. No fertilizer to both the crops (T_1) and no fertilizer to soybean and NPK to safflower (T_2) recorded significantly low safflower equivalent yield (1546; 1815 kg/ha) compared to all other treatments (Table 2). Substitution of part of recommended fertilizer of soybean (100% N & K_2O, 15% P_2O_5) in soybean-safflower system through safflower crop residues (3 t/ha)

Table 1: Effect of nutrient management practices on seed yield (kg/ha) of soybean and safflower

	Treatment		Soybean			Safflower			
	Soybean	Safflower	2010-11	2011-12	Mean	2009-10	2010-11	2011-12	Mean
T_1	No fertilizer (control)	No fertilizer (control)	1300	1580	1440	1277	650	250	726
T_2	No fertilizer (control)	NPK	1301	1500	1401	1756	905	390	1017
T_3	5 t FYM/ha	NPK	1644	1820	1732	1773	908	520	1067
T_4	NPK	N	1602	1960	1781	1486	733	540	920
T_5	NPK	NP	1728	2000	1864	1643	868	490	1000
T_6	NPK	NPK	1775	2050	1913	1679	905	510	1031
T_7	NPK (P through SSP)	NPK (P through SSP)	1697	2050	1874	1635	900	480	1005
T_8	NPK	50 %NPK + 5 t FYM/ha	1792	2090	1941	1523	815	550	963
T_9	NPK	NPK + 5 t FYM/ha	1810	2375	2093	1848	1150	680	1226
T_{10}	NPK	NPK+ soybean residues	1848	2375	2112	1642	1095	680	1139
T_{11}	NPK + safflower residues	NPK + soybean residues	1927	2350	2139	1716	1120	700	1179
T_{12}	NPK	50% NPK+ *Azotobacter* +PSB	1821	2040	1931	1315	788	460	726
	Mean		1687	2016	1852	1608	903	521	1011
	S.Em±		75	68	81	109	89	42	65
	C.D (P=0.05)		225	204	243	319	268	126	195

2009-10: Soybean crop was failed due to one month dry spell

and glyricidia loppings (2 t/ha) sustained the productivity of the system (Padmavathi *et al.,* 2012).

Economic returns: Application of NPK to soybean and NPK + 5 t FYM/ha to safflower (T_9) recorded the maximum gross returns (Rs.53196/ha) followed by NPK + safflower residues to soybean and NPK + soybean residues to safflower (T_{11}) (Rs. 52734/ha) and NPK to soybean and NPK + soybean residues to safflower (T_{10}) (Rs. 51524/ha) (Table 3). Owing to high cost of cultivation (Rs. 20750/ha) in the treatment T_9, the net returns (Rs 32446/ha) were comparatively lower than that of T_{11} (Rs. 33734/ha) and T_{10} (Rs.32524/ha) treatments. The highest net returns (Rs. 33734/ha) and B:C ratio (2.78) was recorded with the T_{11}. Application of NPK to both the crops in the system recorded Rs. 46123/ha of gross returns, Rs. 26866/ha of net returns with a benefit cost ratio of 2.4.This was closely followed by the treatment NPK to soybean and NP to safflower (T_5) and NPK to soybean and 50% NPK + *Azotobacter* + PSB to safflower (T_{12}) with respect to net returns (Table 3). There was a great reduction in economic returns when imbalanced fertilizers were applied to the soybean-safflower cropping system indicating the importance of the balanced and integrated plant nutrition.

Beneficial Soil microbial properties: Soil microflora (fungi and bacteria) has a greater suite of enzymes for chemical breakdown of organic material and was considered as a labile pool of nutrients called the soil microbial biomass that has a pivotal role in nutrient immobilization and mineralization (Peter Gruhn *et al.,* 2000). At stem elongation stage of safflower (45 DAS), plant growth promoting rhizobacteria (PGPR) were significantly more with NPK + safflower residues to soybean and NPK + soybean residues to safflower (T_{11}) (4451 CFU/ml) followed by the treatment NPK to soybean and NPK + soybean residues to safflower (T_{10}) (3456 CFU/ml) (Table 4). These treatments explain the positive effect exhibited by the organic residues on the beneficial microbial population enhancement. Inclusion of FYM along with inorganic fertilizer to safflower (T_8 and T_9) improved the PGPR compared to NPK alone (32%) and no fertilizer to safflower (36%). Similarly, *Trichoderma* sp were substantially improved with NPK + safflower residues to soybean and NPK + soybean residues to safflower (T_{11}) (142 CFU/ml) followed by the treatments T_9 (94), T_8 (89) and T_{10} (87) where either soybean residues or FYM was applied along with inorganic fertilizer. Similar results were obtained by several workers under different cropping systems (Bolton *et al.,* 1985 and Carter, 1986).

Soil biological activity: Soil biological activity was significantly influenced due to varied integrated nutrient management practices (Table 4). Soil respiration (µg C/g soil/10 days) at stem elongation stage of safflower, was significantly greater with the application of NPK to soybean

Table 2: Effect of nutrient management practices on total system productivity expressed in terms of safflower equivalent yield (kg/ha)

	Treatment		Safflower equivalent yield (kg/ha)			
	Soybean	Safflower	2009-10	2010-11	2011-12	Mean
T_1	No fertilizer (control)	No fertilizer (control)	1277	1761	1600	1546
T_2	No fertilizer (control)	NPK	1756	2017	1672	1815
T_3	5 t FYM/ha	NPK	1773	2313	2075	2054
T_4	NPK	N	1486	2102	2215	1934
T_5	NPK	NP	1643	2345	2199	2062
T_6	NPK	NPK	1679	2422	2262	2121
T_7	NPK (P through SSP)	NPK (P through SSP)	1635	2350	2232	2072
T_8	NPK	50 %NPK + 5 t FYM/ha	1523	2346	2336	2068
T_9	NPK	NPK + 5 t FYM/ha	1848	2697	2710	2418
T_{10}	NPK	NPK+ soybean residues	1642	2674	2710	2342
T_{11}	NPK + safflower residues	NPK + soybean residues	1716	2767	2708	2397
T_{12}	NPK	50% NPK+ *Azotobacter* +PSB	1315	2344	2203	1954
	Mean		1608	2345	2243	2065
	S.Em±		103	114	95	115
	C.D (P=0.05)		310	340	285	345

Market price of soybean: Rs. 18.80/kg; safflower: Rs. 22/kg

Table 3: Effect of nutrient management practices on economic returns in soybean-safflower cropping system (mean of 3 cropping cycles)

	Treatment		N:P:K Price	Economic returns (Rs/ha)			
	Soybean	Safflower	(Rs/ha)	Gross returns	Cost of cultivation	Net returns	B:C ratio
T_1	No fertilizer (control)	No fertilizer (control)	0	34012	16000	18012	2.13
T_2	No fertilizer (control)	NPK	1264	39930	17264	22666	2.31
T_3	5 t FYM/ha	NPK	3014	45188	19014	26174	2.38
T_4	NPK	N	1347	42548	18206	24342	2.34
T_5	NPK	NP	2743	45364	18748	26616	2.42
T_6	NPK	NPK	2995	46662	19000	27662	2.46
T_7	NPK (P through SSP)	NPK (P through SSP)	3514	45584	19514	26070	2.34
T_8	NPK	50 %NPK + 5 t FYM/ha	4104	45496	20122	25374	2.26
T_9	NPK	NPK + 5 t FYM/ha	4745	53196	20750	32446	2.56
T_{10}	NPK	NPK+ soybean residues	2995	51524	19000	32524	2.71
T_{11}	NPK + safflower residues	NPK + soybean residues	2995	52734	19000	33734	2.78
T_{12}	NPK	50% NPK+ *Azotobacter* +PSB	2354	42988	16330	26658	2.63
	Mean		2672	45430	18579	26851	2.45

Prices considered for calculating NPK price: urea, DAP, SSP, MOP and FYM are 5.6, 12, 4.4, 6 and 0.35 Rs/kg respectively

and NPK + 5 t FYM/ha to safflower (T_9) (108) which was on par with T_{10}, T_{11} and T_8. Similar trend was also noticed with respect to soil microbial biomass C and N. Soil mineral N (µg N/g soil) was superior with application of NPK + safflower residues to soybean and NPK + soybean residues to safflower (T_{11}). This was statistically on par with T_{10}, T_8, T_9, T_{12}, T_7, T_5, T_6 & T_4. Lowest mineral was noticed with the application of no fertilizer to both crops (T_1) (8.6) which was on par with that of T_2 and T_3. Application of NPK + safflower residues to soybean and NPK + soybean residues to safflower (T_{11}) significantly improved the net N mineralization (5.2 µg N/g soil/ 10 days) which was on par with that of T_{12}, T_{10}, T_9, T_8, T_7, T_6, T_5, T_4, T_3 and T_2. No application of fertilizer to both the crops (T_1) recorded lowest net N mineralization (3.5). This clearly showed the importance of balanced and integrated use of fertilizers and manures for sustaining soil fertility and crop productivity. Crop residues have been reported to increase soil organic fertility which in turn might improve microbial activity and nutrient supply (Shah *et al.*, 2003). Similar increase was also noticed in greengram-safflower cropping system under rainfed conditions in Vertisols (Suresh *et al.*, 2012).

From the study, it can be concluded that the conjunctive use of recommended dose of NPK fertilizers (20-60-20 kg/ha to soybean and 40-25-25 kg/ha to safflower) along with either crop residues (safflower residues to soybean and soybean residues to safflower) or 5 t FYM/ha (to safflower) to soybean-safflower cropping system resulted in improved crop productivity and soil health.

Table 4: Effect of integrated nutrient management options on soil microbiological population (CFU/ml) and soil biological properties at stem elongation stage of safflower in the third year of cropping cycle 2011-12

	Soybean	**Safflower**	**Plant growth promoting rhizobacteria (PGPR) (CFU/ml)**	***Trichoderma sp*** (CFU/ml)	**Soil respiration (µg C/g soil/ 10 days)**	**Microbial biomass C (µg C/g soil)**	**Microbial biomass N (µg N/g soil)**	**Mineral N (µg N/ g soil)**	**Net N mineralization (µg N/g soil / 10 days)**
T_1	No fertilizer (control)	No fertilizer (control)	2214	18	71	210	31.0	8.6	3.5
T_2	No fertilizer (control)	NPK	2246	19	80	210	31.0	9.4	4.8
T_3	5 t FYM /ha	NPK	2445	25	85	230	34.0	9.2	4.1
T_4	NPK	N	2786	29	84	240	35.4	10.1	4.3
T_5	NPK	NP	2545	28	80	235	34.7	10.8	4.1
T_6	NPK	NPK	2451	32	84	238	35.1	10.4	4.1
T_7	NPK (P through SSP)	NPK (P through SSP)	2490	34	87	241	35.6	10.8	4.4
T_8	NPK	50% NPK + 5 t FYM/ha	2890	89	94	261	38.5	12.4	4.8
T_9	NPK	NPK + 5 t FYM/ha	3127	94	108	268	39.6	12.1	5.1
T_{10}	NPK	NPK + soybean residues	3456	87	105	284	41.9	13.4	5.2
T_{11}	NPK + safflower residues	NPK + soybean residues	4451	142	104	281	41.5	13.8	5.4
T_{12}	NPK	50% NPK + *Azotobacter* + PSB	2543	32	81	234	34.5	10.8	4.0
	S.Em±		310	12	4.8	9.2	1.2	1.42	0.49
	C.D (P=0.05)		932	37	15	28	3.8	4.1	1.6
	Initial status				255	230	35.4	12.5	10.6

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