Indian Journal of Agronomy **56** (4): 340–345 (December 2011)

Effect of integrated nutrient management on soybean (*Glycine max*)–safflower (*Carthamus tinctorius*) cropping system

B.K. ARBAD* AND SYED ISMAIL

Marathwada Agricultural University, Parbhani, Maharashtra 431 402

Received: February 2011; Revised accepted : October 2011

ABSTRACT

To study the effect of various fertilizer doses and manurial treatment in soybean-safflower cropping system on soil properties , yield and nutrient uptake. The soil samples were drawn from the Research farm, Marathwada Agricultural University, Parbhani with an objective to study changes in soil quality and crop productivity under soybean safflower cropping system included with various combinations of N, P, K, Zn, S fertilizers and mannurial FYM treatments. Results from the study showed that the maximum nutrient total uptake of N, P and K in soybean and safflower was recorded due to application of 100 % NPK + FYM @ 10 Mg/ha where as maximum total sulphur uptake in soybean (19.58 kg/ha) and in safflower (18.19 kg/ha) was recorded in treatments applied with 150% NPK and 100% NP + on residual effect of FYM respectively. Zinc uptake was maximum with 100% NPK + FYM @ 10 Mg/ha and in safflower it was recorded highest in 100% NP + residual effect of FYM. And also noticed that after continuous intensive cropping under various fertilizers with FYM treatment improvement occurred in the grain and straw yield and status of soil pH, EC, organic carbon, available N, P_2O_5, K_2O, S and DTPA extractable Zn. Use of FYM and micronutrients helped in maintaining soil fertility. Highest net returns were recorded with 100% NPK + FYM.

Key words *:* Farmyard manure, Nutrient uptake, Safflower, Soil properties, Soybean, Yield

The productivity of oilseeds (935 kg/ha) in India is low as these are cultivated largely under rainfed (75.67%) conditions. Soybean and safflower are grown as major *kharif* and *rabi* crops, respectively in the Marathwada region. Inadequate and imbalanced fertilizer use and emergence of multiple-nutrient deficiencies including those of secondary and micronutrients are the major factors responsible for low productivity of these crops (Singh *et al.*, 2008). The situation has partly risen due to poor recycling of organic manures. Several long term fertilizers experiments in the country have demonstrated that the use of NPK fertilizer alone leads to emergence of micro nutrient deficiencies, while integrated use of organics and inorganics sources of nutrients sustains crop productivity and improves soil health under most cropping systems (Tiwari, 2002). Site specific nutrient management (SSNM) is gaining popularity of late due to its superiority over blanket nutrient recommendations as it takes into account site, season and crop growth variables. This approach enables farmers to apply the right amount of nutrients at the right time. Nutrient application, thus match the crop demands, thereby minimizing the risk of over application of fertilizer. It ensures balanced application of all nutrients to maintain productivity and soil quality over time (Tiwari, 2008). Therefore, the present investigation was undertaken to evaluate the effect of chemical fertilizers alone and in combination with FYM on the productivity soybean–safflower cropping system and their residual effects in soil fertility.

***Corresponding author Email**: arbad_bk@yahoo.co.in

MATERIALS AND METHODS

The field experiment on soybean–safflower cropping system was conducted during *kharif* and *rabi* season in the year 2007–08 and 2008–09 on a Vertisol and was laid out in a randomized block design with twelve treatments replicated four times. The treatments were: 50% NPK, 100% NPK, 150% NPK, 100% NPK + Hand Weeding, 100% NPK + $ZnSO_4$ @ 25 kg/ha, 100% NP, 100% N, 100% NPK + FYM @ 10 Mg/ha, 100% NPK–S, FYM @ 10 Mg/ha, Control (no fertilizer/manure) and a Fallow plot (no crop). The 100% RDF was 30–60–30 N – P_2O_5 – K_2O kg/ha for soybean and 60–40 N – P_2O_5 kg/ha for safflower. The fertilizers used were urea, single super phosphate and muriate of potash. For the treatment NPK–S, Diammonium phosphate (DAP) was used is to eliminate sulphur. All other plots except control and fallow received sulphur through single super phosphate. Zinc was applied

through Zinc sulphate @ 25/ha. Soybean 'JS-335' and safflower 'Sharda' were raised during *kharif* and *rabi* respectively, with recommended package of practices. FYM had 0.27% N, 0.20% P and 0.38% K and was incorporated in soil 7 days before sowing. Sowing of soybean in both the year was done in the 3rd week of June and harvesting in the 2nd week of October, whereas safflower was sown in the last week of October and harvested in the 2nd week of March.

The soil samples were collected after harvesting of safflower in 2009 (after 2 years of study) for analysis of organic carbon, available N, P, K, S and DTPA extractable Zn as per standard procedure. The initial bulk soil samples were collected during the first year from entire experiment field for initial soil analysis. The initial soil pH was 8.1, organic carbon 4.8 g/kg, available N 205.7 kg/ha, available P_2O_5 13.2 kg/ha and available K_2O content 740.2 kg/ha, available Sulphur 25.05 kg/ha and DTPA extractable zinc was 1.25 mg/kg. Thus, the soil was clayey in texture, moderately alkaline in reaction, medium in available nitrogen and phosphorus, sufficient in available potassium and low in available sulphur and zinc.

The plot-wise grain and straw yield of both the crops for both years were recorded. Before harvest five plants were harvested and used for chemical analysis after oven drying. Nitrogen was determined by microkjelddhl method, phosphorus by vanadophosphomolybdate yellow colour method, potassium by Triacid extract on flamephotometer, sulphur by Turbidimetric on spectrophotometer and zinc by an atomic absorption spectrophotometer using a triacid digest of the plant material. The nutrient uptake was worked out by multiplying the nutrient concentration in plant/grain with respective yields.

RESULTS AND DISCUSSION

Seed and straw yield of soybean and safflower

The grain and straw yield was increased significantly showing maximum yields with receiving 150% RDF and was at par 100% RDF with FYM. The higher grain yield due to inorganic alone and in combination with organic sources along with FYM might have increased due to sustained nutrient supply and also as result of better utilization of applied nutrients through improved microbial activity that involved in nutrient transformation and fixation similar findings were reported by Ravankar *et al.* (1995). Safflower crop also responded significantly to residual fertility grain yield and straw was increased from 0.97 tonnes/ha to 1.63 tonnes/ha and straw yield from 2.95 tonnes/ha to 5.15 tonnes/ha with the increase in soil fertility. Maximum grain and straw yield was observed in treatment receiving 150% NPK but was at par with 100% NP on residual effect of FYM. The results are in conformity with finding of Patel *et al*. (2007), who has reported that increase in groundnut yield due to the residual effect of FYM attributed to release of macro and micronutrients during mineralization and carbon which supplies energy to microbes for their activities and favour decomposition and organic matter also acts as source of energy for soil micro flora which brings about chelation of micronutrient cations.

Soil-fertility status

As per data recorded in (Table 1), integrated nutrient management had significantly increased the organic carbon (6.01 g/ha), available nitrogen (240.52 kg/ha), phosphorus (18.51 kg/ha), potassium (795.44 kg/ha) and sulphur (34.73 kg/ha) content in soil as compared to initial values and control plot they declined significantly, due to varying fertility level. Whereas DTPA extractable Zn (1.30 mg/kg) was increased in plot receiving 100% NPK with zinc sulphate @ 25 kg/ha and there was decline in DTPA Zn as compare to initial value in all treatment except where FYM was incorporated. The fertility level of 10 Mg/ha FYM with 100% NPK left the maximum organic carbon content in soil might be due to high C:N ratio of FYM resulting in organic carbon build up in soil and higher available N, P, K, S and DTPA extractable Zn might due to increased activity of micro organism leading to greater mineralization of applied and inherent nutrients. The use of fertilizer alone helps in increasing carbon content of soil due to higher biomass which might be due to the differential rate of oxidation of organic matter by microbes (Trehan, 1997). The reduction in control plot may be due to the fact that crops are grown in this treatment and their grain and straw are harvested, where as in case of fallow plots, the biomass produced is incorporated in the soil itself as reported by Bharadwaj and Omanwar (1994). It was also evident that application of phosphorous in conjunction with nitrogen improved the available nitrogen status of the soil as compared to the application of N alone and was also noted by Sheeba and Chellamuthu (1996). Among the inorganic fertilizers, continuous application of N or NP had depressive effect on the available K content of the soil which may be due to nutrient imbalance in soil. This is in consonance with the findings of Bharadwaj *et al*. (1982). The application of 100% NPK with FYM resulted in significantly higher available S content than the control due to application of single super phosphate and FYM which contained about 12 and 0.05–0.31% of sulphur, respectively (Sachan, 1994). Ingle *et al.* (2006) reported that in wheat, application of Zn in combination with recommended dose of NPK increased available N, P and K over 100% of NPK. The higher availability of Fe and Zn in soil under FYM was mainly due to its

functions in mobilizing the native Fe and Zn and chelation of Fe and Zn was reported by Patil *et al*. (2007).

Nutrient uptake

The pooled mean data of two years (Table 2) noticed that nitrogen, phosphorus, potassium, sulphur and zinc uptake in both crops differed significantly due to different treatments during both the years. The super optimal dose of fertilizes and recommended dose of fertilizer with FYM @ 10 Mg/ha and supplementary nutrients *viz.* zinc @ 25 kg/ha recorded significantly higher uptake of nutrients over the control. Contrary to comparable performance of 150% RDF and 100% RDF + FYM along with micronutrient (zinc) in respect to grain and dry matter of the soybean and safflower which removed higher amount of nutrients when compared with other treatments. Comparatively in soybean higher nutrients uptake of nitrogen, phosphorus, potassium, and zinc was found higher in treatment T_8 treated with 100% RDF along with FYM @ 10 Mg/ha and sulphur uptake was highest in treatment T_3 treated with 150% RDF. Whereas, in safflower higher total nutrient uptake of nitrogen and potassium was in treatment T_3 receiving 150% NP. Where as phosphorus and sulphur was highest in treatment T_8 receiving 100%

Table 1. Effect of inorganic levels and farmyard manure on grain and straw yield of soybean and safflower and soil fertility status after harvest of second cycle of soybean–safflower cropping sequence.

Treatment	Yield (t/ha)				After harvest of safflower (2009)					DTPA
	Soybean		Safflower		Available nutrients (kg/ha)					(mg/kg)
	Grain	Straw	Grain	Straw	OC (g/kg)	N	P	K	S	Zn
50% NPK	2.09	3.21	1.34	4.07	5.18	200	14.53	748	28.60	1.08
100% NPK	2.53	3.83	1.44	4.64	5.37	222	16.73	767	30.44	1.06
150% NPK	2.85	4.28	1.63	5.15	5.71	236	18.33	788	33.08	1.01
100% NPK+HW	2.35	3.59	1.45	4.77	5.40	224	16.90	763	30.26	1.03
100% NPK+Zn	2.64	4.07	1.46	4.91	5.48	226	16.75	762	29.34	1.30
100% NP	2.33	3.65	1.23	4.07	5.26	219	16.71	740	29.83	1.08
100% N	1.98	3.04	1.16	3.85	5.09	211	10.52	736	21.05	1.10
100% NPK+FYM	2.84	4.31	1.60	4.81	6.01	240	18.51	795	34.73	1.29
100% NPK-S	2.44	2.70	1.36	4.39	5.32	228	16.88	785	19.41	1.02
FYM	2.33	3.57	1.13	3.41	5.98	221	17.80	760	28.75	1.18
Control	1.45	2.21	0.97	2.95	4.85	164	10.47	732	21.30	0.93
Fallow	-	-	-	-	5.57	202	13.40	760	24.90	1.25
Mean	2.35	3.59	1.34	4.28	5.45	216	15.63	760	27.64	1.11
SEm±	1.24	1.61	0.75	1.47	0.21	7.26	0.51	17.87	1.20	0.034
CD (P=0.05)	3.60	4.66	2.19	3.34	0.60	20.11	1.43	NS	3.32	0.096
Initial	—	—	—	—	4.80	205	13.20	740	25.05	1.25

Table 2. Effect of inorganic levels and farmyard manure on N, P, K, S and Zn. uptake in soybean and safflower during 2007-2008 and 2008-2009 (pooled data)

Treatment	Total Nutrient uptake (kg/ha)					Total Nutrient uptake (kg/ha)				
	Soybean					Safflower				
	N	P	K	S	Zn (g/ha)	N	P	K	S	Zn(g/ha)
50% NPK	139	19.37	58	11.26	265.92	57	13.36	89	9.42	70.97
100% NPK	186	28.16	73	15.46	319.8	67	18.84	106	12.97	87.99
150% NPK	215	35.41	8	19.58	351.53	80.	23.85	122	17.71	89.08
100% NPK+HW	167	24.84	6	14.2	255.88	69	18.01	109	12.52	88.07
100% NPK+Zn	199	24.16	78	16.94	391.39	73	16.42	111	15.14	120.69
100% NP	175	26.32	59	14.54	311.63	59	15.85	83	11.19	79.90
100% N	148	16.52	53	8.89	253.58	53	9.74	76	7.66	75.52
100% NPK+FYM	218	35.43	88	18.91	408.20	80	24.51	117	18.19	112.09
100% NPK-S	176	26.29	69	11.54	322.91	67	18.08	101	9.89	86.51
FYM	163	25.90	68	12.97	304.82	51	13.38	80	10.83	68.88
Control	115	10.5	38	6.05	171.86	38	6.90	5	5.69	41.10
Mean	186	24.64	67	13.66	309.31	61	16.29	96	11.92	83.76
SEm±	4.39	0.65	1.88	0.41	8.815	2.08	0.55	3.44	0.37	3.17
CD (P=0.05)	12.68	1.87	5.43	1.18	25.43	6.01	1.58	9.67	1.07	9.02

NP on residual effect of FYM and zinc was highest in treatment T_5 receiving in 100% NP on residual effect of $ZnSO_4$ @ 25 kg/ha applied in *kharif.* The results might be owing to super optimal supply of nutrient sources to both the crops as well as due to indirect effect resulting from reduced loss of organically supply nutrients, this finding is confirmed with Chaturvedi and Chandel. (2005). The better available source (SSP) caused better root development resulting in higher uptake of nitrogen and phosphorus and other nutrients and higher biological fixation (Tanwar and Shakawat, 2003). Total uptake of potassium and sulphur by safflower was higher under RD of NPK + FYM which might be due to higher availability of the plants nutrients from the soil reservoir and additional quantity of the nutrients supplied by FYM. The uptake of zinc by wheat grain and straw increased significantly with increasing levels of zinc over control due to increase in yield and zinc content as result of zinc application as reported by Singh *et al*. (2004). Higher biomass production may be the most pertinent reasoning for higher uptake of nutrients in the treatments referred above.

Balance sheet

The cropping with high intensity under modern and heavy inputs with improved production potential simultaneously removes large quantity of nutrients leading to either depletion or imbalance in the soil. The data on the net gain and loss are presented in (Table 3). Inorganic sources, inorganic combined with organics or organics alone showed a positive building of nitrogen, phosphorous and potassium balance in soil as compared to initial value of composite sample after harvest of 2nd cycle of soybean-safflower sequence. The control plot showed a negative available N, P_2O_5 and K_2O balance in soil. The actual N balance in soybean–safflower sequence after harvest of 2nd cycle showed maximum build up in treatments treated with 100% NPK+FYM (+34.82 kg/ha) and 150% NPK (+30.99 kg/ha). Whereas, depletion in available N was noticed in 50% NPK (–5.69 kg/ha) control (–41.4 kg/ha) and fallow plot (–3.18 kg/ha). As far as phosphorus balance is concerned, P balance was maximum in 100% NPK + FYM (5.31 kg/ha) followed by 150% NPK (5.13 kg/ha). The calculated P balance was negative in 100% N (–2.68 kg/ha) and Control plot (–2.73 kg/ha). Other treatments were positive as compared to initial value. As far as potassium is considered, there was slight increase in available potassium as compare to initial value of experimental soil. There was negative balance in treatments, which were devoid of K fertilizers. Maximum build up was recorded in treatment 100% NPK + FYM (55.25 kg/ha) and all other treatments showed positive build up except 100% N and control (–7.80 kg/ha) plot. In general treatments receiving 100% NPK through inorganic and FYM treatments recorded high build up of nutrients which might be due to more availability of nutrients from both the sources. Whereas highest negative nutrient balance was in control plot due to continuous removal of nutrients by the crop without application of fertilizers depleted nutrient balance and less in fallow plot might be due to leaching quit natural in unfertilised follow plot. Similar results were reported by Vyas *et al.* (2003), the positive balance of N, P_2O_5, and K_2O was the result of low uptake over total quantity of N, P and K applied to the crops.

Grain equivalent yield and economics

During the year 2007-08, the soybean grain equivalent yield was significantly highest in treatment 100% N, P and K + FYM (49.66 kg/ha). However, during year 2008–09, soybean grain equivalent was significantly highest in 150% NPK (₹46.85 kg/ha). The economics of soybean from 2007–08 data revealed that the GMR was highest in 100% N, P and K + FYM (₹56,558) but due to high cost

Table 3. Balance sheet of available N, P_2O_5 and K_2O (kg/ha) in soil as influenced by different treatments after two years cycle

Treatment	Initial (kg/ha)			Added through fertilizers (kg/ha)			Calculated available (kg/ha)			Actual balance (kg/ha)			Net loss or gain (kg/ha)		
	N	P_2O_5	K_2O	N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
50% NPK	205.7	13.2	740.2	90	100	30	295.7	113.20	770.2	200.0	14.5	748.3	-5.6	+1.3	+8.1
100% NPK	205.7	13.2	740.2	180	200	60	385.7	213.20	800.2	222.3	16.7	767.3	+16.6	+3.5	+27.1
150% NPK	205.7	13.2	740.2	270	300	90	475.7	313.20	830.2	236.6	18.3	788.4	+30.9	+5.1	+48.2
100% NPK+HW	205.7	13.2	740.2	180	200	60	385.7	213.20	800.19	224.6	16.9	763.0	+18.9	+3.7	+22.9
100% NPK+Zn	205.7	13.2	740.2	180	200	60	385.7	213.20	800.2	226.6	16.8	762.2	+20.9	+3.6	+22.0
100% NP	205.7	13.2	740.2	180	200	00	385.7	13.20	740.2	211.9	16.7	740.9	+6.2	+3.5	+0.7
100% N	205.7	13.2	740.2	180	00	00	385.7	13.20	740.2	219.8	10.5	736.8	+14.2	-2.7	-3.9
100% NPK+FYM	205.7	13.2	740.2	180	200	60	385.7	213.20	800.2	240.5	18.5	795.4	+34.8	+5.3	+55.2
100% NPK-S	205.7	13.2	740.2	180	200	60	385.7	213.20	800.2	228.9	16.9	785.3	+23.2	+3.7	+4.5
FYM	205.7	13.2	740.2	00	00	00	205.7	13.20	740.2	221.4	17.8	761.0	+15.7	+4.6	+20.1
Control	205.7	13.2	740.2	00	00	00	205.7	13.20	740.2	164.3	10.5	732.4	-41.4	-2.7	-7.8

Table 4. Soybean and safflower grain equivalent, gross monetary returns, net monetary return and benefit cost ratio as influenced by different nutrient management practices (2007-08 and 2008-09)

Treatment	Grain equivalent yield (t/ha) 2007-08	Monetary return of soybean (×10³ ₹/ha) 2007-08			Monetary return of safflower (×10³ ₹/ha) 2008-09			Grain equivalent yield (t/ha) 2008-09	Monetary return of soybean (×10³ ₹/ha) 2008-09			Monetary return of soybean (×10³₹ /ha) 2008-09		
		GMR	NMR	B:C	GMR	NMR	B:C		GMR	NMR	B:C	GMR	NMR	B:C
50% NPK	3.73	40.9	28,438	2.28	20.9	12,923	1.61	3.58	33.0	20,527	1.63	36.1	27,024	2.97
100% NPK	4.28	48.1	34,117	2.44	22.8	13,688	1.51	4.15	41.6	27,601	1.96	38.6	28,433	2.78
150% NPK	4.82	55.3	39,720	2.54	24.6	14,487	1.43	4.69	45.5	29,958	1.92	44.9	33,674	2.98
100% NPK+HW	4.16	46.4	32,593	2.35	22.5	13,660	1.54	3.95	36.8	22,921	1.65	39.5	29,356	2.90
100% NPK+Zn	4.54	52.3	37,859	2.62	22.9	13,801	1.53	4.17	40.9	26,573	1.85	39.7	29,570	2.92
100% NP	3.96	47.4	33,746	2.47	18.2	9,265	1.03	3.60	35.2	21,609	1.58	34.3	24,193	2.38
100% N	3.29	38.1	26,497	2.27	16.4	8,628	1.11	3.36	31.8	20,066	1.70	33.2	2,278	2.73
100%NPK+FYM	4.97	56.5	37,108	1.90	25.6	16,501	1.81	4.46	43.7	24,391	1.26	42.4	36,162	3.12
100% NPK-S	4.30	49.8	36,133	2.63	21.3	12,492	1.42	3.76	35.9	22,369	1.65	36.8	26,889	2.71
FYM	3.99	48.0	31,652	1.93	18.1	11,194	1.62	3.33	34.1	17,854	1.09	30.2	22,349	2.83
Control	2.52	27.7	17,092	1.61	14.1	7,253	1.06	2.77	26.0	15,194	0.71	27.3	19,475	2.49
Mean	4.05	46.4	32,269		20.9	12,172		3.80	36.8	22,642		36.6	27,400	
SEm+	0.28	2.1	1,394		1.1	504		0.28	1.8	1,062		1.5	967	
CD (P=0.05)	0.44	6.2	4,022		3.1	1,453		0.79	5.2	3,063		44.9	2,789	

of FYM with RDF proved less profitable. Whereas NMR was highest in 150% N, P and K (₹39,720) but B:C ratio was highest in 100% N, P and K–S (2.36) due to low cost of fertilizer. As compare with safflower GMR, NMR and B:C ratio was highest in treatment receiving 100% NP on residual effect of FYM as cost of FYM was considered in soybean economics and due to higher yields. In year 2008–09 economics of soybean revealed that GMR and NMR was highest in 150% NPK but B:C ratio was highest in treatment receiving 100% N, P and K (1.96) due low cost of fertilizer as compare to 150% N, P and K. Whereas safflower GMR was highest with 150% NP and NMR and B:C ratio was high in 100% NP on residual effect of FYM due to high yield.

The grain, straw yield, nutrient concentration and uptake of nitrogen, phosphorus, potassium in grain and straw of soybean and safflower in sequence was found to be influenced by super optimal dose of chemical fertilizer (150% N, P and K) and FYM treated treatments which recorded relatively higher nitrogen, phosphorus and potassium uptake as compared to other treatments. Integrated plant nutrient supply proved most efficient to sustainable productivity of soybean-safflower cropping system with maximum build up of available N, P_2O_5, K_2O, sulphur and zinc. The substitution of FYM and $ZnSO_4$ in *rabi* season proved superior on residual effect. Thus, it was found desirable to improve soil health and sustained the productivity of soybean-safflower sequence on vertisols.

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