International Journal of Plant & Soil Science

Volume 37, Issue 11, Page 274-287, 2025; Article no.IJPSS.147355
ISSN: 2320-7035

Effect of Different Nutrient Management Practices on Yield, Economics and Soil Fertility Response in Sunflower Rabi Sorghum System under Rainfed Condition

Kamble Anand Shankar [a++*], Bhat S. N. [b#], Basavanneppa, M. A. [a†], Satyanarayana Rao [b‡] and Venkanna R [a^]

[a] OFRI, UAS, Raichur, India.
[b] AC, UAS, Raichur, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2025/v37i115843

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/147355

Original Research Article

Received: 26/08/2025
Published: 17/11/2025

ABSTRACT

A long term field experiment has been initiated in 2008-09 on permanent site at Organic Farming Research Station, MARS, UAS, Raichur with sunflower-rabi sorghum cropping system of two years rotation under rainfed condition. The five crop rotation cycles were completed in the year 2020-21.

[++] Associate Professor (Agronomy); [#] Professor (Soil Science); [†] Professor and Head; [‡] Former Dean and Professor (Agronomy); [^] Assistant Professor (Agriculture Entomology);
**Corresponding author: E-mail: anandsk2833@gmail.com;*

Cite as: *Kamble Anand Shankar, Bhat S. N., Basavanneppa, M. A., Satyanarayana Rao, and Venkanna R. 2025. "Effect of Different Nutrient Management Practices on Yield, Economics and Soil Fertility Response in Sunflower Rabi Sorghum System under Rainfed Condition". International Journal of Plant & Soil Science 37 (11):274–287. https://doi.org/10.9734/ijpss/2025/v37i115843.*

The experiment consisted five different nutrient management practices *viz*., 75% organic, 100% organic, integrated (50% organic + 50% inorganic), 100% in organic and RDF+ FYM. In the experiment strip plot design was followed. The organic system and recommended package were on par with each other (368, 411 and 398 kg/ha) and superior over inorganic package (321 kg/ha) with respect to seed yields and net returns (24316 Rs/ha). The soil fertility status (OC%, Available N, P_2O_5 and K_2O kg/ha) were improved substantially with organic (0.68%, 164.0, 66.2 and 865.0 kg/ha, respectively) and integrated management practices (0.60%, 162.5, 63.2 and 805.0 kg/ha). Whereas, integrated application of nutrient sources like organic and fertilisers resulted in significantly higher available N, P_2O_5 and K_2O than chemical fertilizers alone (0.46%, 154.2, 48.5, 775.0 kg/ha, respectively) and 75% organic (0.55%, 143.3, 51.3 and 785.0 kg/ha, respectively) nutrient management practices. The net and B:C ratio was found to be on par with RDF+FYM and integrated management practices over the years. The organic nutrient management recorded increasing net returns and benefit cost ratio over the years compared to inorganic and 75% organic nutrient management treatment.

Keywords: Cropping system; economics; nutrient management treatment; uptake of nutrient; fertility.

1. INTRODUCTION

"Indian agriculture scenario has faced many problems after green revolution viz., stagnation or even decrease in production and productivity of major crops, deterioration of soil fertility, decline in factor productivity, low diversity of production systems and increasing cost of production. For increasing and maintaining soil quality for enhancing and sustaining agricultural productivity is importance for India's food and nutritional security. Even though food is surplus in India with present status of about 329.7 million tonnes food grain production per annum, it is estimated that about 4-5 million tonnes additional food grains each year as rising population persists" (Anonymous., 2023). "Due to increasing population, the demand for essential needs viz., food, feed, fodder, fibre, fuel, pulses and oilseed products is rapidly increasing. To meet the future demand we would need better planning and resource management as well as intensification of crop production. It is anticipated that in India in the year 2050, total food grain demand will reach 400 million tonnes" (Anonymous., 2023). "One of the alternatives to achieve this goal is to raise crop productivity through good management practices like improved varieties and the matching production technology to sustain soil fertility and crop productivity in the future. Intensive cultivation and growing exhaustive crops have made the soil deficient in macro as well as in micronutrients. These constraints have cropped-up partially as a result of continuous cropping without proper nutrient management and indiscriminate use of agrochemicals on soil and crops" (Sharma & Subehia, 2014). To mitigate all these ill effects, the possible way is through the use of only organics or integrated nutrient management either in crops or cropping system in long term. Especially the long term experiments which are offer a great unique opportunity to test the relevance of these concepts in different cropping systems. It also provides insights into the consequences of land management strategies that cannot be obtained through other means. Keeping all these in mind the present study on Productivity, profitability and soil fertility of sunflower-rabi sorghum cropping system as influenced by long term effect of organic, inorganic and integrated nutrient management practices in vertisol was initiated in 2008-09 at Organic Farming Research Institute, UAS, RAICHUR (Urkurkar et al., 2010).

2. MATERIALS AND METHODS

This long term experiment study on the "Influence of different nutrient management practices on crop yield response, economics and nutrient status of sunflower-rabi sorghum cropping system of two years rotation under rainfed condition" was carried out on permanent site at Organic Farming Research Institute, MARS, UAS, Raichur has been initiated in 2008-09 on at MARS, Raichur. The five crop rotation cycles were completed in the year 2020-21. The soil of the experimental site is medium black soil with clay texture. Experiment consisted of five treatments viz., T1: 75 % N through organics, T2: 100 % N through organics, T3: Integrated N management (50 % N through organics and 50 % N through organics), T4: 100 % N through inorganics (RDF), T5: Recommended package of practice (RPP), which were replicated four times and laid out in RCBD design. The optimum NPK i.e.,100% NPK (67-35-67 kg N-P2O5-K2O ha-1 for sunflower and 50-25-00 kg N-P2O5-K2O ha-1

for rabi sorghum) was fixed at the initiation of experiment on same layout and treatments are being followed till date. RSFH-130 and M-35-1 varieties in sunflower and sorghum, respectively were used in the experiment. In organic nutrient management practices 100% and 75% recommended dose of nitrogen (RDN) given through 1/3rd farm yard manure (FYM), 1/3rd vermicompost (VC) and 1/3rd green leaf manure (GLM), in integrated nutrient management treatment 50% RDN given through fertilizers and 50% RDN through 1/3rd FYM, 1/3rd VC and 1/3rd GLM, in inorganic nutrient management practices 100% recommended chemical fertilizers only were added and in Recommended package of practice (RPP) 100% recommended chemical fertilizers only were added with recommended Farm yard manures to the both crops.

The soil is having initial available N, P_2O_5 and K_2O were 118.71, 36.55 and 478.2 kg/ha, respectively. The organic carbon of the soil was 0.55% content. The 75% organic, 100% organic, integrated (50% organic + 50% inorganic), 100% inorganic and Recommended package of practice (RDF + FYM) strips of one acre were laid out with the sunflower – rabi sorghum cropping system. The strips were separated by the hedge rows of glyricidia and maintained by pruning at a height of one meter across the five plots of all nutrient management practices were laid out. The design followed was strip plot with five main plots and in each plots four replications were made.

These organic manures were applied based on the equivalent basis of nitrogen content and nutrient requirement of each crop. Phosphorus requirement of the crops were supplemented through rock phosphate in organic nutrient management practices. The nutrient composition of FYM, vermicompost and green leaf manure were 0.5, 1.4 and 0.5 % N, respectively. The land was ploughed, cultivated and harrowed twice to get fragile tilth and weeds were removed before sowing of the seeds. According to the treatment details organic manures were applied fifteen days before sowing of crops for both organic and integrated nutrient management plots. Basal application of entire nitrogen, phosphorus and potassium as per package of practice for sunflower and rabi sorghum crops, entire phosphorus and potassium and 50% of nitrogen was applied in the form of chemical fertilisers viz., urea, single super phosphate (SSP) and murate of potash (MoP), respectively at the time of sowing. The seeds of Sunflower with 60 cm row and 30 cm plant to plant and for rabi sorghum (45 cm x 15 cm) were sown with tractor and covered with soil as per the spacing recommended for each crop with bullock drawn implement. “To control pest and disease no chemical management practices were followed in organic nutrient management strip. Whereas, in INM strips integrated pest management (IPM) and integrated disease management (IDM) and chemicals in inorganic nutrient management plots were taken up. The crops were harvested when the crops reached physiological maturity. The cost of cultivation for each nutrient management practices and cropping systems was worked out by taking into consideration of inputs used for crop nutrition, plant protection and harvesting. The yield of crops and existing market price of the commodity were considered to work out the gross income for each nutrient management practices. Net profit in each nutrient management practices was calculated by deducting the cost of cultivation from the gross income. Soil samples were collected at the harvest of each crop at every year of LTFE. Yields were recorded separately for each five replicated plots in each block” (Sharma & Subehia, 2014). The samples were collected and were analysed for physical and chemical properties following standard procedures. The data collected from the treatmentwise from the plots and laboratory analysis were subjected to statistical analysis by adopting Fischer’s method of analysis of variance. The level of significance used in ‘F’ and ‘t’ test was P=0.05. Critical difference was calculated wherever ‘F’ test was significant.

3. RESULTS AND DISCUSSION

The OC of soil was significantly affected by nutrient management treatments. Under 100% organic nutrient management treatments, significant build up of organic carbon at the end of five cycles (0.68) (Table 1) as compared to initial values (0.55) of LTFE. “This can be ascribed to continuous use of organic manures. Organic carbon contents of soil changes rapidly with addition of organic manures. The increase of organic carbon with addition of subabul and sorghum stubbles” was also obsereved by Bellakki and Badanur (1994). On the other hand, under inorganic nutrient management practices, there was decline in organic carbon content from 0.55 % (initial value of LTFE) to 0.46 % (end of five cycles, Table 1 and Fig. 1). This might be due to use of fertilizers alone for a long period, which depletes the organic matter.

Table 1. Organic carbon content of soil as influenced by different nutrient management practices at harvest of sunflower- rabi sorghum cropping system

Treatments	Organic carbon (%)								
	2012-13 SF	2013-14 RS	2014-15 SF	2015-16 RS	2016-17 SF	2017-18 RS	2018-19 SF	2019-20 RS	2020-21 SF
T_1: 75 % Rec 'N'/P through organics	0.65	0.67	0.71	0.62	0.61	0.60	0.61	0.57	0.55
T_2: 100 % Rec 'N'/P through organics	0.65	0.67	0.72	0.60	0.63	0.65	0.67	0.68	0.68
T_3: Integrated system (50% through organics + 50 % through in organics)	0.66	0.67	0.68	0.50	0.60	0.61	0.60	0.59	0.60
T_4: RDF	0.67	0.68	0.65	0.50	0.54	0.54	0.50	0.45	0.46
T_5: RDF+ FYM (+Recommended package)	0.67	0.68	0.70	0.52	0.58	0.58	0.60	0.64	0.65
S. Em±	0.01	0.01	0.01	0.04	0.03	0.03	0.04	0.03	0.05
C. D. at 5 %	NS	NS	0.03	0.10	0.08	0.08	0.10	0.09	0.13
	Initial status: 0.55 per cent			SF: Sunflower; RS: Rabi Sorghum					

Table 2. Available nitrogen content of soil as influenced by different nutrient management practices at harvest of sunflower- rabi sorghum cropping system

Treatments	Available nitrogen (kg/ha)								
	2012-13 SF	2013-14 RS	2014-15 SF	2015-16 RS	2016-17 SF	2017-18 RS	2018-19 SF	2019-20 RS	2020-21 SF
T_1: 75 % Rec 'N'/P through organics	124.2	129.0	185.8	137.0	145.2	150.8	150.0	148.5	143.3
T_2: 100 % Rec 'N'/P through organics	120.1	130.6	191.7	140.2	153.3	160.6	163.5	162.0	164.0
T_3: Integrated system (50% through organics + 50 % through in organics)	135.1	136.8	173.4	139.0	151.6	163.1	160.2	161.3	162.5
T_4: RDF	141.0	145.2	154.1	135.3	145.0	151.0	150.6	152.8	154.2
T_5: RDF+ FYM (Recommended package)	144.7	151.2	166.8	155.4	160.9	165.8	166.2	163.7	166.3
S. Em±	5.58	5.36	4.17	3.06	2.94	4.66	4.13	3.60	3.92
C. D. at 5 %	16.58	15.65	12.18	8.10	8.52	NS	11.97	10.92	10.55
	Initial status: 118.71 kg/ha			SF: Sunflower; RS: Rabi Sorghum					

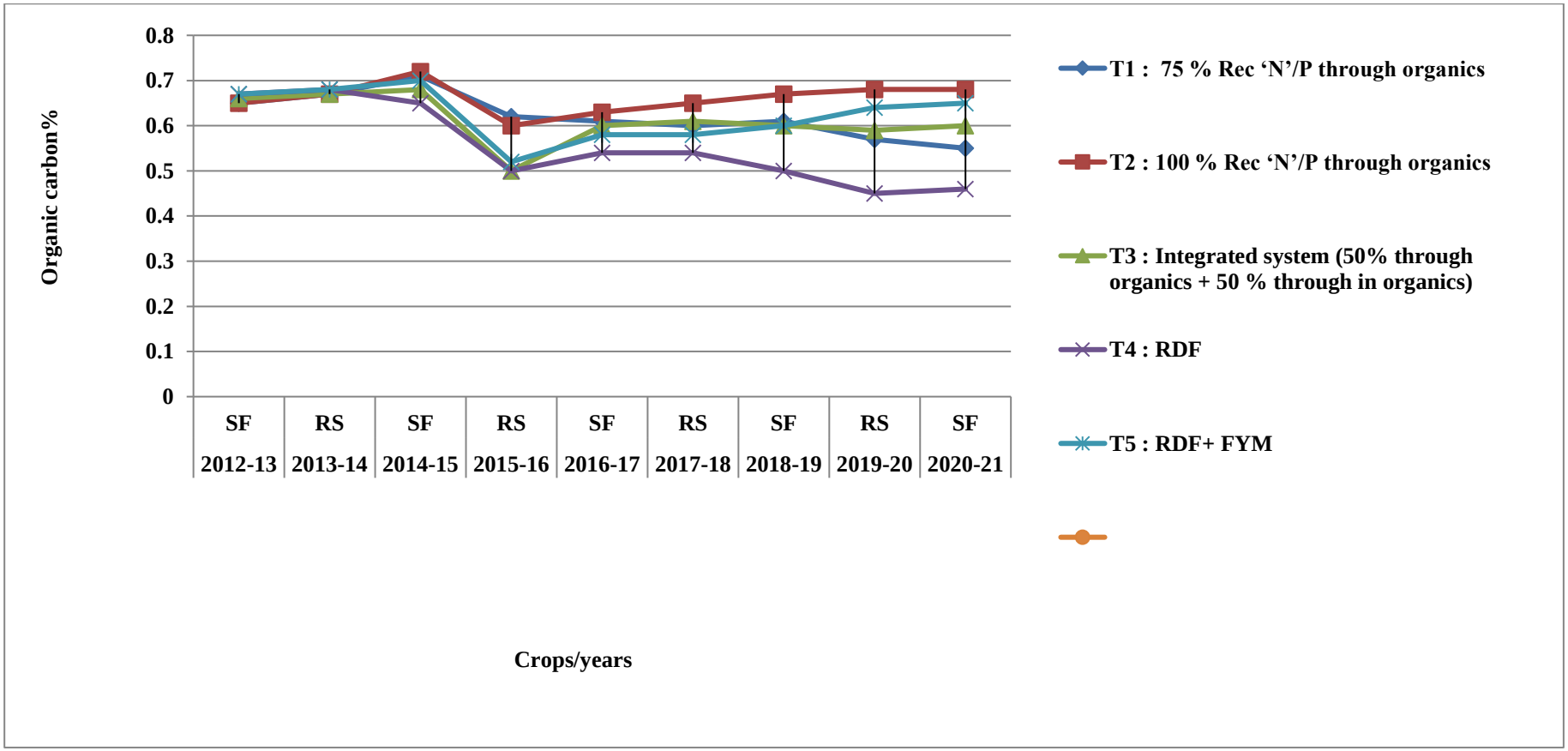

Fig. 1. Effect of different nutrient management practices at harvest on Organic carbon content of soil in sunflower- rabi sorghum cropping system

The nutrient management practices had significant effect on soil fertility status. The available N (162.5, 166.3 and 166.3 kg/ha), P2O5 (66.2, 63.1 and 67.2 kg/ha) and K2O (865.0, 805.0 and 892.0 kg/ha) showed build up in soil over the years under both organic, integrated nutrient management practices kg/ha) and RDF + FYM respectively compared to 75% organic and RDF alone (Tables 2, 3, 4) (Figs. 2, 3, 4). "The available nutrients were significantly high under these organic and integrated nutrient management practices compared to inorganic nutrient management practices, however was on par with organic nutrient management practices both at harvest of sunflower and rabi sorghum. Whereas, under inorganic nutrient management practices there was declining trend of available nutrient and at the end of fifth cycle" (Sharma & Subehia, 2014).

"The organic matter in soil affects soil fertility and the C and N mineralization capacities of the soil, which determines the availability of plant nutrients. Thus, soil productivity decreases as soil organic matter content decreases. Continuous application throughout the solubilising action of certain organic acids produced during FYM decomposition and its greater capacity to hold K in the available form. This improvement in soil fertility was attributed to addition of FYM and other organics which enhance the growth and activity of microorganisms. They also involve in the biological cycling of elements and transformation of the mineral compounds and thus increases the availability of nutrients in soil" was reported by Vidyavathi et al., (2011).

"Inclusion of organic manures in organic agriculture is beneficial, as these improve the soil fertility and crop productivity. Inclusion of organic sources has more advantage. The benefit of including organic sources in nutrient management improves soil fertility status" was reported by Jawale, et al., (1998) and Das et al. (2010). "This indicated that addition of organic and slow release of nutrients from the organics. Whereas, under inorganic nutrient management treatments, nutrient status after fourth year of LTFE was drastically reduced as compared to the nutrient status at the end of fifth year of LTFE and at initial LTFE. This is attributed that exhausting nature of the crop and lack of nutrient source for their replenishment in the soil. Integrated nutrient management treatment recorded significantly higher uptake of all major nutrient N, P and K both crops when compared to inorganic and organic nutrient management practices. The response of crops to integrated nutrient management is due to higher availability of these nutrients in soil reservoir besides the additional quantity of nutrients supplied by FYM and inorganic fertilizers. This was credited to continuous supply of N, P and K throughout the crop growth periods as the nutrients from inorganic sources were available to the crop in the early stages and in the later stages of the crop growth, the slow and continuous release of nutrients from the organic source made available Therefore creating a reservoir of soil nutrients for several years after application, use of FYM, Vermicompost and GLM attribute to the mineralization of N in soil and due to high enzyme activities in the soil amended with organic manures will increase the transformation of nutrients to available form. Similarly, the P availability in soil increased due to use of organics. During decomposition of organic manure, various organic acids will be produced which solubilise phosphatase and other phosphate bearing minerals and thereby lowers the phosphate fixation and increase its availability. available phosphorus content increased due to addition of FYM over initial and control. The build up of soil available K due to green manuring or FYM application is due to addition of K applied reported that, uptake of N, P and K was increased with full dose of NPK + 10 t FYM compared to control" was also reported by the scientists Manna et al. (2006).

Application of FYM along with N and P fertilizers resulted in the highest total uptake of N, P and K by soybean which was due to higher availability of these nutrients in soil reservoir besides the additional quantity of nutrients supplied by FYM. Basavaraju (2007) revealed that "the crop removal of N, P and K was highest when organic manures (FYM, vermicompost, crop residues and green manuring) and inorganic fertilizers applied in equal proportion to supply the recommended level of N (150 kg/ha) to maize".

This was ascribed to continuous supply of N, P and K throughout the crop growth period as the nutrient from inorganic sources were available to the crop in the early stages and in the later stages of the crop growth, the slow and continuous release of nutrients from the organic source made available.

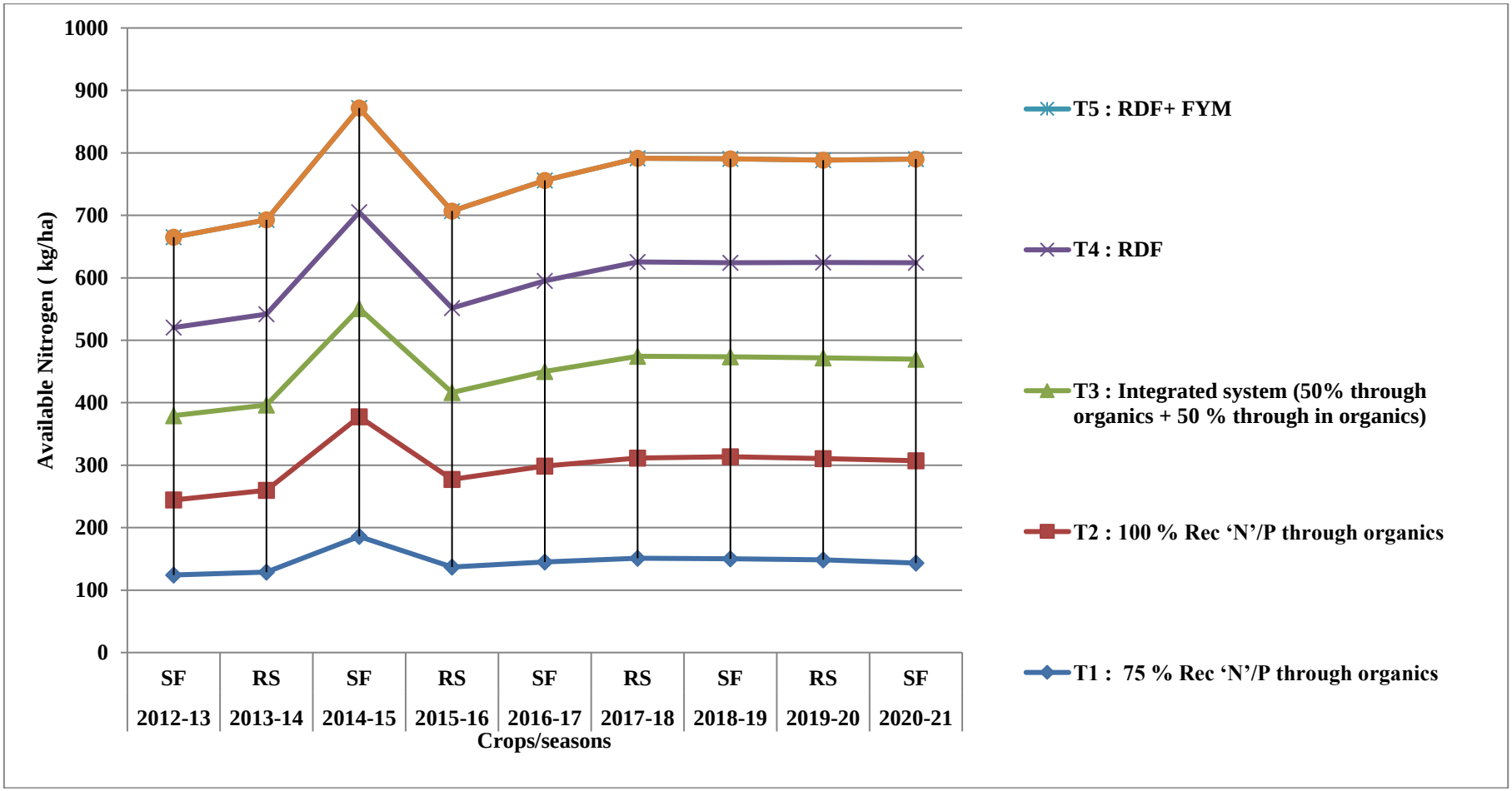

Fig. 2. Effect of different nutrient management practices at harvest on Available Nitrogen content of soil in sunflower- rabi sorghum cropping system

Table 3. Available Phosphorus content of soil as influenced by different nutrient management practices at harvest of sunflower- rabi sorghum cropping system

Treatments	Available phosphorus as P_2O_5 (kg/ha)								
	2012-13 SF	2013-14 RS	2014-15 SF	2015-16 RS	2016-17 SF	2017-18 RS	2018-19 SF	2019-20 RS	2020-21 SF
T_1: 75 % Rec 'N'/P through organics	43.8	47.9	58.3	33.5	40.3	52.2	56.3	55.0	51.3
T_2: 100 % Rec 'N'/P through organics	39.6	43.3	62.7	47.5	44.3	62.6	66.2	67.0	66.2
T_3: Integrated system (50% through organics + 50 % through in organics)	46.6	51.1	63.9	48.0	43.7	55.1	60.7	62.3	63.1
T_4: RDF	48.3	52.2	55.5	46.1	30.3	45.8	47.0	45.6	48.5
T_5: RDF+ FYM (+Recommended package)	53.3	56.9	64.4	67.4	55.5	72.4	79.0	70.0	67.2
S. Em±	2.32	2.27	2.18	9.8	3.7	2.84	4.90	4.3	5.9
C. D. at 5 %				30.3	11.4	8.75	13.72	12.2	15.9
	Initial status: 36.55 kg/ha		SF: Sunflower; RS: Rabi Sorghum						

Table 4. Available Potassium content of soil as influenced by different nutrient management practices at harvest of sunflower- rabi sorghum cropping system

Treatments	Available potassium as K_2O (kg/ha)								
	2012-13 SF	2013-14 RS	2014-15 SF	2015-16 RS	2016-17 SF	2017-18 RS	2018-19 SF	2019-20 RS	2020-21 SF
T_1: 75 % Rec 'N'/P through organics	495.1	506.1	519.6	607.9	751.0	788.9	790.2	780.0	785.0
T_2: 100 % Rec 'N'/P through organics	485.1	496.1	523.8	615.1	752.8	800.7	835.0	853.0	865.0
T_3: Integrated system (50% through organics + 50 % through in organics)	498.3	511.9	535.3	620.9	708.6	757.6	780.6	792.0	805.0
T_4: RDF	512.5	524.3	539.6	616.5	727.7	740.0	760.2	767.0	775.0
T_5: RDF+ FYM (+Recommended package)	545.9	550.0	569.2	673.9	761.6	809.1	845.3	875.0	892.0
S. Em±	13.59	10.99	10.83	7.74	22.4	32.9	30.3	37.6	39.2
C. D. at 5 %				23.8	NS	NS	NS	NS	NS
	Initial status: 478.2 kg/ha		SF: Sunflower; RS: Rabi Sorghum						

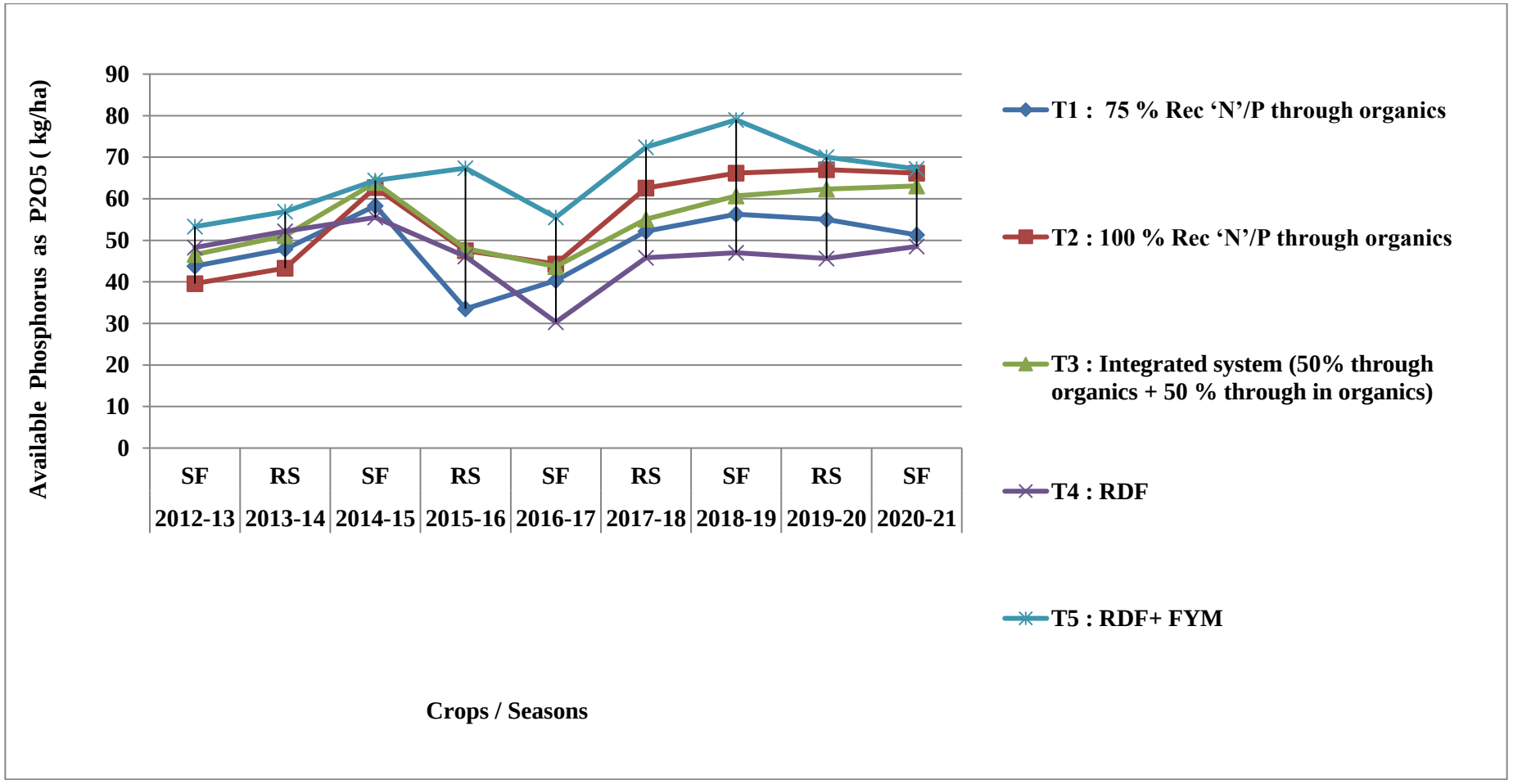

Fig. 3. Effect of different nutrient management practices at harvest on Available Phosphorus content of soil in sunflower- rabi sorghum cropping system

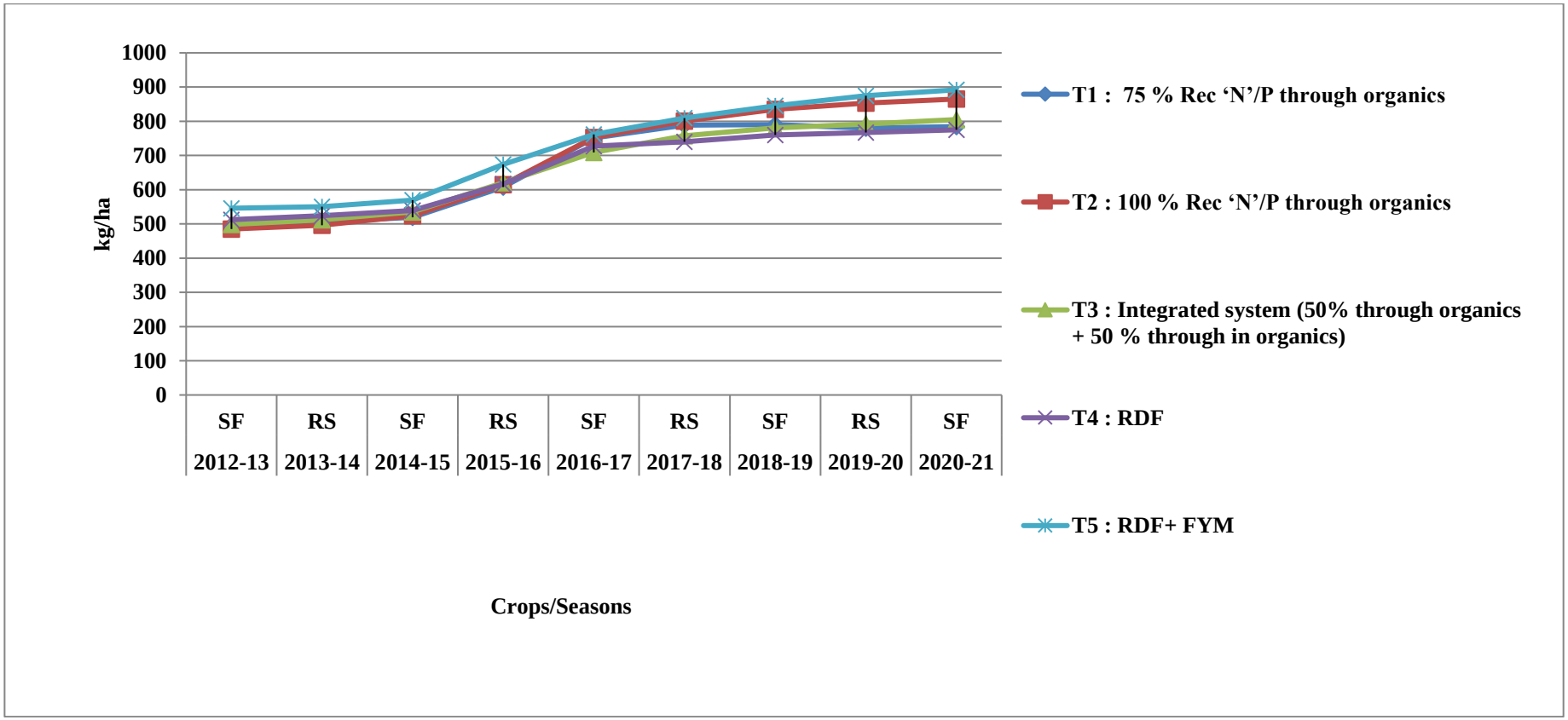

Fig. 4. Effect of different nutrient management practices at harvest on Available Potassium content of soil in sunflower- rabi sorghum cropping system

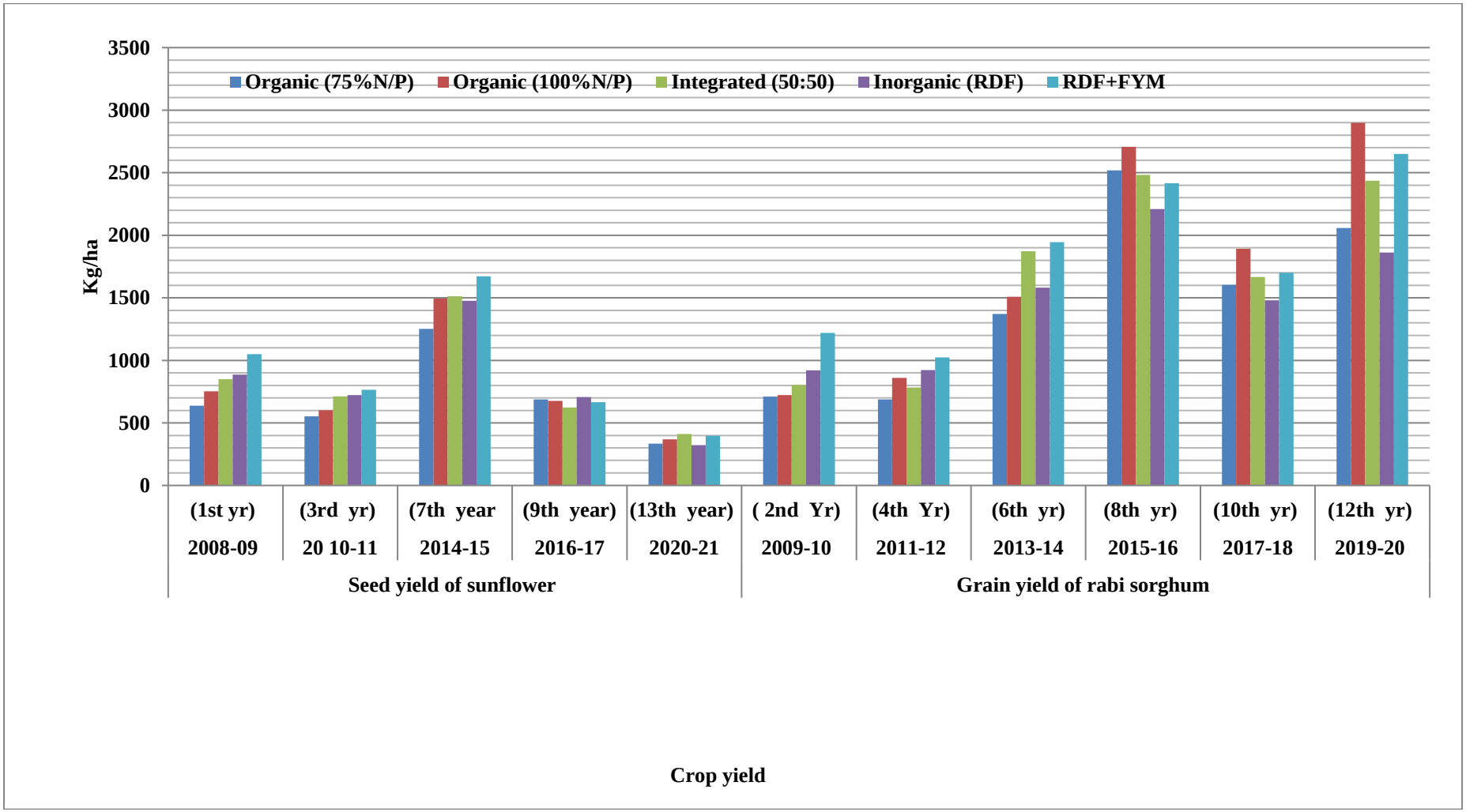

Fig. 5. Effect of different nutrient management practices at harvest on yield and economics in sunflower- rabi sorghum cropping system

Table 5. Effect of different nutrient management practices on yield and economics of sunflower - *rabi* sorghum cropping system

Treatments	Seed yield of sunflower (kg/ha)					Grain yield of rabi sorghum (kg/ha)						Economics (Pooled)		
	2008-09 (1st yr)	2010-11 (3rd yr)	2014-15 (7th yr)	2016-17 (9th yr)	2020-21 (13th yr)	2009-10 (2nd yr)	2011-12 (4th yr)	2013-14 (6th yr)	2015-16 (8th yr)	2017-18 (10th yr)	2019-20 (12th yr)	Gross returns Rs./ha	Net returns Rs./ha	B:C
Organic (75%N/P)	637	553	1252	687	335	710	688	1370	2518	1603	2058	40876	26162	2.42
Organic (100%N/P)	752	602	1494	676	368	723	860	1508	2706	1892	2898	49984	33734	2.62
Integrated (50:50)	850	712	1513	623	411	803	782	1873	2483	1665	2435	35227	22305	2.43
Inorganic (RDF)	885	723	1476	706	321	920	923	1581	2210	1480	1863	36604	24316	2.65
RDF+FYM	1050	764	1672	666	398	1220	1024	1945	2416	1700	2650	41658	27753	2.74
S.Em. ±	42	42	75	34	21	56	50	127	96	74	165	-	-	-
C.D.at 5%	130	128	231	NS	45	172	156	392	290	228	509	-	-	-

The yield data recorded with sunflower crop after 3rd cycle showed that treatments of integrated system, organic system and recommended package were on par with each other (368, 411 and 398 kg/ha) and superior over inorganic package (321 kg/ha) with respect to seed yields and net returns (24316 Rs/ha). Whereas in sorghum after 4th cycle treatments of organic system, integrated system and recommended package were on par with each other with respect to yield (2898, 2435 and 2650 kg/ha) and superior over inorganic package with respect to seed yields (1863 kg/ha) and net returns (24316 Rs/ha) (Table 5). These results are in conformity with the findings of Soumya et al. (2025) and Sharma & Subehia (2014) and Mirza et al. (2024).This is attributed that higher yield of the crops in integrated, organic and RDF + FYM nutrient management practices in both sunflower and. Whereas, lower yield of crops in 100% inorganic and 75% organic nutrient management practices might have resulted in significantly increase in net returns and benefit cost ratio, which is be due to higher gross returns and lower cost of cultivation of and higher market price under organic nutrient management practices (Fig. 4).

4. CONCLUSION

Sunflower crop after 3rd cycle and sorghum after 4th cycle showed that treatments of integrated system, organic system and recommended package were on par with each other and superior over inorganic package with respect to seed yields and net returns. The soil fertility status (OC %) and (Available amajor nutrients viz., N, P_2O_5 and K_2O kg/ha) and economics were also improved substantially with organic and integrated management practices.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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