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The Effect of Site Specific Nutrient Management (SSNM) on Sunflower Production

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Authors' contributions

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

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ABSTRACT

A field experiment was conducted during *Kharif* and *Rabi* seasons of 2017-18 to 2021-22 at Regional Agricultural Research station Nandyal to study the SSNM effect on yield system economics of sunflower based emerging cropping systems and soil nutrient status. Maize-sunflower cropping system recorded significantly higher sunflower equivalent yield which is on par with Soybean- sunflower cropping system. Gross and net returns were highest with maize – sunflower cropping system with 100% STCR fertilizer dose followed by Soybean - sunflower cropping system with 100% STCR fertilizer dose. Minimum returns were obtained when Sunflower - chickpea cropping system with 50% STCR adopted. Under ID condition cultivation of maize – sunflower cropping system with 100% STCR fertilizer dose to *rabi* sunflower showing effect on

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productivity and profitability of cropping system instead of sunflower- chickpea cropping system with RDF. Initial and final soil available nitrogen, phosphorous and potassium nutrients status was estimated in all rabi crop seasons of investigation which shown significant effect due to cropping systems and fertilizer doses.

Keywords: Cropping systems; LUE; net returns; STCR equation; SSNM sunflower equivalent yields; soil available NPK.

1. INTRODUCTION

Sunflower is an introduced oilseed crop which has made much impact and is gaining more importance in recent years. In India, it is cultivated over an area of 4.7 lakh hectares producing 4.3 lakh tons with a productivity of 697 kg ha^{-1} [1]. The major states that grow sunflower include are Karnataka, Andhra Pradesh, Maharashtra and Tamil Nadu. Globally it is cultivated on 250 lakh hectares with a production of 340 lakh tons having the productivity of 1391 kg ha-1 [2] World major sunflower production comes from Ukraine, Russia, European Union, Argentina and china. Sunflower is a drought tolerant crop due to its deep tap root, which makes it the best substitute for all rain fed crops Patil et al. [3].

Sunflower (*Helianthes annus L.*) is generally considered as a"premium oil" because of its light colour and high level of unsaturated fatty acids and have high value. Normally farmers of Andhra Pradesh in Indi will follow, sunflower- chickpea oil seed cropping system under medium deep black soils. In recent years new emerging crops like Bt. cotton, Maize and soybean were introduced in sunflower based cropping systems for cultivation due to high monitoring benefits. More over farmers usually follow blanket application of fertilizer doses (RDF) which leads to low yields and decreasing of soil nutrient status. Oilseed based cropping systems have high nutrient demands and require integrated nutrient management. The response of annual oilseeds crops to major, secondary and micronutrients is significant, emphasizing the need for ensuring adequate nutrient supply to oilseeds [4].

As the production potential of sunflower crop is much higher than the present average on the farmers' field, there is a scope to increase the production by matching with balanced nutrition through soil testing and crop demand. Site Specific Nutrient Management (SSNM) is a "repackaging" of strategies which includes site and season specific knowledge of crop nutrients requirements and indigenous nutrient supplies and are required to increase productivity, yields and nutrient use efficiency in different cropping systems with a target yield approach. SSNM improved the seed and oil yields of sunflower and increased the profitability with conservation of soil fertility in sunflower cropping system in alfisols [5]. Application of soil test value based NPK along with limiting micronutrient, boron and FYM 5 t/ha along with *Trichoderma vidride* has recorded significantly higher seed yield 2376 kg/ha [6]. Under this background present study was under taken to know the impact of SSNM on sunflower equivalent yield, net returns and effect on soil available NPK status.

2. MATERIALS AND METHODS

Field experiments were carried out for six consecutive *kharif* and *rabi* seasons of 2017-18 to 2021-22 at R.A.R.S. Farm, Nandyal, Andhra Pradesh. The treatments comprised of four emerging cropping systems *viz.,* Cotton-Sunflower, (CS_1) Maize- Sunflower (CS_2) Soybean-Sunflower (CS_3) and Sunflower-Chickpea (CS_3) as main plot treatments and three fertilizer doses *viz.* Recommended dose of fertiliser (F_1), 100% STCR (F_2), and 50% STCR (F_3) as sub plot treatments. During *kharif* season, Cotton, Maize, Soybean and Sunflower crops were raised as bulk crops and applied recommended dose of fertilizer dose to each crop in respective main plots. Experimental design was RBD for *kharif* season and split- plot, for rabi season with three replications.

The site was situated at an altitude of 216 m above mean sea level at 15°29'19'' N latitude and 78° 29'11'' E longitude, mostly under rainfed conditions, categorized in the Scarce rainfall Agro-climatic Zone of Andhra Pradesh. Soil of the site was medium in fertility and slightly saline in reaction having pH 8.42, electrical conductivity 0.24 dSm^{-1}, organic carbon 0.32% with available nitrogen, phosphorus and potassium of N, 143, 53 and 451 kg/ha, respectively. During *kharif* season, Cotton, Maize, Soybean and Sunflower crops were raised as bulk crops under rainfed condition in the month of 2nd FN of July in every

year duly following the recommended package of practices. After harvest of *kharif* crops soil samples were collected in each plot and analysed the available NPK status. *Rabi* crops viz. sunflower and chickpea were sown. Sowing of sunflower seeds was done in rows, 60 cm apart with 30 cm between plants and chickpea was done in rows, 30 cm apart with 10 cm between plants. Healthy and matured seeds NDSH-1012 sunflower hybrid variety and JG-11 chickpea desi variety having high germination percentage were used for sowing. Seed rate @ 5 kg ha^{-1} of sunflower and 50 kg ha^{-1} of chickpea was adopted and sown in the open furrows made with the help of hand hoe. The seeds were dropped to a depth of 5 cm and covered thoroughly. *Kharif* and *rabi* equivalent yields, system economics and soil available nutrients status were estimated based on standard procedures.

2.1 Calculation of STCR Fertilizer Doses

Soil samples were collected in all treatments after harvesting of kharif crops and estimated soil available nitrogen, phosphorous and potassium content by following standard procedures and calculated STCR fertilizer dose by using the following equations.

for Sunflower	Chickpea
N=8.23 T-0.46 SN	N= 5.03T-0.27 SN
P= 8.91 T – 4.24 SP	P= 9.71T-1.82 SP
K= 3.08 T – 0.10 SK	K= 6.23T-0.22 SK

T: Target yield: (25 qt/ha), SN: soil available nitrogen, SP: soil available phosphorous, SK: soil potassium

2.2 Equivalent Yields and Economics

The seed yield of the *kharif* and *rabi* crops was converted in to sunflower equivalents on the basis of price of seed of crops involved in the cropping system.

The total cost of cultivation of double cropping system (ha^{-1}) was calculated for each treatment on the basis of input cost of both the seasons. Gross returns (ha^{-1}) was computed by considering the prevailing market price of the outputs. Net return (ha^{-1}) were arrived by deducting the cost of cultivation from gross returns of corresponding cropping system. Cost benefit ratio was worked out for each system to study the SSNM effect on yield system economics of sunflower based emerging cropping systems and soil nutrient status.

2.3 Soil Initial and Final Nutrient Status

The soil samples were air dried under shade pounded with mortar and pestle and passed through 2.0 mm sieve and were analysed for nutrient status by adopting standard procedures. The available nitrogen was determined by alkaline permanganate method outlined by Subbaih and Asija [7] and the results are expressed in kg ha^{-1}. The available phosphorus content of soils was extracted by using Olsen's extractant as described by Olsen et al. [8] and phosphorus in the extract was determined by Murphy and Riley method (using ascorbic acid as a reducing agent) using spectrophotometer (Jasco V-530 UV/ Visible spectrophotometer) at 660 nm wavelength. Available potassium in the soils was extracted by neutral normal ammonium acetate and determined by using the flame photometer [9].

3. RESULTS AND DISCUSSION

3.1 *Kharif* Crops Growth, Yield Attributes and Yields under Cropping Systems

Observations on days to reach different phenophases, initial and final plant population and plant height and yield attributes of cotton, maize , soybean and sunflower crop were recorded and predicted in Tables (1 and 2). Mean data showed normal trend with RDF and lower incidence of pest and disease incidence during crop growth period except sunflower. Sunflower equivalent yields were significantly higher with maize crop which is on par with cotton and soybean equivalent yields. Kharif sunflower seed yields were significantly lower among four crops tested where severe incidence of alternaria and powdery mildew incidence was observed at the time of reproductive phase due to heavy and contiguous rains during the month of September in all *kharif* seasons. tested.

3.2 *Rabi* Crops Growth and Yield Attributes under Cropping Systems and Fertilizer Doses

Observations on days to reach different phenophases, initial and final plant population and plant height and yield attributes of sunflower and chickpea crops under three fertilizer doses were recorded in Tables 1 and 2 and results indicated that application of 100% STCR fertilizer dose has resulted higher values followed by RDF application in both sunflower and chickpea crops

Table 1. Days to reach different phenophases, initial and final plant population and plant height of different crops under different cropping systems and fertiliser doses

Cropping system	***Kharif* Cotton**		***Rabi* Sunflower**		
CS1: Cotton-Sunflower	***F1 (RDF)***	***F1 (RDF)***	***F2 (STCR)***	***F3 (50%STCR)***	**Mean**
Days for field emergence	*6*	*6*	*6*	*6*	6
Initial plant population (L/ha)	0.49	0.53	0.53	0.53	0.53
Final plant population (L/ha)	0.49	0.52	0.51	0.50	0.51
Days to 50 %flowering	62	52	52	52	52
Plant height at harvest	143	168	171	155	165
Days to maturity	210	95	95	95	95
CS2: Maize-Sunflower	***Kharif* Maize**		***Rabi* Sunflower**		
Days for field emergence	5	6	6	6	6
Initial plant population (L/ha)	0.83	0.53	0.53	0.53	0.53
Final plant population (L/ha)	0.82	0.51	0.52	0.50	0.51
Days to 50 %flowering	55	52	52	52	52
Plant height at harvest	198	165	170	158	164
Days to maturity	110	95	95	95	95
CS3: Soybean-Sunflower	***Kharif* Soybean**		***Rabi* Sunflower**		
Days for field emergence	6	*6*	*6*	*6*	6
Initial plant population (L/ha)	3.33	0.53	0.53	0.53	0.53
Final plant population (L/ha)	3.20	0.52	0.51	0.50	0.51
Days to 50 %flowering	36	52	52	52	52
Plant height at harvest	73	168	171	155	165
Days to maturity	100	95	95	95	95
CS4: Sunflower-Chickpea	***Kharif* Sunflower**		***Rabi* Sunflower**		
Days for field emergence	*6*	6	6	6	6
Initial plant population (L/ha)	0.53	3.33	3.33	3.33	3.33
Final plant population (L/ha)	0.51	3.10	3.13	3.16	3.13
Days to 50 %flowering	53	39	38	40	39
Plant height at harvest	163	46.9	45.2	48.4	46.8
Days to maturity	98	100	100	100	100

tested under four cropping systems tested. However 50% STCR fertilizer dose application recorded lower values of growth and yield attributes in both rabi crops tested under four cropping systems.

3.3 *Rabi* Crops Sunflower Equivalent Yields under Cropping Systems and Fertilizer Doses

Sunflower equivalent yields of *rabi* crops were shown in Table 4 which indicated significant influence due to cropping systems and fertilizer doses tested but interaction effect was not significant in both levels. Among cropping systems, soybean- sunflower cropping system recorded significantly higher sunflower equivalent yields followed by maize-sunflower cropping system and both are on par. Significantly lower sunflower equivalent yields were recorded with cotton- sunflower and sunflower- chickpea cropping systems. Higher yields in soybean-sunflower and maize- sunflower cropping systems may be due to sowing of sunflower in month of 1st FN of November which facilitated the crop to grow in favourable environment as the soybean and maize crops were medium duration crops in contrary cotton crop was long duration crop and rabi sunflower was sown in the month of 1st FN of January. Lower sunflower equivalent yields in sunflower- chickpea cropping systems may be due to lower market price compared with sunflower crop.

Among fertilizer doses 100% STCR treatment recorded significantly higher sunflower equivalent yields followed by RDF treatment. Significantly lower sunflower equivalent yields were recorded when 50% STCR doses were applied to rabi crops.

The balanced application of NPK may positive effect on crop growth and seed yield. Similar results were reported by Debina sanasam et al. [6] that application of soil test value based NPK along with limiting micronutrient, boron and FYM 5 t/ha along with Trichoderma vidride has recorded significantly higher seed yield.

3.4 Cropping System Equivalent Yields and Economics

System productivity was estimated by converting kharif crop yields and rabi crop yields were converted to sunflower equivalent yields and presented in Table 6 and outline indicates that maize – sunflower cropping system with 100% STCR fertilizer dose recorded higher sunflower equivalent yields, followed by Soybean - sunflower

cropping system with 100% STCR fertilizer dose. Sunflower - chickpea cropping system with 50% STCR fertilizer dose recorded lower values of sunflower equivalent yields.

Table 2. Yield attributes in *Kharif* crops under different cropping systems

Cropping system	***Kharif* cotton**			
CS1: Cotton-Sunflower	***F1***	***F1***	***F1***	**Mean**
No. of sympodial branches	*23*	*22*	*25*	23.3
No. of monopodial branches	1	1	2	1.6
No. of bolls	24	26	21	23.6
Boll weight (g)	3.8	3.6	3.9	3.7
CS2: Maize-Sunflower	***Kharif* Maize**			
Cob number per m2	8	7.8	7.9	7.9
Cob length (cm)	17.3	16.5	19.3	17.7
No. of kernals rows per cob	14.3	16.1	15.8	15.4
Seed number per cob	296	301	274	290.3
Test weight	327.4	301.8	291.5	306.9
CS3: Soybean-Sunflower	***Kharif* Soybean**			
No. of pods per plant	38	31	27	32
Length of pod (cm)	3.81	3.92	2.79	3.51
Seed per plant	1.78	1.88	1.95	1.87
1000 seed weight (g)	65.7	68.3	62.2	65.4
CS4: Sunflower - Chickpea	***Kharif* Sunflower**			
Head diameter	12.5	14.6	14.1	13.7
No. of grains/ head	258	301	179	246
Seed weight (g/head)	22.3	21.5	20.9	21.6
Test weight (g/100 seeds)	4.19	4.25	4.17	4.20

Table 3. Yield attributes in *Rabi* crops under different cropping systems and fertilizer doses

Cropping system	***Rabi* Sunflower**			
CS1: Cotton-Sunflower	***F1(RDF)***	***F2 (STCR)***	***F3 (50%STCR)***	**Mean**
Head diameter	*12.8*	*13.5*	*10.6*	12.3
No. of grains/ head	356	512	259	375
Seed weight (g/head)	27.2	34.1	20.4	27.2
Test weight (g/100 seeds)	4.8	5.1	4.7	4.8
Volume weight (g/100 ml)	33.5	38.3	33.7	35.2
CS2: Maize-Sunflower	***Rabi* Sunflower**			
Head diameter	15.3	16.8	14.1	15.4
No. of grains/ head	638	712	506	619
Seed weight (g/head)	37.2	40.3	30.4	35.9
Test weight (g/100 seeds)	5.1	5.1	4.8	5.0
Volume weight (g/100 ml)	39.4	40.1	37.3	38.9
CS3: Soybean-Sunflower	***Rabi* Sunflower**			
Head diameter	15.6	17.1	14.6	15.7
No. of grains/ head	649	752	517	639
Seed weight (g/head)	37.8	41.5	31.1	36.8
Test weight (g/100 seeds)	5.1	5.2	4.9	5.1
Volume weight (g/100 ml)	38.7	41.3	38.5	39.5
CS4: Sunflower- Chickpea	***Rabi* chickpea**			
No.of branches/plant	8.7	8.5	6.8	8.0
No. of pods/plant	29.4	35.5	29.2	31.3
Seed yield (g/plant)	8.2	8.7	7.8	8.2
Test weight (g/100 seeds)	31.5	32.0	30.9	31.4

Table 4. *Kharif* crop seed yield and sunflower equivalent yield under different cropping systems

Cropping system	***Kharif* crop**	**Seed yield (kg/ha)**	**Sunflower equivalent yield (kg/ha)**
Cotton- Sunflower	Cotton	1253	1526
Maize- Sunflower	Maize	4876	1787
Soybean- Sunflower	Soybean	1540	1257
Sunflower- Chickpea	Sunflower	653	653
S E m +			**111**
C D			**323**
CV (%)			**11.5**

Table 5. Yield of *Rabi* crop (Sunflower equivalent yield (Kg/ha) under different cropping systems and fertiliser levels

Cropping systems	Fertiliser dose			Mean
	F1 (RDF)	100 % STCR	50 % STCR	
CS1: Cotton-Sunflower	812	1224	421	**819**
CS2: Maize-Sunflower	1746	2431	1329	**1835**
CS3: Soybean-Sunflower	2062	2395	1481	**1979**
CS4: Sunflower- Chickpea	780	1029	692	**833**
Mean	**1350**	**1769**	**980**	
	SEm	CD (P=0.05)	CV	
Main	71	212	10.5	
Sub	39	117	12.2	
M x S	142	NS	14.0	

Cropping system cost of cultivation, gross and net returns and benefit cost ratio was calculated for all treatments and presented in Table 6. Gross and net returns were highest with maize – sunflower cropping system with 100% STCR fertilizer dose followed by Soybean - sunflower cropping system with 100% STCR fertilizer dose. Minimum returns were obtained when Sunflower - chickpea cropping system with 50% STCR adopted. Under ID condition cultivation of maize – sunflower cropping system with 100% STCR fertilizer dose to *rabi* sunflower showing effect on productivity and profitability of cropping system instead of sunflower-chickpea cropping system with RDF. The same line of results was reported by Amgain et al. [10].

3.5 Soil Available Nutrient Status

Initial and final soil available nitrogen, phosphorous and potassium nutrients status was estimated in all rabi crop seasons of investigation and presented in Tables 8, 9 and 10 which shown significant effect due to cropping systems and fertilizer doses.

Soil available nitrogen content was significantly increased (Fig. 1), with sunflower- chickpea cropping system followed by soybean- sunflower cropping system after two years of experimentation. However after six years of experimentation soil available nitrogen content was maintained without depletion. Available nitrogen content was significantly improved from third year onwards with adoption of 100% STCR fertilser dose followed by RDF application. However soil available nitrogen content was significantly decreased due to application of 50% STCR fertilizer dose [11].

Soil available phosphorous content values were not significantly differing with cropping systems but available status was little improvement was observed. However fertilizer doses were significantly differ from third year onwards and significantly higher values were recorded with application of RDF treatment field [12].

Table 6. Sunflower equivalent yields and system economics influenced by sunflower based emerging cropping systems

Cropping system	Sunflower equivalent yield of the system (kg/ha)	System economics (Rs/ha)			Benefit cost ratio
		Cost of cultivation	Gross returns	Net returns	
CS1: Cotton-Sunflower with RDF	2338	86769	140280	53511	1.62
CS1: Cotton-Sunflower with 100% STCR	2750	89653	165000	75347	1.84
CS1: Cotton-Sunflower with 50% STCR	1947	82781	116820	34039	1.41
CS2: Maize-Sunflower with RDF	3533	75777	211980	136203	2.80
CS2: Maize-Sunflower with 100% STCR	4218	78659	253080	174421	3.22
CS2: Maize-Sunflower with 50% STCR	3116	72540	186960	114420	2.58
CS3: Soybean-Sunflower with RDF	3319	64667	199140	134473	3.08
CS3: Soybean-Sunflower with 100% STCR	3652	69276	219120	149844	3.16
CS3: Soybean-Sunflower with 50% STCR	2738	61855	164280	102425	2.66
CS4: Sunflower- Chickpea with RDF	1433	61874	85980	24106	1.39
CS4: Sunflower- Chickpea with 100% STCR	1682	64182	100920	36738	1.57
CS4: Sunflower- Chickpea with 50% STCR	1345	58109	80700	22591	1.39

Market Price: Cotton- Rs.74/-, Maize- Rs. 22/-, Soybean- Rs. 49/-, Sunflower - Rs.60/- Chickpea - Rs. 40/--, per Kg

Table 7. Fertilizer doses (NPK kg/ha) applied for *rabi* Sunflower/chickpea from 2017-18 to 2022-23

Year	Cotton-Sunflower			Maize-Sunflower			Soybean-Sunflower			Sunflower-Chickpea		
	F1 (RDF)	*F2 (STCR)*	*F3 (50% STCR)*	*F1 (RDF)*	*F2 (STCR)*	*F3 (50% STCR)*	*F1 (RDF)*	*F2 (STCR)*	*F3 (50% STCR)*	*F1 (RDF)*	*F2 (STCR)*	*F3 (50% STCR)*
2017-18	75-90-30	146.6-55.7-37.6	72.8-32.5-18.4	75-90-30	146.9-59.9-37.3	73.4-34.6-19.1	75-90-30	144.2-66.7-36.9-	72.6-32.3-19.1	20-50-0	35.3-68.4-85.6	17.4-35.8-44.6
2018-19	75-90-30	146.3-55.2-36.8	73.4-31.0-18.8	75-90-30	142.2-58.7-36.8	71.1-33.4-19.7	75-90-30	141.0-66.2-36.9	70.51-30.6-18.4	20-50-0	37.5-69..3 -88.1	17.2-35.1-42.6
2019-20	75-90-30	145.7-52.3-36.5	74.0-29.7-19.1	75-90-30	141.8-55.3-36.1	73.0-39.7-19.8	75-90-30	141.1-59.9-36.4	73.2-34.8-19.4	20-50-0	38.4-72.1-92.1	17.6-35.0-41.9
2020-21	75-90-30	142.6-54.5-35.9	73.4-29.3-19.5	75-90-30	140.6-54.8-35.7	72.8-39.1-19.6	75-90-30	139.0-61.2-35.2	72.9-35.2-19.7	20-50-0	38.5-74.8-93.35	18.5-34.4-42.0
2021-22	75-90-30	140.6-49.3-35.9	72.9-28.2-19.7	75-90-30	141.5-52.3-35.4	72.8-34.8-19.9	75-90-30	138.5-52.3-35.4	72.8-32.7-19.8	20-50-0	39.0-79.1-96.0	18.7-35.8-42.1
2022-23	75-90-30	138.2-48.4-35.4	71.9-28.1-19.6	75-90-30	140.1-48.5-35.2	72.0-31.9-19.9	75-90-30	136.5-49.8-35.1	68.2-31.0-19.9	20-50-0	41.5-79.5-93.81	18.0-35.7-41.8

Table 8. Soil available Nitrogen status (kg/ha) as influenced by different cropping systems and fertilizer doses during 2017-18 to 2022-23

	2017-18		2018-19		2019-20		2020-21		2021-22		2022-23	
Cropping systems	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
CS1: Cotton-Sunflower	128.8	130.4	129.5	136.4	133.8	139.5	132.9	139.9	137.1	145.2	141.2	142.6
CS2: Maize-Sunflower	129.5	130.9	133.6	136.8	134.9	139.2	136.9	139.3	135.6	147.3	138.8	142.4
CS3: Soybean-Sunflower	131.1	135.8	134.3	138.4	158.7	140.0	158.6	146.9	169.9	148.6	164.6	151.7
CS4: Sunflower- Chickpea	129.9	132.8	134.1	140.1	133.9	156.1	133.5	164.4	140.7	170.3	142.7	176.8
S E m +	2.9	6.7	3.8	5.4	4.1	3.9	3.6	4.7	5.8	3.1	3.6	4.3
C D	NS	NS	NS	NS	12.1	11.7	10.7	10.8	17.4	9.4	10.8	12.9
Fertiliser levels												
100% RDF	129.2	134.7	134.6	139.0	135.4	142.0	137.8	141.6	139.3	149.7	142.5	148.2
100% STCR	130.2	134.1	136.8	143.1	138.0	145.4	141.6	149.5	143.0	156.5	148.1	157.2
50% STCR	130.1	123.6	117.3	121.8	120.8	116.2	111.6	126.8	122.7	121.9	120.0	118.3
S E m +	1.7	1.4	2.2	3.0	2.8	3.6	2.1	2.9	2.1	1.6	2.0	2.1
C D	NS	4.2	6.6	9.0	8.3	10.7	6.2	8.7	6.4	4.8	5.8	6.2

Table 9. Soil available Phosporous status (kg/ha) as influenced by different cropping systems and fertilizer doses during 2017-18 to 2022-23

	2017-18		2018-19		2019-20		2020-21		2021-22		2022-23	
Cropping systems	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
CS1: Cotton-Sunflower	37.9	38.1	38.3	39.1	38.9	39.8	39.5	40.8	40.5	39.9	41.7	42.5
CS2: Maize-Sunflower	37.8	38.1	38.3	37.8	37.8	38.3	38.4	40.4	40.0	41.6	41.9	43.1
CS3: Soybean-Sunflower	37.3	37.5	37.7	38.0	38.0	38.2	38.0	40.6	39.9	41.2	41.2	40.9
CS4: Sunflower- Chickpea	38.6	38.9	37.9	39.0	39.1	42.3	41.4	43.1	43.0	41.4	43.5	42.0
S E m +	1.9	2.4	1.1	2.2	2.5	1.9	1.6	3.1	2.7	3.3	2.2	1.6
C D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertiliser levels												
100% RDF	38.3	38.6	38.2	38.9	39.3	41.8	43.8	43.4	45.5	47.3	48.1	52.2
100% STCR	38.0	38.2	38.2	39.2	39.4	40.2	39.6	41.6	41.2	40.1	41.7	41.3
50% STCR	37.5	37.6	37.8	37.3	36.7	36.9	36.6	36.7	37.9	38.6	38.4	37.8
S E m +	0.9	1.1	0.6	1.1	1.2	0.4	0.9	0.6	0.3	0.8	1.0	0.9
C D	NS	NS	NS	NS	NS	1.2	2.7	1.8	0.9	2.4	2.9	2.7

Table 10. Soil available Potassium status (kg/ha) as influenced by different cropping systems and fertilizer doses during 2017-18 to 2022-23

Cropping systems	2017-18		2018-19		2019-20		2020-21		2021-22		2022-23	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
CS1: Cotton-Sunflower	394.1	394.4	394.7	393.2	394.0	394.6	393.6	396.6	396.4	397.0	397.7	401.8
CS2: Maize-Sunflower	390.6	393.5	389.9	393.7	392.8	396.6	395.8	396.4	394.9	391.8	396.7	399.3
CS3: Soybean-Sunflower	391.5	391.9	391.8	395.4	392.7	399.8	398.7	397.7	397.4	398.9	397.8	400.8
CS4: Sunflower- Chickpea	398.3	398.5	397.9	403.3	403.2	408.1	408.0	409.0	408.7	400.8	409.6	413.0
S E m +	8.6	6.6	5.5	11.1	10.5	12.2	10.0	8.4	9.7	10.3	14.7	11.5
C D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertiliser levels												
100% RDF	390.6	392.1	393.9	396.3	401.2	403.2	408.9	411.8	415.7	418.3	422.9	423.6
100% STCR	396.1	395.3	396.5	394.9	399.1	400.6	404.7	407.3	416.6	417.2	419.8	421.9
50% STCR	394.3	393.4	392.3	390.0	392.3	388.7	388.6	381.5	375.8	373.4	373.6	369.7
S E m +	5.3	2.3	2.7	5.2	3.1	4.5	3.9	2.4	3.3	3.6	5.1	4.6
C D	NS	NS	NS	NS	NS	NS	NS	7.3	9.9	10.7	15.3	13.8

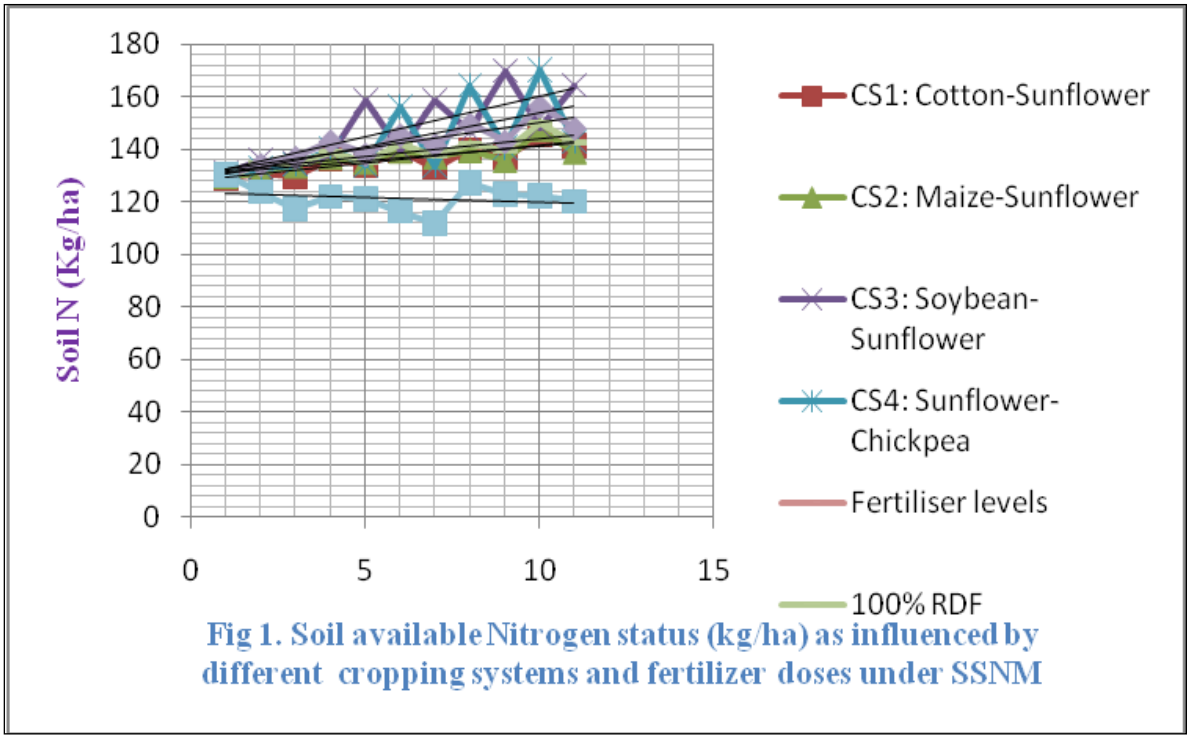

Fig 1. Soil available Nitrogen status (kg/ha) as influenced by different cropping systems and fertilizer doses under SSNM

Similar trend was followed in soil available potassium content as in available phosphorous content. But significantly higher values of available potassium were recorded with RDF treatment followed by 100% STCR fertilizer treatment. However 50% STCR fertilizer treatment observed depletion of available potassium after six years of experimentation [13,14]. Soybean is a legume crop which fixes the atmospheric nitrogen every year that enrich the soil which will be sustained by cultivation of sunflower in second season and finally the available nitrogen was higher side. Similarly application of 100% STCR fertilizer doses to *rabi* sunflower crop has supplied balanced macronutrients and has a positive effect on soil nutrient status in long run. But blanket application of RDF has negative effect on cost of phosphorous fertilizer and observed higher phosphorous values.

4. CONCLUSION

In a nutshell, by the end of the experiment, maize – sunflower cropping system with 100% STCR fertilizer dose to *rabi* sunflower had greater yield advantage, gross and net returns, as well as the B:C ratio. Soil nutrient status was maintained without mining by adopting soybean- sunflower with 100% STCR fertilizer dose along with moderate yields and monitory returns. Finally it is concluded that soybean- sunflower cropping system with adoption of SSNM was ideal productive cropping system, with lower doses of fertilizers, sustainable yields and maintenance of soil fertility and health in light of changing climate.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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