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RESEARCH PAPER

Effect of nutrient management approaches on the quality of soil and crops, sustainability of yield in maize – chickpea sequential cropping system

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Abstract : Field experiments were conducted during 2010-11 and 2011-12 at Agricultural Research Station, Raddewadagi, Jewargi taluk, Kalaburagi district, University of Agricultural Sciences, Raichur to study the nutrient management approaches on the quality of soil and crops, sustainability of yield in maize-chickpea sequential cropping system involving SSNM and STCR targeted yield of 7 or 8 t ha^{-1} in clayey soils of Vertisol of UKP area. The application of nutrients through SSNM approach for targeted yield of 8.0 t ha^{-1} produced significantly higher grain yield and sustainability yield index (8.62 and 0.80, respectively) as compared to absolute control, farmers practice, state recommendation and STL method and it was at par with STCR approach for targeted yield of 8.0 t ha^{-1} (8.37 t ha^{-1} and 0.77, respectively), SSNM approach for targeted yield of 7.0 t ha^{-1} (7.59, t ha^{-1} and 0.68, respectively), STCR approach for targeted yield of 7.0 t ha^{-1} (7.46 t ha^{-1} and 0.67, respectively), 125 per cent SSNM approach for targeted yield of 8.0 t ha^{-1} (6.45 t ha^{-1} and 0.55, respectively) and 125 per cent SSNM approach for targeted yield of 7.0 t ha^{-1} (6.35, t ha^{-1} and 0.54, respectively). Organic carbon content was non-significant in maize-chickpea sequence cropping system. However, significantly higher available N, P_2O_5 and K_2O (301.05, 62.93 and 439.38 kg ha^{-1}, respectively) were noticed with nutrients applied through 125 per cent SSNM approach for targeted yield of 8.0 t ha^{-1} as compared to absolute control, farmers practice, state recommendation, STL method and 125 per cent SSNM approach for targeted yield of 7.0 t ha^{-1} after harvest of second crop in maize-chickpea sequence cropping system and it was at par with SSNM or STCR approach for targeted yield of 7.0 or 8.0 t ha^{-1}. Application of nutrients through SSNM approach for targeted yield of 8.0 t ha^{-1} recorded significantly higher protein (6.59%) and protein yield (568.01 kg ha^{-1}) and also its residual effect was recorded significantly higher protein content (20.28%) and protein yield (606.31 kg ha^{-1}) in chickpea as compared to other treatments.

Key Words : Maize-chickpea sequential cropping system, Grain yield, Sustainability yield index, SSNM, STCR, Protein, Protein yield

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INTRODUCTION

Maize and chickpea are the most important commercial crops grown in UKP command area. Lower productivity and quality of maize and chickpea was attributed to poor soil health as a consequence of continuous and imbalanced use of fertilizers without soil testing. Over reliance on use of chemical fertilizers has been associated with decline in soil physical and chemical properties, crop yield and significant land problems, such as soil degradation due to over exploitation of land and soil pollution, the one based on soil test (SSNM and STCR) is gaining more important. A judicious use of fertilizers is essential since the cost of fertilizers has gone up very high in recent years. The targeting of crop yields is of importance so as to obtain varying production levels and to monitor the stress on soil fertility, since exhaustion of the nutrients from the soil is directly proportional to the yield level obtained. This also ensures judicious use of fertilizers and allows altering the profit per unit investment of fertilizers. Among the various methods of fertilizer applications, the one based on 'yield targeting' (SSNM and STCR) is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve if good agronomic practices are followed in raising the crop. The site specific nutrient management (SSNM) approach does not significantly aim to either reduce or increase fertilizer use. Instead, it aims to timely application of nutrients at optimal rates in order to achieve higher yields and higher efficiency of nutrient use by the crops.

Information on nutrient management on individual crops is available, while cropping system, it is lacking. The nutrient management in cropping system is more efficient and judicious than individual crop, as following crop take care of the residual effects of nutrients. Maize-chickpea is the predominant cropping sequence of UKP command area. Applications of nutrients based on the soil test results in SSNM and STCR under field situation had been found to be more useful and profitable and it provides balanced nutrient application in cropping system. At this critical juncture there is an urgent need to optimize nutrient recycling to sustain crop production without affecting soil health and protection of environment from pollution. In view of the above, the present investigation is undertaken to study the effect of nutrient management approaches on the quality of soil and crops, sustainability of yield in maize –chickpea sequential cropping system in Vertisol of Upper Krishna Project (UKP) command area" at Agricultural Research Station, Raddewadagi, dist. Kalaburagi, University of Agricultural Sciences, Raichur during *Kharif* and *Rabi* seasons of 2013-14 and 2014-15.

MATERIAL AND METHODS

Field experiments were conducted during *Kharif* and *Rabi* seasons of 2013-14 and 2014-15 at ARS, Raddewadagi, dist. Kalaburagi, UAS, Raichur, Karnataka on Vertisols. The soil was medium black with clayey in texture having pH 8.21 and electrical conductivity 0.29 dSm^{-1}. The soil was low in available nitrogen (224.20 kg ha^{-1}), medium in available phosphorus (50.60 kg ha^{-1}) and high in available potassium (340.80 kg ha^{-1}). The organic carbon content of soil was low (4.5 mg kg^{-1}). The experiment was repeated on the same site for two years. The experiment was laid out in Randomized Complete Block Design (RCBD) and the treatments were replicated thrice. The treatment includes targeted yield of maize through SSNM, STCR along with absolute control (No NPK and FYM), farmers practice (109: 58: 38 kg N: P_2O_5: K_2O ha^{-1}), state recommendation (150: 75: 39 kg N: P_2O_5: K_2O ha^{-1}), STL method (175: 75: 26, N, P_2O_5 and K_2O kg ha^{-1}). The quantity of fertilizers was calculated based on targeted yield equations developed by STCR scheme (Anonymous, 2007) for maize crop *viz.*, FN = 3.41 T - 0.08 SN ($KMnO_4$ - N); FP_2O_5 = 1.94T - 0.41 SP_2O_5 (Olsen's - P_2O_5) and FK_2O = 2.28T - 0.072 SK_2O (NH_4OAC - K_2O). Accordingly, the quantity of N, P_2O_5 and K_2O for 7.0 and 8.0 t ha^{-1} were 220.78: 114.89: 135.05 and 254.88: 134.29: 157.85 kg ha^{-1}, respectively. Similarly for SSNM, the quantity of N, P_2O_5 and K_2O required were calculated based on the nutrient removal by maize crop per tonne. The average removal of N, P_2O_5 and K_2O from the soil to produce one tonne of maize grain was 26.3, 13.9 and 35.8 kg ha^{-1}, respectively (Singh *et al.*, 2005). Accordingly, the nutrients required were calculated by multiplying targeted yield with nutrient removal. After calculating, the soil nutrient ratings (low and high) are considered for recommendation of fertilizers @ $\pm$ 30 percent. Accordingly, the quantity of N, P_2O_5 and K_2O for 7.0 and 8.0 t ha^{-1} were 239.30: 97.30: 175.42 and 273.52: 111.2: 200.48: N, P_2O_5, K_2O kg ha^{-1}, respectively. Similarly, for 125 per cent SSNM targeted yield of 7 and 8 t ha^{-1}, the quantity of N, P_2O_5, K_2O required were 299.13: 121.63: 219.28 and 341.9: 139: 250.6: N, P_2O_5, K_2O kg ha^{-1}, respectively. Maize (NK 6240) was sown on 25th and 12th July and harvested on November 10th and October 31th during 2013-14 and 2014-15, respectively. Basal dose of fertilizers (50 % N and 100 % P and K) were applied and mixed with soil at the base of seed row based on the treatments at 4-5 cm deep and 5 cm away from the seed as basal dose. Remaining half dose of nitrogen in the form of urea was top dressed at 30 days after sowing (DAS). The required amount of FYM @ 10 t ha^{-1} was applied for all treatments uniformly for main crop (except T_1 and T_2) during both the years of experimentation. The residual effects of maize crop treatments were studied using chickpea crop in the same plot during 2013 and 2014. After harvest of maize, chickpea (JG 11) was sown on 14th and 5th November and harvested on 18th and 2nd February during first and second year, respectively. The yield of both the crops was recorded at harvest. Soil samples collected after harvest of maize crop were analyzed for organic carbon, available N, P_2O_5 and K_2O by Walkely and Black's wet digestion method, alkaline potassium permanganate method (Subbiah and Asija, 1956), Olsen's and flame photometry method, respectively (Jackson, 1973). The quality parameter protein content of maize and chickpea were estimated by multiplying the nitrogen content by a factor of 3.45 and 6.25, respectively. Nitrogen content in the seeds of maize and chickpea was estimated by Kjeldhal's method (Jackson, 1973).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Soil chemical fertility :

Organic carbon content and available nutrients increased in the soil from first to second year of maize and chickpea cultivation in sequence (Table 1). There was no significant difference in organic carbon of soil with the adaptation of different nutrient management approaches. Among them, higher (4.55 g kg^{-1}) organic carbon was resulted with treatment receiving T_{10}: 125 per cent SSNM approach targeted yield of 8.0 t ha^{-1} (4.55 g kg^{-1}) as compared to other treatments. Lowest organic carbon (0.48 g kg^{-1}, each) was noticed with absolute control, farmers practice and state recommendation may be due to addition of less amount of biomass than other treatments. The results are in line with the findings of Singh *et al.* (2012). The significantly

Table 1: Organic carbon, available N, P_2O_5 and, K_2O in soil after harvest of second crop in maize-chickpea sequence as influenced by different nutrient management approaches

Treatments	Organic carbon (g kg^{-1})			Available N (kg ha^{-1})			Available P_2O_5 (kg ha^{-1})			Available K_2O (kg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_1	4.47	4.48	4.48	178.22	182.00	180.11	23.11	26.11	24.61	298.44	313.44	305.94
T_2	4.47	4.48	4.48	235.02	250.02	242.52	35.88	37.88	36.88	347.00	357.00	352.00
T_3	4.47	4.48	4.48	240.02	255.02	247.52	38.55	43.55	41.05	350.13	363.13	356.63
T_4	4.50	4.50	4.50	243.88	261.88	252.88	41.48	49.48	45.48	351.00	368.00	359.50
T_5	4.50	4.50	4.50	254.51	277.51	266.01	53.03	56.85	54.94	363.44	383.44	373.44
T_6	4.52	4.53	4.53	262.75	291.75	277.25	55.41	60.13	57.77	375.03	410.03	392.53
T_7	4.51	4.52	4.52	260.05	282.72	271.38	53.88	56.03	54.96	365.00	391.00	378.00
T_8	4.52	4.53	4.53	264.25	292.25	278.25	55.85	56.88	56.37	394.00	432.00	413.00
T_9	4.52	4.53	4.53	275.81	306.81	291.31	56.13	60.41	58.27	400.05	441.05	420.55
T_{10}	4.54	4.55	4.55	284.55	317.55	301.05	58.93	66.93	62.93	416.88	461.88	439.38
S.E.±	0.32	0.34	0.22	11.82	14.76	13.28	2.86	3.53	3.17	19.45	27.36	23.42
C.D. (P=0.05)	NS	NS	NS	35.50	44.32	39.92	8.52	10.65	9.56	58.42	82.10	70.23

T_1: Absolute control (No NPK and FYM)
T_2: Farmers practice
T_3: State recommendation
T_4: STL method
T_5: STCR approach (Targeted yield : 7.0 t ha^{-1})
T_6: STCR approach (Targeted yield : 8.0 t ha^{-1})
T_7: SSNM approach (Targeted yield : 7.0 t ha^{-1})
T_8: SSNM approach (Targeted yield : 8.0 t ha^{-1})
T_9: 125% SSNM approach (Targeted yield : 7.0 t ha^{-1})
T_{10}: 125% SSNM approach (Targeted yield : 8.0 t ha^{-1})

Note: FYM @ 10 t ha^{-1} and deficient nutrients were applied for all treatments except T_1 and T_2 for maize crop NS=Non-significant higher available N, P_2O_5 and K_2O, (301.05, 62.93 and 439.38, kg ha^{-1}, respectively) were noticed with nutrients applied through 125 per cent SSNM approach for targeted yield of 8.0 t ha^{-1} as compared to absolute control, farmers practice, state recommendation, STL method and 125 per cent SSNM approach for targeted yield of 7.0 t ha^{-1} after harvest of second crop in maize-chickpea sequence cropping system and it was at par with SSNM or STCR approach for targeted yield of 7.0 or 8.0 t ha^{-1}. Biradar and Jayadeva (2013) reported significantly higher nutrient uptake (504.8, 103.1 and 212.3 N, P and K kg ha^{-1}, respectively) in SSNM through fertilizers for targeted yield of 10 t ha^{-1} over 100 per cent RDF (219.4, 32.2 and 73; N, P and K kg ha^{-1}). It could be due to enhanced nutrient pool at elevated fertility level which might have contributed to higher residual nutrient status of soil by retaining part of external applied nutrients in soil. Similar opinion of elevated fertility levels increased the available nutrient status of the soil after harvest of crop by several researchers. This might be due to nodulation of legume crop which fixes atmospheric N and intern increases 'N' in soil was more with SSNM treatments. It was also in accordance with Tomar *et al.* (1990) that inclusion of pulses in intensive agriculture is beneficial and improves the soil fertility and crop productivity. The benefits of including legumes in cropping cycle which improves the soil fertility status. Similarly, Varalakshmi *et al.* (2005) reported that the legume cropping helped to increase the available N, P_2O_5 and K_2O content of the soil. Vidyavathi *et al.* (2011) reported that the available N, P_2O_5 and K_2O were significantly higher in legume based cropping systems during both the seasons of the study than non-legume system.

Yield and sustainability yield index of maize:

Pooled results showed that, application of nutrients through SSNM approach targeted yield of 8.0 t ha^{-1} produced higher seed yield and sustainability yield index of maize (8.62 t ha^{-1} and 0.80, respectively) followed by STCR approach targeted yield of 8.0 t ha^{-1} (8.37 t ha^{-1} and 0.77), SSNM approach targeted yield of 7.0 t ha^{-1} (7.59 t ha^{-1} and 0.68), STCR approach targeted yield of 7.0 t ha^{-1} (7.46 t ha^{-1} and 0.67), 125 per cent SSNM approach targeted yield of 8.0 t ha^{-1} (6.45 t ha^{-1} and 0.55) and 125 per cent SSNM approach targeted yield of 7.0 t ha^{-1} (6.35 t ha^{-1} and 0.54) (Table 2). The higher yield can be attributed to the ability of targeted yield approaches to satisfy the nutrient demand of crop more efficiently. Further, higher grain yield of maize could be due to superior yield components like, length of cob,

Table 2 : Effect of nutrient management approaches on the yield and sustainability yield index in maize-chickpea sequence

Treatments	Grain yield (t ha^{-1})			SYI	Seed yield (q ha^{-1})			SYI
	2013-14	2014-15	Pooled		2013-14	2014-15	Pooled	
T_1	2.70	3.12	2.91	0.14	19.80	18.83	19.32	0.54
T_2	4.53	4.95	4.74	0.35	28.48	26.98	27.73	0.82
T_3	5.59	6.05	5.82	0.48	28.75	28.65	28.70	0.85
T_4	6.06	6.45	6.25	0.53	29.06	29.17	29.12	0.87
T_5	7.22	7.71	7.46	0.67	29.34	29.73	29.54	0.88
T_6	8.12	8.63	8.37	0.77	29.41	29.88	29.65	0.88
T_7	7.36	7.83	7.59	0.68	29.40	29.87	29.63	0.88
T_8	8.43	8.81	8.62	0.80	29.64	30.15	29.90	0.89
T_9	6.15	6.55	6.35	0.54	29.14	29.68	29.41	0.88
T_{10}	6.23	6.67	6.45	0.55	29.26	29.73	29.50	0.88
S.E.±	0.77	0.76	0.78		0.17	0.30	0.24	
C.D. (P=0.05)	2.33	2.30	2.33		0.56	0.96	0.75	

T_1: Absolute control (No NPK and FYM)
T_2: Farmers practice
T_3: State recommendation
T_4: STL method
T_5: STCR approach (Targeted yield : 7.0 t ha^{-1})
T_6: STCR approach (Targeted yield : 8.0 t ha^{-1})
T_7: SSNM approach (Targeted yield : 7.0 t ha^{-1})
T_8: SSNM approach (Targeted yield : 8.0 t ha^{-1})
T_9: 125% SSNM approach (Targeted yield : 7.0 t ha^{-1})
T_{10}: 125% SSNM approach (Targeted yield : 8.0 t ha^{-1})

Note: FYM @ 10 t ha^{-1} and deficient nutrients were applied for all treatments except T_1 and T_2 for maize crop number of grain rows per cob and hundred seed weight. Significant increase in the yield with the application nutrients through SSNM or STCR might be due to balanced supply of nutrients that might have contributed to better translocation of photosynthate from source to sink and higher growth attributing characters like higher number of leaves and dry matter production and its accumulation into different parts of plant and yield attributing characters. The results are in collaboration with the findings of Biradar *et al*. (2006) that nutrient application on the basis of SSNM principles resulted in significantly higher grain yields over farmer practice and recommended dose of fertilizers. The studies are also confirmed with the findings of Biradar *et al*. (2013) and Dhillon *et al*. (2006) that application of nutrients through SSNM for targeted yield recorded significantly higher grain yield as compared to farmers practice, RDF and STL method. Mandal *et al*. (2009) reported that SSNM based nutrient management recorded significantly higher grain yield which may be due to better nutrient availability during the crop growth period. These results are in conformity with the findings of Al Zubaidi and Al Semak (1992) and Kumar *et al*. (2012).

Chickpea :

The pooled results showed superior seed yield and sustainability yield index (29.90 q ha^{-1} and 0.89/0.88, respectively) of chickpea due to residual effect of nutrient through SSNM or STCR or 125 per cent SSNM approach targeted yield of 7 or 8.0 t ha^{-1} over absolute control (19.32 q ha^{-1} and 0.54, respectively), farmers practice (27.73 q ha^{-1} and 0.82, respectively), state recommendation (28.70 q ha^{-1} and 0.85, respectively) and STL method (29.12 q ha^{-1} and 0.87, respectively) (Table 2). The better performance of succeeding chickpea could be due to higher amount of available nitrogen, phosphorus and potassium after harvest of maize. The results are in conformity with the findings of Gawai and Pawar (2005) that the residual effect of application of 100 per cent RDF and 5 t FYM ha^{-1} to proceeding crop sorghum resulted in significantly higher grain yield of chickpea.

Quality of maize :

Protein percentage was significantly influenced by adaptation of different nutrient management approaches. Higher protein content and protein yield were recorded (6.59% and 568.01 kg ha^{-1}, respectively) with the

Table 3 : Protein content and protein yield as influenced by different nutrient management approaches in maize-chickpea sequence

Treatments	Maize grain						Chickpea seed					
	Protein content (%)			Protein yield (kg ha^{-1})			Protein content (%)			Protein yield (kg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_1	5.69	5.80	5.74	153.70	180.84	167.16	16.88	17.06	16.97	334.13	321.29	327.75
T_2	5.80	5.93	5.87	262.56	293.73	278.00	17.50	17.81	17.66	498.40	480.58	489.61
T_3	6.31	6.35	6.33	352.92	384.05	368.45	18.75	18.94	18.84	539.06	542.56	540.82
T_4	6.31	6.35	6.33	382.60	409.45	395.99	19.13	19.25	19.19	555.77	561.52	558.64
T_5	6.35	6.42	6.38	458.33	494.75	476.45	19.31	19.50	19.41	566.63	579.74	573.16
T_6	6.42	6.62	6.52	521.06	571.65	546.09	19.44	19.88	19.66	571.66	593.87	582.71
T_7	6.38	6.52	6.45	469.75	510.56	489.99	19.38	19.50	19.44	569.63	582.47	576.03
T_8	6.49	6.69	6.59	546.77	589.65	568.01	20.19	20.38	20.28	598.36	614.31	606.31
T_9	6.35	6.35	6.35	390.40	415.79	403.10	19.25	19.31	19.28	560.95	573.20	567.06
T_{10}	6.31	6.42	6.37	393.33	428.01	410.56	19.25	19.44	19.34	563.26	577.88	570.54
S.E.±	0.04	0.10	0.07	30.12	32.10	30.81	0.30	0.31	0.30	11.23	11.96	11.59
C.D. (P=0.05)	0.16	0.32	0.21	90.40	96.28	92.49	0.90	0.92	0.91	33.75	35.94	34.82

T_1:	Absolute control (No NPK and FYM)	T_6:	STCR approach (Targeted yield : 8.0 t ha^{-1})
T_2:	Farmers practice	T_7:	SSNM approach (Targeted yield : 7.0 t ha^{-1})
T_3:	State recommendation	T_8:	SSNM approach (Targeted yield : 8.0 t ha^{-1})
T_4:	STL method	T_9:	125% SSNM approach (Targeted yield : 7.0 t ha^{-1})
T_5:	STCR approach (Targeted yield : 7.0 t ha^{-1})	T_{10}:	125% SSNM approach (Targeted yield : 8.0 t ha^{-1})

Note: FYM @ 10 t ha^{-1} and deficient nutrients were applied for all treatments except T_1 and T_2 for maize crop treatment receiving SSNM approach targeted yield of 8.0 t ha^{-1} followed by STCR approach targeted yield of 8.0 t ha^{-1} (6.52% and 546.09 kg ha^{-1}, respectively) over absolute control (5.74% and 167.16 kg ha^{-1}, respectively) (Table 3). The reason for higher protein may be due to increase availability of nutrients particularly nitrogen which is an integral part of protein. Higher protein yield may also be attributed to higher kernel yield with higher protein content in the seed which may due to balanced dose of nitrogen and phosphorus as compared to other treatments. The results are in agreement with the findings of Arya and Singh (2000) that application of 90 kg P_2O_5 ha^{-1} resulted significantly higher protein yield compared to 60, 30 and 0 kg P_2O_5 ha^{-1} in maize. Miao *et al*. (2007) had endorsed that significant increase in corn yield and protein content by application of nitrogen from 143 to 303 kg ha^{-1} and 0 to 235 kg ha^{-1}, respectively. Application of 120 kg N ha^{-1} resulted in significantly higher protein content (10.44%) in maize compared to 80, 40 and 0 kg N ha^{-1} in maize (Meena *et al.*, 2007). This is also in conformity with the findings of Umesh *et al.* (2014).

Chickpea :

Protein percentage was significantly influenced by residual effect of different nutrient management approaches. Higher seed protein content and protein yield were recorded (20.28% and 606.31 kg ha^{-1}, respectively) with the residual effect of nutrients applied through SSNM approach targeted yield of 8.0 t ha^{-1} followed by STCR approach targeted yield of 8.0 t ha^{-1} (19.66% and 582.71 kg ha^{-1}, respectively) as compared to absolute control (16.97% and 327.75 kg ha^{-1}, respectively). This may be due to optimum availability of nitrogen and phosphorus after the harvest of preceding crop. The results are also in conformity with the findings of Shankar *et al.* (2014) in greengram.

In conclusion application of nutrients through SSNM approach targeted yield of 8.0 t ha^{-1} was superior in maize-chickpea sequence cropping system to produce crops with superior quality, higher and sustainable productivity besides maintaining soil health.

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