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Transformation of NPK nutrients in soil as influenced by different fertilizer recommendation approaches to soybean [*Glycine max*. (L)] crop in a Vertisol

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Abstract
The field experiments were conducted at the Main Agricultural Research Station, Dharwad during *kharif* season of the year 2015 and 2016 to study the effect of different fertilizer recommendation approaches to soybean on NPK transformation in soil. The treatments consisted of different fertilizer recommendation approaches *viz*., site specific nutrient management (SSNM) and soil test crop response (STCR) each targeted yield at 20, 25. 30 and 35 q ha^{-1} and soil test laboratory (STL) approach and these were compared with graded levels of fertilizer (125 and 150 % of RDF) and control (RDF). The experiment laid out in randomized completely block design with twelve treatments replicated thrice.
Pooled data of two years indicated that inorganic forms of nitrogen, phosphorus and potassium significantly influenced due to different fertilizer recommendation approaches. In most of the soils, more than 90 per cent of nitrogen is mainly organic in nature and only a small portion is in inorganic form. Inorganic forms (mineralizable-N) of nitrogen are ammonium (NH_4) and nitrate (NO_3) and plants normally utilize nitrogen in only nitrate and ammonical forms. Different inorganic forms of nitrogen *viz*., NH_4-N and NO_3-N and mineral-N and total-N contents in soil was recorded significantly higher in the treatment with target yield 35 q ha^{-1} under SSNM which was on par with 30 q ha^{-1} under the same management practice and both the treatments differed significantly to the remaining treatments. All the inorganic forms of phosphorus such as saloid-P, Al-P, Fe-P, Ca-P, occluded-P and reductant-P were recorded significantly higher in the treatment received 150 per cent RDF and were at par with the treatment 125 per cent RDF and SSNM yield target at 35 q ha^{-1}but differed significantly to other treatments. Soil potassium exists in dynamic equilibrium in four different forms *viz*., water soluble-K, exchangeable-K (exch-K), non-exchangeable-K (non-exch-K) and lattice-K and all these forms are recorded higher in yield target at 30 and 35 q ha^{-1} under SSNM compared to other remaining approaches.

Keywords: SSNM, STCR, STL, targeted yield, soybean and NPK fractions/forms

Introduction
A healthy soil is a prerequisite for the health of all living beings. In Indian context, diagnosis of soil health is often considered synonymous to soil testing carried out for the assessment of soil fertility or appraisal of salinity/ alkalinity problems. It must be improved to maintain soil health and to enhance the crop productivity. Accordingly, fertilizer requirements of crops vary due to their differential production potential and ability to mine nutrients from native and fertilizer sources. The fertilizer requirement of crop also depends upon the yield targets to be achieved and for achieving definite yield target, a definite quantity of nutrients is required to be applied to the crop and can be calculated by considering the contribution of soil available and fertilizer nutrients for total uptake.
In this context, among the several aspects of soil test based nutrient recommendation approaches, site-specific nutrient management (SSNM), soil test crop research (STCR) and soil test laboratory (STL) method are important. These days farming has to be treated as any other business and we must try to utilize the available resources in the most efficient manner possible. Owing to its importance in plant nutrition, soil testing is one which practically applies the knowledge of soil science to crop production. It is a tool for rapid soil chemical analysis to assess the available nutrient status of a soil, interpretation of the test results and making fertilizer recommendations based on crop responses and economic considerations (Dwivedi *et al*., 2015) [1].

In most of the literature, fertilizer recommendations and research efforts typically adopt the nutrient balance technique and fertilizer effect regression equations to calculate the optimum nutrient application rates for maximum crop yield and economic return. However, such approaches do not consider the transformation of different nutrient forms into consideration and, thus, are not able to accurately evaluate the potential environmental risk from fertilization in agricultural ecosystems. Therefore, it is imperative to investigate the effect of different nutrient application via mineral fertilizers or manure on the transformation of nutrient forms and the risk of nutrient loss from agricultural ecosystems in order to accurately assess the environmental impact of nutrient fertilization. In this context experiment was conducted on transformation of NPK nutrients in soil as influenced by different fertilizer recommendation approaches to soybean in a Vertisol.

Material and Methods

The field experiments were conducted on transformation of nutrients in soil as influenced by different fertilizer recommendation approaches to soybean in a Vertisolat Main Agricultural Research Station, Dharwad during *kharif* season of 2015 and 2016 under *rainfed* situation and the treatments consisted of different fertilizer recommendation approaches *viz*., site specific nutrient management (SSNM) and soil test crop response (STCR) approaches yield targeted at 20, 25, 30 and 35 q ha^{-1} and soil test laboratory (STL) approach and were compared with 125 and 150 per cent of RDF and control (RDF). The experiments were laid out in randomized completely block design with twelve treatments replicated thrice.

Initial soil sample was analysed for various physical and chemical properties and fertilizer recommendations/ levels for different approaches were worked out based on these soil test values and soils of the experimental site was low in nitrogen (173 kg ha^{-1}), medium in phosphorus (34 kg ha^{-1}) and high in potassium (369 kg ha^{-1}) and different forms of nitrogen content in soil *viz*., total N, NH_4-N and NO_3-N contentswas520, 8.0, 17.5 and 494 mg kg^{-1} and P fractions such assaloid-P, Fe-P, Al-P, Ca-P, reductant-P, occulded-P, organic-P and total P content was8.0, 12.0, 24.5, 42.3, 24.5, 12.3, 213.0 and 336 mg kg^{-1} and potassium fractions *viz*., water soluble-K, exchangeable-K, non-exchangeable-K, lattice-K and total-K content in soil was20, 144, 620, 4466 and 5250 mg kg^{-1}.

Results and Discussion

Nitrogen: In most of the soils, more than 90 per cent of nitrogen is mainly organic in nature and only a small portion is in inorganic form. Inorganic forms (mineralizable-N) of nitrogen are ammonium (NH_4) and nitrate (NO_3) and plants normally utilize nitrogen in these forms. However mineral-N which includes both NH_4 and NO_3-N forms in soil and these forms of nitrogen content in soil differed significantly due to different fertilizer recommendation practices to soybean (Table 1). Pooled data of two years indicated that higher NH_4-N (22.35 mg kg^{-1}), NO_3-N (10.01 mg kg^{-1}) and mineral-N (32.36 mg kg^{-1}) contents in soil were recorded in the treatment with target yield 35 q ha^{-1} under SSNM which was on par with 30 q ha^{-1} under the same management practice and both the treatments differed significantly to the remaining treatments. The higher NH_4-N, NO_3-N and mineral-N contents in soil in SSNM treatments might be due to addition of higher doses of N fertilizers (urea and DAP). There was a small and consistent increasing trend in exchangeable NH_4-N content in soil with increasing dose of nitrogen fertilizer as reported by Prasad and Rokima (1991) [77]. Higher NO_3-N in SSNM treatment could be attributed to the conversion of applied mineral-N through nitrification process (Yadav and Singh, 1991) [19]. Muthuswamy *et al*. (1975) [6] reported that increasing levels of nitrogen increased the NH_4-nitrogen in soil.

Organic-N content in soil did not differ significantly due to different fertilizer management practices to soybean and it ranged from 478.4 to 510.4 mg kg^{-1}. Further, total-N (542.8 mg kg^{-1}) content in soil was significantly higher in target yield 35 q ha^{-1} under SSNM compared to all the treatments except 30, 25 q ha^{-1} under SSNM and 30 q ha^{-1} under STCR. Higher total-N content in SSNM treatments might be due to higher application of nitrogenous fertilizer. Tabassum *et al*. (2010) [16] also reported similar results and the study revealed that application of graded levels of N increased the total-N, mineralizable-N, inorganic-N and organic-N content in soil. Lower NH_4-N (15.28 mg kg^{-1}), NO_3-N (5.81 mg kg^{-1}), mineral-N (21.08 mg kg^{-1}) and total-N (499.5 mg kg^{-1}) were recorded in blanket recommendation (control) compared to all the treatments which might be due to lower dose of nitrogen application.

Table 1: Effect of different approaches of fertilizer recommendation to soybean on different forms of nitrogen content in soil at harvest

Treatments	NH_4-N			NO_3-N			Mineral-N			Organic-N			Total-N		
	---------------------------(mg kg^{-1})-------------------------														
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	15.46	15.09	15.28	6.03	5.58	5.81	21.50	20.67	21.08	479.7	477.1	478.4	501.2	497.8	499.5
T_2	16.57	15.94	16.25	6.56	6.01	6.29	23.13	21.95	22.54	481.7	479.9	480.8	504.8	501.8	503.3
T_3	17.03	17.02	17.02	6.95	6.29	6.62	23.98	23.31	23.64	484.9	483.5	484.2	508.9	506.8	507.8
T_4	16.60	16.13	16.36	6.54	5.92	6.23	23.14	22.05	22.59	480.1	477.6	478.8	503.2	499.6	501.4
T_5	16.48	16.54	16.51	6.45	6.01	6.23	22.93	22.55	22.74	504.0	506.0	505.0	526.9	528.6	527.8
T_6	18.57	19.88	19.23	7.93	7.77	7.85	26.50	27.65	27.08	505.3	504.7	505.0	531.8	532.3	532.0
T_7	20.93	21.73	21.33	9.66	9.05	9.35	30.59	30.78	30.69	503.6	502.3	502.9	534.2	533.0	533.6
T_8	21.90	22.80	22.35	10.11	9.91	10.01	32.01	32.70	32.36	509.3	511.5	510.4	541.3	544.2	542.8
T_9	16.16	15.24	15.70	6.27	5.82	6.05	22.43	21.06	21.75	467.1	466.4	466.8	489.5	487.5	488.5
T_{10}	16.60	15.67	16.13	6.38	6.10	6.24	22.98	21.77	22.37	479.7	477.9	478.8	502.7	499.7	501.2
T_{11}	16.92	16.07	16.50	6.86	6.80	6.83	23.78	22.87	23.33	489.5	486.8	488.2	513.3	509.7	511.5
T_{12}	19.15	19.77	19.46	8.03	8.12	8.07	27.18	27.89	27.53	492.5	492.4	492.4	519.6	520.3	520.0
S.Em.±	0.6	0.5	0.4	0.3	0.2	0.2	0.7	0.6	0.5	9.1	11.1	6.6	8.9	11.3	6.6
C.D. @ 0.05	1.7	1.5	1.3	0.8	0.7	0.5	1.9	1.9	1.5	NS	NS	NS	26.1	33.0	19.3
CV (%)	4.6	4.5	4.2	4.5	4.3	4.0	4.2	4.2	4.0	4.3	4.6	4.1	4.3	4.8	4.1

T_1: RPP (control); T_2: 125 % of RDF; T_3: 150 % of RDF; T_4: STL based NPK application; T_5: SSNM targeted @ 20 q ha^{-1} ; T_6: SSNM targeted @ 25 q ha^{-1} ; T_7: SSNM targeted @ 30 q ha^{-1}; T_8: SSNM targeted @ 35 q ha^{-1}; T_9: STCR targeted @ 20 q ha^{-1}; T_{10}: STCR targeted @ 25 q ha^{-1}; T_{11}: STCR targeted @ 30 q ha^{-1}; T_{12}: STCR targeted @ 35 q ha^{-1}

Phosphorus: Total-P content in soil includes all the inorganic and organic forms. Inorganic forms of P include saloid-P, aluminum-P (Al-P), iron-P (Fe-P), occluded-P, calcium-P (Ca-P) and reductant-P. Saloid-P is the loosely bound phosphorus fraction in soil. Aluminum-P and iron-P are dominant in acid soil while calcium-P is dominant in calcareous soil and occulded-P is locked up or covered in oxides of iron and aluminium.

Pooled data of two years indicated that, all the inorganic forms of phosphorus such as saloid-P, Al-P, Fe-P, Ca-P, occluded-P and reductant-P were significantly influenced by the different fertilizer recommendation practices in soybean (Table 2 and 3). Significantly higher saloid-P in soil was recorded in T_3 with 150 per cent RDF (11.3 mg kg^{-1}) compared to all other treatments except target yield 35 and 30 q ha^{-1} under SSNM and 35 q ha^{-1} under STCR. Higher saloid-P in soil under this treatment might be due to application of higher dose of phosphatic fertilizer with lower uptake as discussed in chapter 4.7.2.

The higher content of Fe-P in soil than saloid-P but lower than Ca-P might be due to the calcareous nature of the experimental soil (61.2 g free $CaCO_3$ kg^{-1}). However, Ca-P and reductant-P contents in soil were higher in T_3 (59.9 and 31.4 mg kg^{-1}, respectively) and were at par with T_2 and T_8 but differed significantly to other treatments. Aluminum-P, Fe-P and occluded-P in soil were significantly higher in T_3 (33.8, 18.4 and 16.9 mg kg^{-1}, respectively) compared to all the treatments. The higher buildup of inorganic phosphorus fractions in the treatment with 150 per cent RDF might be due to higher rate of phosphorus addition in this treatment which resulted in higher inorganic forms of phosphorus in soil. Significant increase in all the forms of phosphorus in the treatment with 150 per cent RDF might have increased the total-P content in soil. Similarly, Majumdar *et al*. (2002) [5] reported that significant increase in all the forms of P in the treatment with higher P fertilizer application could be attributed to the transformation of applied P into saloid-P, Ca-P, Al-P, Fe-P, occulded-P and reductant-P. Application of P fertilizers in combination with nitrogen and potassium fertilizers raised the different fractions of phosphorus in soil and this increase being more at higher rates of P addition due to build-up of phosphate in soil which got transformed into different inorganic-P fractions (Shrilatha and Sharma, 2015) [10]. Similar findings were also recorded by Sihag *et al*. (2005) [11], Singh *et al* (2010) [13] and Sharma *et al.* (2009) [9].

Organic-P content in soil was not significantly influenced by different fertilizer management practices in soybean (Table 3). Total-P status in soil was significantly higher in the treatment with 150 per cent RDF (386.7 mg kg^{-1}) compared to all the treatments but at par with control, 125 per cent RDF and STL. This was because of application of high dose P fertilizer applied to soil was transformed to different inorganic fractions and hence might have increased all the inorganic fractions. This might have resulted in higher total-P content in soil. Lower values of inorganic forms was recorded in T_9 with target yield 20 q ha^{-1} under STCR followed by 25 q ha^{-1} under the same management practice. Lower values in STCR yield targeted at 20 q ha^{-1} might be due to higher removal of phosphorus by the crops in absence of P supplementation through external source which might have depleted the different inorganic forms of P in soil. The results are in conformity with Shrilatha and Sharma (2015) [10] and Swarup (2002) [15].

Potassium: Soil potassium exists in dynamic equilibrium in four different forms *viz*., water soluble-K, exchangeable-K (exch-K), non-exchangeable-K (non-exch-K) and lattice-K. Exchangeable-K and water soluble are very important for the growth of plants and microbes. Major portion of soil potassium exists as constituent of mineral structure and in fixed or non-exchangeable form with very little fraction as water soluble and exchangeable-K.

Water soluble-K and exchangeable-K contents in soil differed significantly due to different fertilizer recommendation practices to soybean (Table 4) and pooled analysis of two years indicated that water soluble-K (21.9 mg kg^{-1}) content in soil was higher in the treatment with 35 q ha^{-1} yield target under SSNM and was at par with 30 q ha^{-1} yield target under the same management practice but differed significantly to the remaining treatments. Similarly, exchangeable-K content (152.7 mg kg^{-1}) in soil was also higher in the said treatment and was on par with 30 and 25 q ha^{-1} under STCR. Higher values for these two fractions of potassium in the said treatment were attributed to application of higher doses of K fertilizer. The present findings are similar to the findings of Jat *et al*. (2014) [3] who observed higher exchangeable and water soluble fractions in soil due to application of higher doses of K fertilizer (60 kg K_2O ha^{-1}) to wheat. The results are in line with the findings of Jatav *et al*. (2010) [4], Sawarkar *et al*. (2013) [8] and Vinutha *et al*. (2011) [18]. In the present investigation, lower water soluble and exchangeable potassium contents in soil were noticed in control and STL which could be due to lower doses of application of K fertilizer. The lower content of water soluble-K in soil might be attributed to the fact that the K in the soil solution is more easily utilized by the crop (Sparks, 1980) [14]. Non exchangeable, mineral and total potassium contents in soil did not differ due to various treatments.

When compared to the initial value, there was a significant buildup in total-K content in soil in the treatments with 25, 30 and 35 q ha^{-1} yield targets under SSNM and 30 and 35 q ha^{-1} under STCR. Application of higher dose of potassium fertilizer than the recommended might be the contributing factor. Lower total-K status in STL might be due to lower dose of potassium application than the recommended and transformation of native non-exch-K into exch-K and water-soluble forms to meet the crop requirements. Similar results were also recorded by Gowda *et al*. (2011) [2] and Vinutha *et al*. (2011) [18].

The lower mineral-K content in the treatments with 35 q ha^{-1} yield target both in SSNM and STCR might be due to higher doses of application of K fertilizers along with FYM which might have created acidic condition causing release of small portion of mineral-K into non-exch-K and exch-K (Thippeshappa *et al*., 2011) [17]. Similar findings were also reported by Singh (2012) [12].

Table 2: Effect of different approaches of fertilizer recommendation to soybean on saloid-P, aluminium-P, iron-P and calcium-P content in soil at harvest

Treatments	Saloid-P			Aluminium-P			Iron-P			Calcium-P		
	---------------------------(mg kg^{-1})-------------------------											
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	10.0	9.9	10.0	27.5	29.4	28.5	16.2	15.2	15.7	56.0	53.4	54.7
T_2	10.5	10.4	10.4	30.4	31.6	31.0	17.8	16.4	17.1	58.6	56.0	57.3
T_3	11.3	11.2	11.3	32.9	34.7	33.8	19.5	17.3	18.4	60.6	59.2	59.9
T_4	10.1	10.8	10.4	28.9	33.0	30.9	17.6	13.3	15.5	57.0	55.6	56.3
T_5	10.0	10.1	10.1	26.0	26.3	26.2	11.6	12.4	12.0	51.1	46.2	48.6
T_6	10.3	10.3	10.3	28.1	27.3	27.7	12.9	12.7	12.8	52.8	50.0	51.4
T_7	10.9	10.8	10.8	29.0	28.5	28.7	13.0	13.1	13.1	55.7	52.5	54.1
T_8	11.0	11.0	11.0	29.8	30.0	29.9	13.9	13.3	13.6	57.9	56.1	57.0
T_9	8.4	8.0	8.2	21.8	22.8	22.3	11.6	11.3	11.4	39.3	40.3	39.8
T_{10}	8.9	8.7	8.8	25.5	23.2	24.4	12.4	12.1	12.2	42.5	41.5	42.0
T_{11}	10.3	9.1	9.7	27.3	26.4	26.8	13.1	14.0	13.5	46.7	47.8	47.3
T_{12}	11.0	10.5	10.7	29.8	31.4	30.6	14.2	14.8	14.5	54.5	52.5	53.5
S.Em.±	0.3	0.3	0.2	0.9	0.8	0.7	0.5	0.5	0.4	1.7	1.5	1.1
C.D. @ 0.05	0.8	0.9	0.7	2.7	2.5	1.9	1.4	1.4	1.2	4.9	4.4	3.3
CV (%)	4.1	4.3	3.8	4.5	4.3	4.0	4.4	4.3	4.0	4.6	4.3	4.1

T_1: RPP (control); T_2: 125 % of RDF; T_3: 150 % of RDF; T_4: STL based NPK application; T_5: SSNM targeted @ 20 q $ha^{-1;}$ T_6: SSNM targeted @ 25 q ha^{-1} ; T_7: SSNM targeted @ 30 q ha^{-1}; T_8: SSNM targeted @ 35 q ha^{-1}; T_9: STCR targeted @ 20 q ha^{-1}; T10: STCR targeted @ 25 q ha^{-1}; T_{11}: STCR targeted @ 30 q ha^{-1}; T_{12}: STCR targeted @ 35 q ha^{-1}

Table 3: Effect of different approaches of fertilizer recommendation to soybean on reductant-P, occluded-P, organic-P and total-P content in soil at harvest

Treatments	Reductant-P			Occluded-P			Organic-P			Total-P		
	---------------------------(mg kg^{-1})-------------------------											
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	26.5	29.6	28.1	14.0	15.0	14.5	217.7	216.7	217.2	367.9	369.2	368.5
T_2	29.2	31.0	30.1	15.0	16.2	15.6	212.6	217.6	215.1	374.1	379.2	376.6
T_3	30.0	32.8	31.4	16.1	17.8	16.9	216.0	214.1	215.1	386.3	387.0	386.7
T_4	25.7	28.0	26.8	15.1	12.8	13.9	215.9	215.6	215.7	370.2	369.0	369.6
T_5	21.1	26.4	23.8	11.8	11.0	11.4	213.1	213.1	213.1	344.7	345.4	345.1
T_6	22.4	27.8	25.1	12.0	11.6	11.8	208.6	208.8	208.7	347.1	348.5	347.8
T_7	24.7	28.9	26.8	12.4	11.8	12.1	203.8	205.3	204.5	349.4	350.4	349.9
T_8	25.2	29.5	27.4	12.9	12.0	12.5	202.3	203.1	202.7	353.0	355.0	354.0
T_9	22.1	23.1	22.6	11.7	10.9	11.3	214.0	213.0	213.5	328.8	329.4	329.1
T_{10}	22.8	23.5	23.2	12.0	12.2	12.1	205.9	208.8	207.4	330.0	330.0	330.0
T_{11}	24.1	26.2	25.2	12.4	12.7	12.6	211.0	207.7	209.4	344.9	343.9	344.4
T_{12}	25.8	27.2	26.5	12.8	12.6	12.7	211.0	206.0	208.5	359.0	355.0	357.0
S.Em.±	0.7	0.8	0.6	0.4	0.4	0.3	11.5	12.0	11.6	11.2	11.7	11.4
C.D. @ 0.05	2.0	2.3	1.7	1.2	1.3	1.0	NS	NS	NS	32.8	34.3	33.4
CV (%)	4.3	4.6	4.0	4.2	4.5	4.1	4.2	4.5	4.3	4.3	4.6	4.0

T_1: RPP (control); T_2: 125 % of RDF; T_3: 150 % of RDF; T_4: STL based NPK application; T_5: SSNM targeted @ 20 q ha^{-1} ; T_6: SSNM targeted @ 25 q ha^{-1} ; T_7: SSNM targeted @ 30 q ha^{-1}; T_8: SSNM targeted @ 35 q ha^{-1}; T_9: STCR targeted @ 20 q ha^{-1}; T_{10}: STCR targeted @ 25 q ha^{-1}; T_{11}: STCR targeted @ 30 q ha^{-1}; T_{12}: STCR targeted @ 35 q ha^{-1}

Table 4: Effect of different approaches of fertilizer recommendation to soybean on different forms of potassium content in soilat harvest

Treatments	Water soluble-K			Exchangeable-K			Non exchangeable-K			Mineral-K			Total-K		
	---------------------------(mg kg^{-1})-------------------------														
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	14.8	16.1	15.5	128.8	134.2	131.5	615.7	619.3	617.5	4477.6	4470.6	4474.1	5237.0	5240.2	5238.6
T_2	15.6	17.0	16.3	131.3	136.4	133.8	623.6	622.6	623.1	4464.1	4463.4	4463.7	5234.6	5239.4	5237.0
T_3	15.9	17.9	16.9	140.5	139.5	140.0	625.9	624.2	625.1	4447.1	4455.6	4451.4	5229.4	5237.3	5233.3
T_4	15.0	16.2	15.6	129.7	134.8	132.3	618.5	620.6	619.5	4462.2	4460.7	4461.4	5225.4	5232.3	5228.8
T_5	17.5	19.3	18.4	139.4	139.1	139.3	621.9	622.4	622.2	4468.9	4470.4	4469.7	5247.7	5251.2	5249.5
T_6	18.2	21.4	19.8	146.7	145.0	145.9	626.2	627.3	626.7	4461.7	4459.4	4460.5	5252.8	5253.1	5253.0
T_7	19.5	23.0	21.2	148.1	149.6	148.8	629.1	630.3	629.7	4459.1	4451.3	4455.2	5255.8	5254.2	5255.0
T_8	20.4	23.4	21.9	151.2	154.1	152.7	636.7	639.6	638.1	4452.0	4440.6	4446.3	5260.3	5257.6	5259.0
T_9	15.2	17.9	16.5	133.9	137.0	135.5	621.3	620.0	620.7	4467.1	4467.3	4467.2	5237.6	5242.2	5239.9
T_{10}	15.4	19.0	17.2	140.0	140.5	140.3	623.2	623.8	623.5	4466.3	4465.0	4465.6	5244.9	5248.4	5246.6
T_{11}	18.2	21.2	19.7	141.9	147.4	144.7	626.1	627.4	626.7	4465.3	4456.0	4460.7	5251.4	5252.1	5251.7
T_{12}	19.5	21.8	20.6	146.5	148.5	147.5	630.1	637.1	633.6	4458.4	4449.7	4454.0	5254.5	5257.0	5255.8
S.Em.±	0.6	0.6	0.3	4.5	4.6	4.0	17.8	15.0	11.6	132.3	123.2	92.2	133.4	126.2	95.0
C.D. @ 0.05	1.7	1.9	1.0	13.3	13.6	11.7	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	4.8	5.0	4.5	4.6	4.7	4.2	4.4	4.7	4.0	4.2	4.0	3.8	4.6	4.3	4.0

T_1: RPP (control); T_2: 125 % of RDF; T_3: 150 % of RDF; T_4: STL based NPK application; T_5: SSNM targeted @ 20 q ha^{-1}; T_6: SSNM targeted @ 25 q ha^{-1}; T_7: SSNM targeted @ 30 q ha^{-1}; T_8: SSNM targeted @ 35 q ha^{-1}; T_9: STCR targeted @ 20 q ha^{-1}; T_{10}: STCR targeted @ 25 q ha^{-1}; T_{11}: STCR targeted @ 30 q ha^{-1}; T_{12}: STCR targeted @ 35 q ha^{-1}

Conclusion

Yield targeted at 30 q ha^{-1} under SSNM practice recorded higher NH_4-N, NO_3-N and mineral-N contents in soil. As far as total-N content in soil is concerned, there was statistical parity among different yield targets under SSNM approach, while 35 q ha^{-1} under STCR approach was significantly superior to other targets and control. Different P-fractions were higher in 150 per cent RDF followed by 125 per cent RDF and yield target 35 and 30 q ha^{-1}. Whereas, mineral-K and total-K contents in soil were significantly higher in 35 and 30 q ha^{-1} yield target under SSNM while non-exchangeable K was higher in control.

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