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Response of wheat (*Triticum aestivum* L.) to precision nutrient management approaches in vertisol under northern transitional zone of Karnataka

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Abstract
A field experiment was conducted at the Research Farm of All India Co-ordinated Wheat and Barley Improvement Project (AICW & BIP), MARS, UAS, Dharwad during *rabi*, 2020. The experiment was laidout in completely randomized block design with fifteen treatments replicated thrice. The treatments consisted of different fertilizer recommendation approaches namely site specific nutrient management (SSNM) and soil test crop response (STCR) for targeted yields at 40, 45, 50 and 55 q ha^{-1}, Nutrient Expert (NE) approach target yield at 40 q ha^{-1} and soil test laboratory (STL) and these were compared with graded levels of fertilizer application (125 and 150% of RDF) and RPP. The growth, yield attributes, yield and economics in wheat was significantly influenced by the precision nutrient management approaches. The results revealed that the significant increase in plant height and total dry matter accumulation in wheat at 45 (36.60 cm and 1.42 g plant^{-1}) and 75 DAS (68.00 cm and 6.86 g plant^{-1}) and at harvest (89.00 cm and 14.1 g plant^{-1}) was observed in site specific nutrient management for yield target at 50 q ha^{-1}. The photosynthetic parameters namely leaf area index, SPAD and NDVI values at 45 (1.30, 45.1 and 0.52, respectively) and 75 DAS (2.32, 49.6 and 0.72, respectively) were also significantly increased with the same treatment. Yield target at 50 q ha^{-1} under SSNM practice significantly increased the number of effective tillers m^{-2} (276.1), number of grains panicle^{-1} (39.9), grain weight panicle^{-1} (1.80 g), test weight (44.9 g), grain (50.2 q ha^{-1}) and straw (73.8 q ha^{-1}) yields in wheat. Further, it resulted in higher gross (Rs. 1,44,482 ha^{-1}) and net (Rs. 92,527 ha^{-1}) returns and B:C ratio (2.78).

Keywords: economics, growth, SSNM, STCR, targeted yield, wheat

Introduction
Precision agriculture is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality. There are various approaches which are used for fertilizer recommendations in wheat, like precision nutrient management through spatial variability assessment, soil test laboratory (STL), site specific nutrient management (SSNM), soil test crop response (STCR), nutrient expert (NE) etc. Among them, soil test based fertilizer application with specific yield targets is important. The soil test laboratory is purely based on soil test analysis while, site specific nutrient management and soil test crop response are plant need based approaches with specific yield targets.
The site specific nutrient management and soil test crop response approaches aim to apply nutrients at optimal rate and time to achieve higher economical yields leading to higher net returns in crops. Nutrient Expert is a decision support tool for nutrient management in wheat based on site specific nutrient management principle.
Cereals, especially wheat, constitute the staple food in India and meet about 61 per cent of the protein requirement of the country. Wheat ranks first in the area and production at global level, and India is the second largest wheat producer in the World followed by China. In India, the area under the crop is estimated to be around 31.35 million hectare with annual production of 107.86 million tones and productivity of 3440 kg ha^{-1} (Anon., 2021) [1]. Major wheat producing states in India are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan and Bihar. In Karnataka, wheat is grown over an area of 1.50 million hectare with the production of 1.63 million tones and productivity of 1198 kg ha^{-1} (Anon., 2021) [1]. When compared to the other states wheat productivity in Karnataka is low.

Material and Methods

The field experiment was conducted at the Research Farm of All India Co-ordinated Wheat and Barley Improvement Project (AICW & BIP), Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *rabi*, 2020 under *irrigated* condition. The wheat variety used for the experiment was UAS-334 (Bread wheat). The soil of the experimental site was clay loam in texture with neutral soil pH (7.67) and low total soluble salts content (0.26 dS m^{-1}). The experimental soil was low in nitrogen (176.9 kg ha^{-1}), medium in phosphorus (33.77 kg ha^{-1}) and high in potassium (361.68 kg ha^{-1}) and fertilizer recommendations were worked out based on these soil test values as per the treatments (Table 1). The application of zinc sulphate and iron sulphate at 20 kg ha^{-1} each along with FYM at 7.5 t ha^{-1} was applied to all the treatments except absolute control (T_1) and RDF (T_2). The chemical fertilizers were applied as per treatments. Recommended nitrogen, phosphorus and potassium were applied through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Recommended Fe and Zn were applied in the form of iron sulphate and zinc sulphate. The entire quantity of fertilizer mixture containing entire dose of phosphorus, potassium, iron sulpahte and zinc sulphate were applied to each plot at the time of sowing. Nitrogen was applied in split, half as basal and half at 30 days after sowing (DAS).

Table 1: Quantity of fertilizers applied in different treatments

Treatment details		Quantity of fertilizers applied (kg ha^{-1})		
		N	P_2O_5	K_2O
T_1	Absolute control	-	-	-
T_2	RDF	100	75	50
T_3	RPP	100	75	50
T_4	125% RDF	125	93.75	62.5
T_5	150% RDF	150	112.5	75
T_6	STL based NPK application	125	75	25
T_7	SSNM yield target @ 40 q ha^{-1}	200.4	29.33	98.4
T_8	SSNM yield target @ 45 q ha^{-1}	225	33	110.4
T_9	SSNM yield target @ 50 q ha^{-1}	250	36.67	123.2
T_{10}	SSNM yield target @ 55 q ha^{-1}	275	40.33	135.2
T_{11}	STCR yield target @ 40 q ha^{-1}	170.7	0.0	20.04
T_{12}	STCR yield target @ 45 q ha^{-1}	208.4	0.0	32.49
T_{13}	STCR yield target @ 50 q ha^{-1}	246.1	0.0	44.94
T_{14}	STCR yield target @ 55 q ha^{-1}	283.8	7.25	57.39
T_{15}	Nutrient Expert yield target @ 40 q ha^{-1}	80	53	45

Results and Discussion

Growth of wheat as influenced by precision nutrient management practices:

The growth of wheat was significantly influenced by precision nutrient management approaches (Table 2). The results indicated that application of nutrients through site specific nutrient management approach for yield target at 55 q ha^{-1} recorded significantly higher plant height and dry matter production at 45 DAS (38.4 cm and 1.45 g $palnt^{-1}$), 75 DAS (69.8 cm and 7.10 g $palnt^{-1}$) and at harvest (91.4 cm and 14.6 g $palnt^{-1}$) but was statistically similar to yield targets at 50 and 45 q ha^{-1} under the same nutrient management practice and these treatments were significantly superior over remaining treatments including RPP. The higher plant height and dry matter accumulation might be due to better nutrients availability throughout the crop growth period as per the crop demand. Similar results were also recorded by Biradar *et al*. (2013) [2] who reported that nutrients recommendation through SSNM practice for targeted yield at 10 t ha^{-1} in maize significantly increased the total dry matter production at harvest (501.4 g $plant^{-1}$) and was at par with STCR approach for targeted yield at 8.0 t ha^{-1} (247.35 g $plant^{-1}$). The increased dry matter production in maize was attributed to taller plants, more number of leaves $plant^{-1}$ and higher leaf area index which led to greater accumulation of photosynthates. Further, the lower plant height and dry matter accumulation at 45 DAS (21.00 cm and 0.74 g $palnt^{-1}$), 75 DAS (47.10 cm and 3.38 g $palnt^{-1}$) and at harvest (63.30 cm and 6.90 g $palnt^{-1}$) were recorded in absolute control. The lower plant height and dry matter accumulation in absolute control might be due the absence of nutrients supply through external source. The results are in line with the findings of Shreenivas *et al*. (2017) [7] in maize crop.

The photosynthetic parameters namely leaf area index, soil plant analysis development (SPAD) and Normalized difference vegetative index (NDVI) values were also significantly influenced by precision nutrient management approaches (Table 2). The application of nutrients through site specific nutrient management for yield targeting at 55 q ha^{-1} recorded significantly higher leaf area index, SPAD and NDVI values at 45 (1.35, 47.8 and 0.54, respectively) and 75 DAS (2.39, 52.1 and 0.75, respectively) when compared to RPP (45 DAS-1.13, 35.9 and 0.34, respectively, 75 DAS-1.84, 38.3 and 0.60, respectively) but was on par with yield targeted at 50 and 45 q ha^{-1} under the same nutrient management practice. It is because plant canopies intercept light with varying degrees of efficiency associated mainly with leaf area index. The efficiency of intercepting of incident light, combined with efficiency of photochemical reaction of the leaves determine the efficiency of the canopy in utilizing radiation energy per unit of land area. The SPAD values are indirect indicator of relative content of chlorophyll and leaf nitrogen. Precise application of fertilizer nitrogen through site specific nutrient management approach increased the SPAD and NDVI values. Similar observations were also recorded by Joshi and Chandrashekar (2017) [3] at University of Agriculture Sciences, Dharwad who noted that application of fertilizers through SSNM approach for targeted yield at 10 t ha^{-1} to maize crop significantly increased the SPAD and NDVI values at different phenological stages of maize crop. The higher SPAD and NDVI values might be due to the balanced application of nutrients prescribed under SSNM approach that led to more chlorophyll content in the maize plants.

Table 2: Growth of wheat as influenced by precision nutrient management practices

Treatments	Plant height (cm)			Dry matter accumulation (g plant^{-1})			LAI		SPAD value		NDVI value	
	45 DAS	75 DAS	Harvest	45 DAS	75 DAS	Harvest	45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS
T_1	21.0	47.1	63.3	0.74	3.38	6.9	0.96	1.41	25.5	25.8	0.23	0.41
T_2	27.5	56.8	75.3	1.14	5.20	10.7	1.11	1.83	35.0	37.8	0.33	0.59
T_3	28.1	57.4	76.0	1.15	5.22	10.9	1.13	1.84	35.9	38.3	0.34	0.60
T_4	30.7	59.9	79.6	1.24	5.64	11.6	1.17	1.90	37.9	41.9	0.35	0.62
T_5	32.5	62.3	82.1	1.30	5.99	12.3	1.22	1.95	39.4	43.4	0.41	0.65
T_6	29.6	58.0	79.1	1.22	5.54	11.3	1.16	1.88	36.4	38.4	0.34	0.61
T_7	33.8	63.3	84.0	1.35	6.49	13.3	1.25	2.18	40.4	45.7	0.43	0.67
T_8	35.0	64.6	86.6	1.38	6.64	13.6	1.27	2.25	43.4	46.0	0.48	0.69
T_9	36.6	68.0	89.0	1.42	6.86	14.1	1.30	2.32	45.1	49.6	0.52	0.72
T_{10}	38.4	69.8	91.4	1.45	7.10	14.6	1.35	2.39	47.8	52.1	0.54	0.75
T_{11}	26.4	56.3	74.0	1.11	5.04	10.3	1.10	1.82	35.5	39.1	0.38	0.58
T_{12}	29.4	59.7	78.3	1.19	5.40	11.1	1.14	1.86	38.9	40.9	0.39	0.60
T_{13}	31.9	61.0	81.7	1.25	5.60	11.5	1.20	1.94	44.0	43.4	0.45	0.64
T_{14}	33.0	62.8	83.8	1.38	6.29	12.3	1.28	2.13	44.5	47.5	0.50	0.68
T_{15}	27.0	54.5	73.6	1.03	4.70	9.64	1.04	1.82	33.4	35.7	0.32	0.57
SEm±	2.0	2.4	3.1	0.06	0.37	0.74	0.05	0.03	2.6	2.9	0.03	0.03
CD(0.05)	5.8	7.0	9.0	0.17	1.07	2.15	0.15	0.38	7.6	8.5	0.08	0.10
CV (%)	11.2	10.3	12.7	11.6	11.3	11.1	12.4	11.6	11.7	12.2	14.8	12.5

T_1	Absolute control	**T_6**	STL based NPK application	**T_{11}**	STCR yield target @ 40 q ha^{-1}
T_2	RDF	**T_7**	SSNM yield target @ 40 q ha^{-1}	**T_{12}**	STCR yield target @ 45 q ha^{-1}
T_3	RPP	**T_8**	SSNM yield target @ 45 q ha^{-1}	**T_{13}**	STCR yield target @ 50 q ha^{-1}
T_4	125% RDF	**T_9**	SSNM yield target @ 50 q ha^{-1}	**T_{14}**	STCR yield target @ 55 q ha^{-1}
T_5	150% RDF	**T_{10}**	SSNM yield target @ 55 q ha^{-1}	**T_{15}**	Nutrient Expert yield target @ 40 q ha^{-1}

Table 3: Yield attributes and yield of wheat as influenced by precision nutrient management approaches

Treatments	No. of effective tillers (m^{-2})	No. of grains panicle^{-1}	Grain weight panicle^{-1} (g)	1000-grain wt (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
T_1	181.2	22.6	0.93	28.7	15.2	25.7	36.2
T_2	215.5	30.8	1.30	37.0	37.9	57.9	36.7
T_3	219.7	31.3	1.38	37.9	40.0	60.2	36.6
T_4	240.0	34.2	1.52	39.0	42.4	63.5	39.9
T_5	245.0	35.3	1.57	39.6	43.1	64.7	37.9
T_6	234.3	33.5	1.47	39.5	41.4	61.8	40.5
T_7	256.0	37.2	1.62	41.8	44.6	67.3	39.9
T_8	265.4	39.0	1.68	43.0	48.2	71.4	40.0
T_9	276.1	39.9	1.80	44.9	50.2	73.8	40.3
T_{10}	289.8	42.9	1.96	46.5	52.2	78.6	40.0
T_{11}	208.6	30.6	1.28	35.8	37.4	57.2	39.7
T_{12}	217.0	33.2	1.42	38.2	41.2	61.2	40.2
T_{13}	226.0	33.6	1.51	39.1	42.0	63.3	39.8
T_{14}	251.0	36.0	1.59	40.5	43.3	65.2	39.9
T_{15}	204.8	29.7	1.27	36.2	36.6	57.1	39.2
SEm±	13.2	2.4	0.10	1.9	2.9	3.9	0.02
CD(0.05)	38.2	6.8	0.30	5.5	8.4	11.3	NS
CV (%)	12.1	12.0	13.1	12.2	12.2	12.6	10.5

T_1	Absolute control	**T_6**	STL based NPK application	**T_{11}**	STCR yield target @ 40 q ha^{-1}
T_2	RDF	**T_7**	SSNM yield target @ 40 q ha^{-1}	**T_{12}**	STCR yield target @ 45 q ha^{-1}
T_3	RPP	**T_8**	SSNM yield target @ 45 q ha^{-1}	**T_{13}**	STCR yield target @ 50 q ha^{-1}
T_4	125% RDF	**T_9**	SSNM yield target @ 50 q ha^{-1}	**T_{14}**	STCR yield target @ 55 q ha^{-1}
T_5	150% RDF	**T_{10}**	SSNM yield target @ 55 q ha^{-1}	**T_{15}**	Nutrient Expert yield target @ 40 q ha^{-1}

Yield attributes and yield of wheat as influenced by precision nutrient management approaches

The present study indicated that precision nutrient management approaches significantly influenced the yield attributes and yield in wheat (Table 3). Application of nutrients on the basis of site specific nutrient management for yield targeting at 55 q ha^{-1} resulted in increased number of effective tillers m^{-2} (289.8), number of grains panicle^{-1} (42.9), grain weight panicle^{-1} (1.96 g), test weight (46.5 g), grain (52.2 q ha^{-1}) and straw (78.6 q ha^{-1}) yields when compared to other nutrient management approaches but was found at par with yield targets at 50 and 45 q ha^{-1} under the same nutrient management approach. The higher grain and straw yields in the said treatment might be due to the ability of targeted yield approaches to meet the nutrient demand of crop more efficiently and leads to better translocation of photosynthates from source to sink (Rajesh *et al.*, 2018) [6]. Similarly, Sunil *et al.* (2018) [8] at Meerut, Uttar Pradesh highlighted that application of nutrients based on SSNM practice to wheat significantly increased the grain yield to the extent of 16.72, 27.51 and 128.53 per cent over 100 and 50 per cent RDF and Absolute control, respectively. Further, the yield target at 55 q ha^{-1} was not achieved in the present study under site specific nutrient management approach and it was mainly due to the genetic potential of wheat genotype was achieved at 50 q ha^{-1} under the same nutrient management practice (Fig. 1). The application of nutrients through various nutrient management approaches did not significantly influence the harvest index in wheat.

The treatment receiving nutrients through soil test laboratory approach was found at par with 125 and 150 per cent RDF with respect to yield attributes and yield in wheat. Under soil test crop response approach, none of the yield targets were achieved which might be due to omission of major nutrient particularly phosphorus.

Among precision nutrient management approaches, lower yield attributes and yield in wheat was recorded under nutrient expert approach for yield targeting at 40 q ha^{-1} when compared to RPP and it was mainly because of inadequate supply of nutrients.

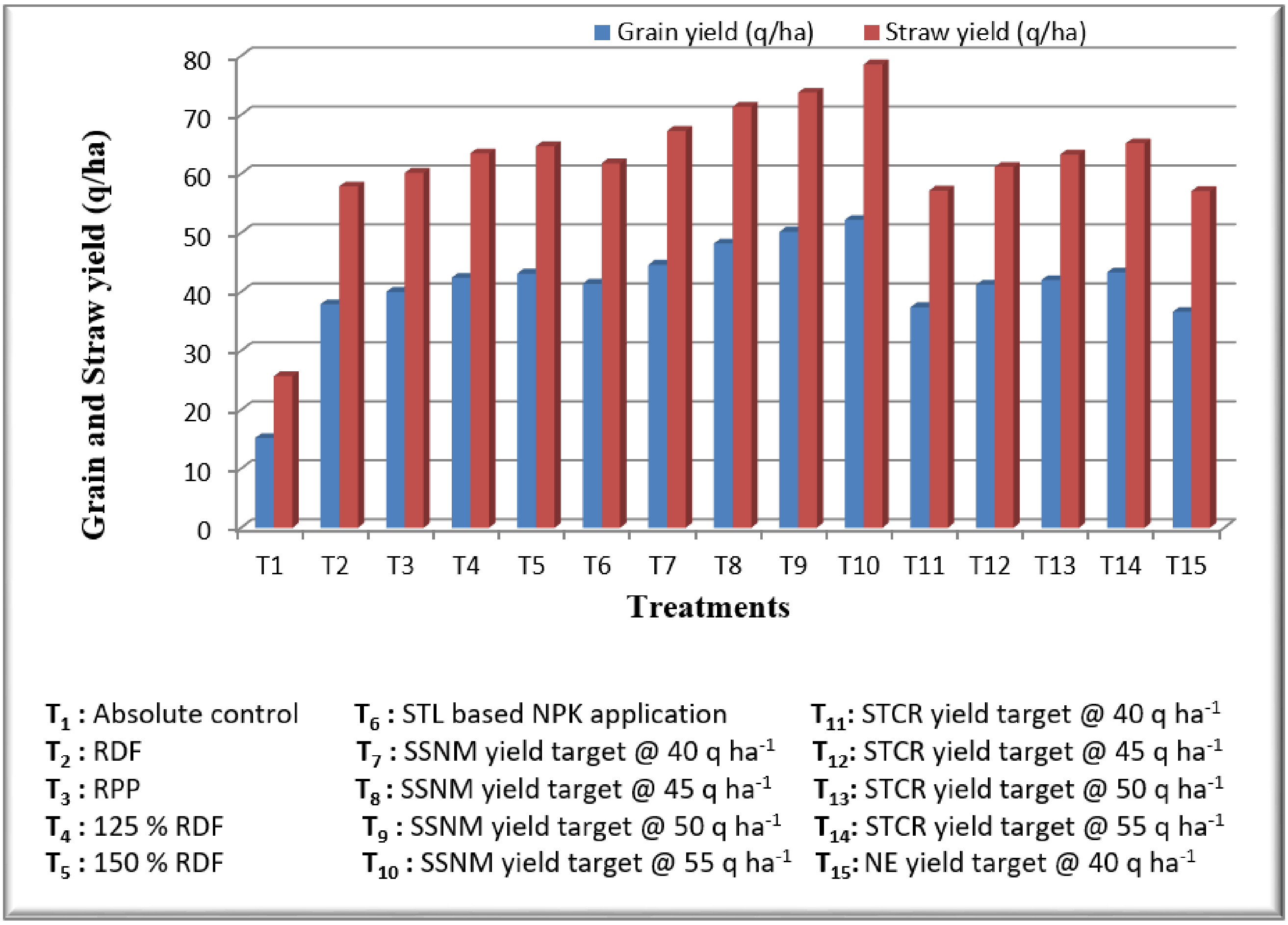

Fig 1: Grain and straw yields in wheat as influenced by precision nutrient management approaches

Economics in wheat as influenced by precision nutrient management approaches

The data indicated that the application of nutrients through different nutrient management approaches significantly influenced the economics in wheat (Table 4). The results revealed that higher gross (Rs. 1,50,368 ha^{-1}) and net (Rs. 97,940 ha^{-1}) returns and B:C ratio (2.87) and was statistically at par with yield targets at 50 (Rs. 1,44,482 ha^{-1}, Rs. 92,527 ha^{-1} and 2.78, respectively) and 45 q ha^{-1} (Rs. 1,38,614 ha^{-1}, Rs. 87,147 ha^{-1} and 2.69, respectively) under the same nutrient management practice and these treatments were significantly superior over remaining treatments (Fig. 2). The higher gross and net returns was attributed to higher grain and straw yields in wheat crop even with higher cost of cultivation (Pampolinoa *et al*., 2007) [5]. Similarly, Mauriya *et al*. (2013) [4] evaluated the effect of application of fertilizers by adopting SSNM approach on the productivity and economics in rice-wheat cropping system. The results indicated that higher net returns of Rs.67, 033 ha^{-1} annum^{-1} was obtained with SSNM mode of fertilizer application, which was Rs. 31,681 and Rs. 16,905 ha^{-1} annum^{-1} higher than farmers' practice and state recommendation, respectively. Higher B:C ratio (2.97) recorded in RDF was due to lower cost of cultivation (Rs. 36,811 ha^{-1}). The lower gross (Rs. 44,165 ha^{-1}) and net (Rs. 10,854 ha^{-1}) returns and B:C ratio (1.15) were recorded in absolute control and it could be due to lower grain and straw yields.

Table 4: Economics in wheat as influenced by precision nutrient management approaches

Treatments	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1	44,165	33,311	10,854	1.15
T_2	1,09,320	36,811	72,509	2.97
T_3	1,15,220	50,661	64,559	2.27
T_4	1,22,096	51,536	70,560	2.37
T_5	1,24,134	52,411	71,723	2.37
T_6	1,19,286	50,336	68,950	2.37
T_7	1,28,590	50,996	77,594	2.52
T_8	1,38,614	51,467	87,147	2.69
T_9	1,44,482	51,955	92,527	2.78
T_{10}	1,50,368	52,428	97,940	2.87
T_{11}	1,07,750	48,566	59,184	2.22
T_{12}	1,18,498	49,029	69,469	2.42
T_{13}	1,20,996	49,491	71,505	2.44
T_{14}	1,24,824	50,144	74,680	2.49
T_{15}	1,05,676	49,874	55,802	2.12
SEm±	8,066	-	8,066	0.16
CD(0.05)	23,367	-	23,367	0.46

Among the different yield targets under site test crop response approach, the yield target level 55 q ha^{-1} was found at par with 40, 45 and 50 q ha^{-1} yield targets with respect to gross and net returns and B:C ratio under the same nutrient management practice.

The application of nutrients through nutrient expert approach for yield targeting at 40 q ha^{-1} resulted in lower gross (Rs. 1,05,676 ha^{-1}), net (Rs. 55,802 ha^{-1}) returns and B:C ratio (2.12) among the different nutrient management approaches. The lowest economic returns in this treatment was mainly due to inadequate supply of nutrients to the crop that led to decrease in grain and straw yields in wheat when compared to other nutrient management approaches.

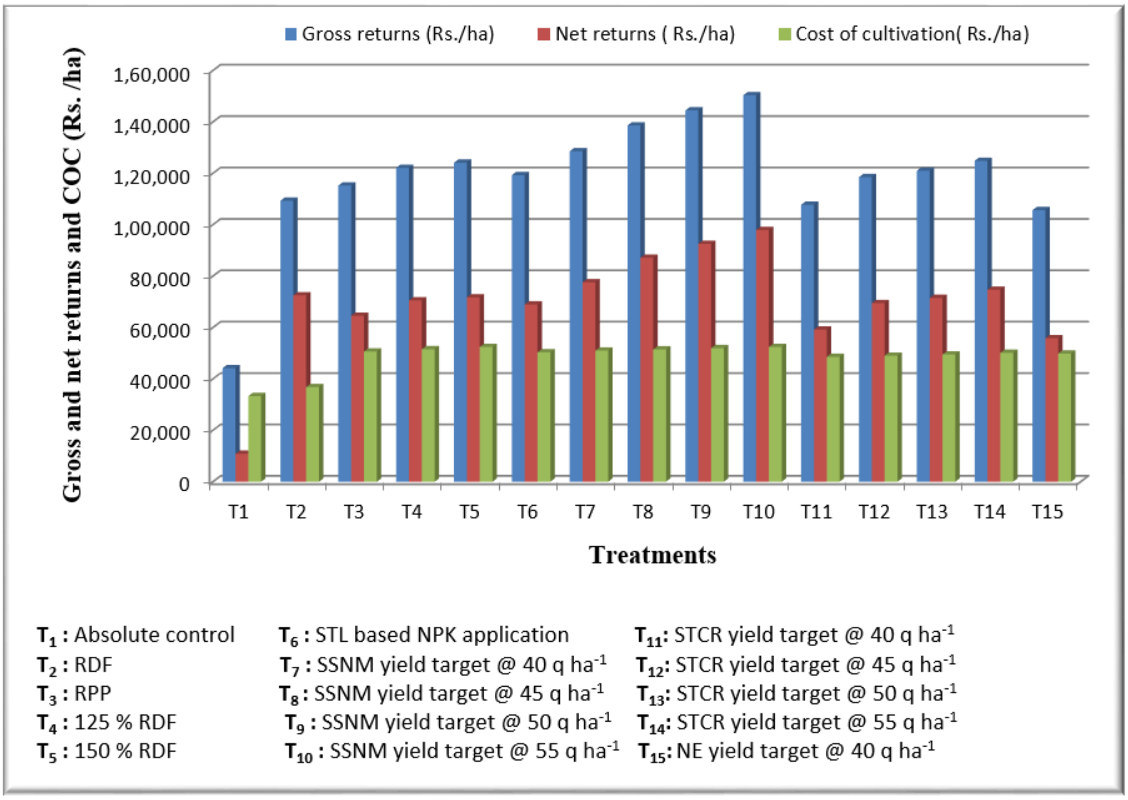

Fig 2: Economics in wheat as influenced by precision nutrient management approaches

Conclusion

That yield target at 50 q ha^{-1} was achieved with site specific nutrient management approach with higher net returns. Hence, it can be concluded that site specific nutrient management is the best approach for attaining higher yield with increased profitability in wheat in Vertisol and was followed by soil test crop response approach.

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