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Studies on Uptake of Nutrients by Bread Wheat (*Triticum aestivum* L.) as influenced by different Nutrient Management Approaches

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ABSTRACT: The present research on wheat was conducted during two consecutive *rabi* seasons (2020-22) at All India Co-ordinate Wheat and Barley Improvement Project, MARS, University of Agricultural Sciences, Dharwad The field research consisted of 15 treatments which are replicated thrice in a Randomized Complete Block Design (RCBD). Nowadays, farmers are trying to get high grain yields in line with food quality, at the same time trying to minimize production costs and to use environmental friendly technologies. The grain yield depends on the concentration and uptake of nutrients by the crop. There are various factors which influences the concentration and uptake of nutrients and among them climatic conditions, soil types, nature of crops and amount of fertilizers are important. Hence, the present investigation is proposed with the objective to study the uptake of major and micronutrients by wheat. The compiled data of two year study indicated that site specific management of nutrient strategy for achieving yield target of 55 q ha^{-1} by bread wheat significantly increased the concentration and uptake of nutrients by providing balanced nutrition tailored to the dynamic crop demand in the season. The study revealed that this particular approach is significantly superior over other approaches *viz*., soil test laboratory approach (STL), soil test crop response approach (STCR) and Nutrient Expert (NE) approach. Therefore, site specific management of nutrients is best approach for getting higher uptake of nutrients by wheat.

Keywords: SSNM, STCR, STL, Targeted yield, Uptake, Wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is described as "King of cereals" which belongs to family *Graminae* with centre of origin south west Asia. It is grown over a wide range of climatic conditions. In India it contributes nearly 25 per cent to the total food grain production. In India, wheat is grown over an area of 31.35 M ha with an annual production of 107.86 M t and productivity of 3440 kg ha^{-1} during 2020-21 (Anonymous, 2021). Major wheat producing states in India are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan and Bihar. Karnataka is unique in wheat cultivation where in all three cultivated species are sown. In Karnataka, the area under wheat is about 1.50 M ha with an annual production of 1.63 M t having productivity of 1198 kg ha^{-1} (Anonymous, 2021). When compared to other states wheat productivity is very low in Karnataka.

One of the main reasons of lower productivity is conventional blanket fertilizer recommendation, leading to imbalanced use of fertilizers and lower fertilizer use efficiency due to lower uptake of nutrients by the crop. Agricultural fields in India are highly variable due to different nutrient supplying capacity of soil. A recent on-farm study conducted by Majumdar *et al*. (2012) using the omission plot studies showed that wheat yield response ranged from 500-4750 kg ha^{-1}, 67-2806 kg ha^{-1} and 0–2222 kg ha^{-1} for N, P and K respectively, which is related to the soil nutrient supplying capacity. Khurana *et al*. (2008) working on irrigated wheat at 56 sites in six main wheat producing regions of Punjab also highlighted the variability in soil fertility across farmers' field sites. So it is imperative that the balanced fertilization in a site- specific manner to boost the attainable yields under on-farm situations.

Balanced nutrition enhances plant's ability to uptake and use nutrient efficiently from the soil (Ranjan *et al*. 2019). In the last five decades, the use of fertilizer has increased at a much faster rate as compared to plant yield (Hinsinger *et al*., 2011). The increase in production by enhancing soil fertility is a major challenge. If the nutrients deplete after the crop harvest, the soil fertility will go down and will create

environmental stress in soil. The most crucial component of modern technologies of crop production is using fertilizer in a balanced way (Zheng *et al*. 2017). Soil fertility evaluation helps the farmers to use fertilizer nutrients according to the need of the crop. Therefore soil testing is now accepted as a procedure for the recommendation of doses and kind of fertilizer nutrients. Fertilizer nutrient recommendations are usually given for different crops by taking into consideration the soil available nutrient status which is being categorised as low, medium and high. Among the various methods of fertilizer recommendations the soil test based- targeted yield approaches is unique in the sense that this method not only indicates the soil test-based fertilizer dose but also the level of yield the farmer can hope to achieve if good agronomic practices are adopted in crop cultivation (Basavaraja *et al*., 2017). In this regard, Site Specific Nutrient Management (SSNM), Soil Test Crop Response (STCR) and Nutrient Expert (NE) approaches are unique in the sense that these methods are efficient to obtain designed yields. These approaches are cost effective and plant need based fertilizer recommendation approaches. These approaches provide principles and tools for supplying crop nutrients to achieve higher yield. At the same time a balanced application of fertilizers based on these approaches takes care of inadequate/ excessive quantities of nutrient application.

Uptake of nutrients by the crop is a incessant process till maturity of the crop. The concentration and uptake of nutrients in plant parts depends on their need in various phenological stages of the plants and it changes from time to time. Hence, it is important to know the concentrations and uptake of nutrients by plants at various crop growth stages. This learning is helpful in analyzing the nutritional necessities of crop which helps in setting up the best approach for crop production. There are various factors which influences the concentration and uptake of nutrients and among them climatic conditions, soil types, nature of crops and amount of fertilizers are important. Hence, the present investigation is proposed with the objective to evaluate the effect of different fertilizer recommendation approaches on the uptake of *irrigated* wheat.

MATERIAL AND METHODS

Site and Soil. The field experiments were conducted for two years on a fixed site during *rabi* under *irrigated* condition. The study area was located in Northern Transition Zone (Zone VIII) of Karnataka and is situated at 15°26' North latitude, 75°07' East longitude and at an altitude of 678 m above mean sea level (MSL). The mean annual rainfall for the past 70 years (1950-2020) was 850.1 mm. The Maximum rainfall of 323.6 mm was received in the month of August followed by October (202.0 mm) during 2020-21. Similarly, during 2021-22 maximum rainfall received during 2021-22 was 187.4 mm in the month of July followed by November (156.2 mm). The mean monthly maximum temperatures of 35.8°C and 35.4°C were recorded in April and minimum temperatures of 14.6°C and 13.2°C were recorded in January, respectively during 2020-21 and 2021-22. The maximum relative humidity of 89 and 87 per cent was recorded in the month of August during 2020-21 and 2021-22, respectively. The initial soil properties and methods employed for analysis of soil are presented in Table 1.

Table 1: Initial soil properties.

Sr. No.	Particulars	Values	Methods employed	Reference
1.	Textural class	Clay loam		
2.	Soil reaction (1:2.5, soil water suspension)	7.67	Potentiometric method	Sparks (1996)
3.	Electrical conductivity (1:2.5, soil water extract) (dS m^{-1})	0.26	Conductometric method	Sparks (1996)
4.	Organic carbon (%)	0.68	Walkley and Black's wet oxidation method	Sparks (1996)
5.	Free calcium carbonate (g kg^{-1})	5.42	Rapid acid neutralization method	Piper (2002)
6.	Available N (kg ha^{-1})	176.9	Modified alkaline permanganate method	Sharawat and Burford (1982)
7.	Available P_2O_5 (kg ha^{-1})	33.77	Olsen's method of extraction followed by Spectrophotometric method	Sparks (1996)
8.	Available K_2O (kg ha^{-1})	361.68	Neutral Normal Ammonium acetate extraction followed by Flame photometric method	Sparks (1996)
9.	Available S (kg ha^{-1})	25.63	0.15% $CaCl_2$. 2 H_2O extraction followed by Turbidimetry	Sparks (1996)
10.	DTPA - extractable micronutrients (mg kg^{-1})		DTPA extraction followed by Atomic absorption spectrophotometric method	Lindsay and Norvell (1978)
a.	Copper	0.58		
b.	Iron	4.34		
c.	Manganese	6.18		
d.	Zinc	0.51		

Experimental design and treatments. The field experiments on wheat were laid out in completely randomized block design with fifteen treatments replicated thrice at AICW&BIP, MARS, UAS, Dharwad. The treatments consisting of various nutrient management approaches viz., site specific nutrient management (SSNM) and soil test crop response (STCR) for yield targets at 40, 45, 50 and 55 q ha^{-1}, Nutrient Expert (NE) yield approach target at 40 q ha^{-1} and soil test laboratory (STL). These different approaches were compared with application of 125 and 150 % of Recommended Dose of Fertilizer, Recommended Package of Practice and absolute control.

The dosage of fertilizer for soil test laboratory approach (T_6) was calculated on the basis of soil test results as suggested Bengar and Zende (1967). The experimental soil was low, medium and very high in available nitrogen (176.9 kg ha^{-1}), available phosphorus (33.77 kg ha^{-1}) and available potassium (361.68 kg ha^{-1}), respectively. Hence, additional 25 per cent of recommended fertilizer dose applied for low soil test ratings, no modification for medium soil rating and 50 per cent reduction in recommended dose of fertilizer for very high soil ratings.

The nutrients required to achieve target yield through site specific nutrient management (SSNM) was calculated by using the formulae as given by (Biradar *et al*., 2012).

Nutrients removal = Target yield (q ha^{-1}) × Nutrient removal by crop (q t^{-1})

Since initial nitrogen status of the experimental soil was low (176.9 kg ha^{-1}), the N dose required to set yield targets were increased by 20 per cent. No change in phosphorus dose was made as it was in medium range (33.77 kg ha^{-1}), while the quantity of K_2O was reduced by 20 per cent as the K status was high (361.68 kg ha^{-1}). The fertilizer doses for STCR treatments (T_{11} to T_{14}) were calculated by using standardized STCR equations for the Vertic Haplusterts brought from MPKV, Rahuri (Maharashtra) developed by AICRP on Soil Test Crop Response experiments, Indian Institute of Soil Science, Bhopal (M. P) for the validation of equations for the present conditions. The following equations were used to calculate the quantity of fertilizers in STCR based treatments.

FN = 7.54 T - 0.74 SN,

FP_2O_5 = 1.90 T - 2.88 SP,

FK_2O = 2.49 T - 0.22 SK

Where, T = Targeted yield (q ha^{-1}),

FN= Nitrogen to be supplied through fertilizer (kg ha^{-1}),

FP_2O_5 = Phosphorus to be supplied through fertilizer (kg ha^{-1}),

FK_2O = Potassium to be supplied through fertilizer (kg ha^{-1}) and

SN, SP and SK are initial soil test values for available N, P_2O_5 and K_2O in kg ha^{-1}, respectively.

Ready reckoner software developed by International Plant Nutrition Institute (IPNI), Gurugram (Haryana) in collaboration with International Maize and Wheat Improvement Center (CIMMYT), Mexico was used for making fertilizer recommendation (T_{15}). The treatment details and fertilizer recommendations based on these soil test values are depicted in Table 2.

Table 2: Quantity of fertilizer applied.

Treatment details	Quantity of fertilizers applied (kg ha^{-1})		
	N	P_2O_5	K_2O
T_1	-	-	-
T_2	100.00	75.00	50.00
T_3	100.00	75.00	50.00
T_4	125.00	93.75	62.50
T_5	150.00	112.50	75.00
T_6	125.00	75.00	25.00
T_7	200.40	29.33	98.40
T_8	225.00	33.00	110.40
T_9	250.00	36.67	123.20
T_{10}	275.00	40.33	135.20
T_{11}	170.70	0.00	20.04
T_{12}	208.40	0.00	32.49
T_{13}	246.10	0.00	44.94
T_{14}	283.80	7.25	57.39
T_{15}	80.00	53.00	45.00

The fertilizers were applied as per treatment recommendation. Nutrients like N, P and K were applied in the form of urea, SSP and MOP, respectively.

Soil analysis. Soil sample was collected from 0 to 30 cm depth before initiating the field experiment. Soil sample was air dried, powdered and sieved through 2 mm sieve and were analyzed for physical and chemical properties. Methods employed for the analysis of soil are depicted in Table 1.

Plant analysis. The plant samples were collected at 45 DAS, 75 DAS and at harvest of the wheat crop. The plant samples were shade dried for 2 to 3 days and then oven dried at 65°C for 12 hours followed by grinding in

Willey mill. The powdered plant samples were stored in butter paper bags for the estimation of nutrients. Methods adopted for the analysis of plant samples are depicted in Table 3.

Table 3.

Sr. No.	Properties	Methods adopted	Reference
1.	Total nitrogen	Modified Micro Kjeldahl method	Tandon (1998)
2.	Phosphorus	Diacid digestion followed by vanado molybdophosphoric yellow colour method	
3.	Potassium	Diacid digestion followed by Flame photometric method	
4.	Sulphur	Diacid digestion followed by Turbidimetery	
5.	Micronutrients (Cu, Fe, Mn and Zn)	Diacid digestion followed by Atomic Absorption Spectrophotometric method	

The uptake of nutrients by the wheat crop was calculated using the following equation.

$$\text{Uptake of Nutrients (kg ha}^{-1}) = \frac{\text{Nutrient concentration (\%)} \times \text{Dry matter production (kg ha}^{-1})}{100}$$

RESULTS AND DISCUSSION

Nutrient concentration and uptake of major nutrients. The highest nutrient concentration and total uptake of nitrogen, phosphorus, potassium and sulphur by wheat crop in pooled analysis was observed in the treatment with targeted yield of 55 q ha^{-1} under SSNM practice (T_{10}) and was statistically on par with yield targets at 50 (T_9) and 45 q ha^{-1} (T_8) under the same nutrient management practice and these treatments were significantly superior over rest of the treatments (Fig.1 to 4 and 9 to 12). The results are in corroboration with Mohanty *et al*. (2016) who revealed that application of nutrients through SSNM approach to wheat in sandy loam soil resulted in higher content and uptake of N (2.44 % and 127.8 kg ha^{-1}, respectively), P (0.44 % and 23.1 kg ha^{-1}, respectively) and K (0.608 % and 31.6 kg ha^{-1}, respectively) by wheat grain. Further, there was also improvement in the content and uptake of N (0.58 % & 32.2 kg ha^{-1}), P (0.059 % & 3.32 kg ha^{-1}) and K (1.89 % & 105 kg ha^{-1}) by wheat straw. It clearly shows that application of balanced fertilization based on target yield approach resulted in significantly higher nutrient contents and their uptake by grain and straw in wheat. The higher nutrient uptake is well reflected in terms of higher grain and straw yields in wheat (Madhusudhan, 2013). Similar results are also obtained by Biradar *et al*. (2013) who reported that the higher uptake of N (504.7 kg ha^{-1}), P (103.5 kg ha^{-1}) and K (212.3 kg ha^{-1}) by wheat grown on clay loam soil with application of fertilizers through SSNM approach for targeted yield of 10 t ha^{-1}. The results are in line with the observations made by Ashok *et al*. (2013) in wheat, Upendra *et al*. (2013) in rice, Sunil *et al*. (2018); Rajesh *et al*. (2018) in rice-wheat cropping sequence.

Further, among the targeted yield levels under STCR approach, 55 q ha^{-1} yield target (T_{14}) recorded highest nutrient contents and their uptake of nitrogen, phosphorus, potassium and sulphur by wheat crop when compared to other targeted yield levels under the same approach (Fig. 1 to 4 and 9 to 12). The higher uptake of nutrients by the crop in the said treatment might be attributed to balanced and optimum dose of fertilizers application by considering soil test crop response results and nutrients requirement to achieve the target yield. Vijaykumar *et al*. (2017) reported that higher N (140 kg ha^{-1}), P (26.9 kg ha^{-1}) and K (143.8 kg ha^{-1}) uptake by rice crop in non-calcareous sandy loam soil was recorded with the application of fertilizers on the basis of STCR approach for targeted yield of 9 t ha^{-1}. According to Anand *et al*. (2019), nutrient application based on STCR approach to wheat crop grown in silty loam soil at Meerut (UP) recorded significantly higher total uptake of N (115.92 kg ha^{-1}), P (33.39 kg ha^{-1}), K (127.23 kg ha^{-1}), S (76.47 kg ha^{-1}) and Zn (223.07 g ha^{-1}) by grain and straw in wheat. The present findings corroborated with the observations of Udayakumar *et al*. (2019) in pearl millet grown in alluvial soil and Vijay *et al*. (2021) also recorded higher uptake of N (79.65 kg ha^{-1}), P (18.44kg ha^{-1}) and K (106.76 kg ha^{-1}) by wheat grain with the application of nutrients through STCR approach. The favourable soil conditions with fertilizer recommendation of STCR approach might have paved the way for better absorption of nutrients, in tune with the growth and activity of roots which might have caused more production of dry matter.

The treatment receiving 150 per cent RDF (T_5) recorded numerically highest total uptake of nutrients by wheat crop than 125 per cent RDF (T_4), STL approach (T_6), RPP (T_3) and RDF (T_2). The higher uptake of nutrients by the wheat crop in the said treatment might be due to higher nutrient availability in the soil from the active pool. Similar observations are also made by Youssef *et al*. (2013) in wheat and Singh (2017) also observed that application of 150 per cent RDF significantly increased the uptake of N, P and K by wheat crop and this might be due to synergetic relation between the nutrients.

Fertilizer recommendation based on STL approach (T_6) to wheat crop resulted in higher uptake of nutrients by wheat crop as compared to RPP (T_3). This is obvious because of application of required quantity of N, P and

K fertilizers to the crop. Basavaraja *et al*. (2014) also reported that application of fertilizers through soil test laboratory approach resulted in higher uptake of N (136.58 kg ha^{-1}), P (13.17 kg ha^{-1}) and K (52.58 kg ha^{-1}) by maize crop in clay loam soil and the lower uptake of N (104.04 kg ha^{-1}), P (9.60 kg ha^{-1}) and K (33.80 kg ha^{-1}) was recorded in control. The results are in conformity with Biswas *et al*. (2015) who reported that application of nutrients through fertilizers as per Soil Test Laboratory recommendation accelerated the uptake of macro and micro nutrients by maize crop resulting in higher yield in maize.

Among various nutrient management approaches, Nutrient Expert practice (T_{15}) resulted in lower uptake of nutrients by wheat crop as compared to RPP (T_3) which might be due to lower or imbalanced supply of nutrients to the crop. There might not be optimum ratio between nutrients in nutrient expert technique leading to imbalanced application of nutrients. On the contrary, Kumar *et al*. (2015) recorded higher uptake of nutrients by maize crop with the application of fertilizers through Nutrient Expert practice which might be due to balanced fertilization based on target yield approach which resulted in significant increase in the content of nutrients and hence their uptake by grain and stover in maize.

Nutrient concentration and uptake of micronutrients. The treatment with 55 q ha^{-1} yield target (T_{10}) under SSNM practice significantly improved the nutrient concentration and uptake of micronutrients by the crop (Fig. 5 to 8 and 13 to 16). The highest uptake of micronutrients in SSNM treatments might be due to balanced and optimum dose of N, P and K fertilizers application along with $FeSO_4$ and $ZnSO_4$ which might have enhanced the growth and yield of the crop. It might also be due to higher dose of nitrogen application in the above said nutrient management practice. Nitrogen also exhibits synergism with many of micronutrients. Similarly, with increase in the levels of potassium application there was an increase in the uptake of other nutrients due to better translocation in plants as potassium has synergetic relation with many of the nutrients (Kumar *et al*., 2015). The results are in agreement with the findings of Hao *et al*. (2007) who revealed that the concentration and uptake of Cu, Fe, Mn and Zn by rice crop increased with increasing levels of nitrogen fertilizer as compared to absolute control indicating that the transportation ability of microelements from root to shoot was improved with nitrogen fertilizer application. There is a synergetic relationship between nitrogen with micronutrients. This relationship was obvious because nitrogen enhances vegetative growth and this further enhances uptake of micronutrients. Findings of the present studies are in accordance with the observations of Singh *et al*. (2008) in rice-wheat cropping system and Gill *et al*. (2009) in wheat based cropping.

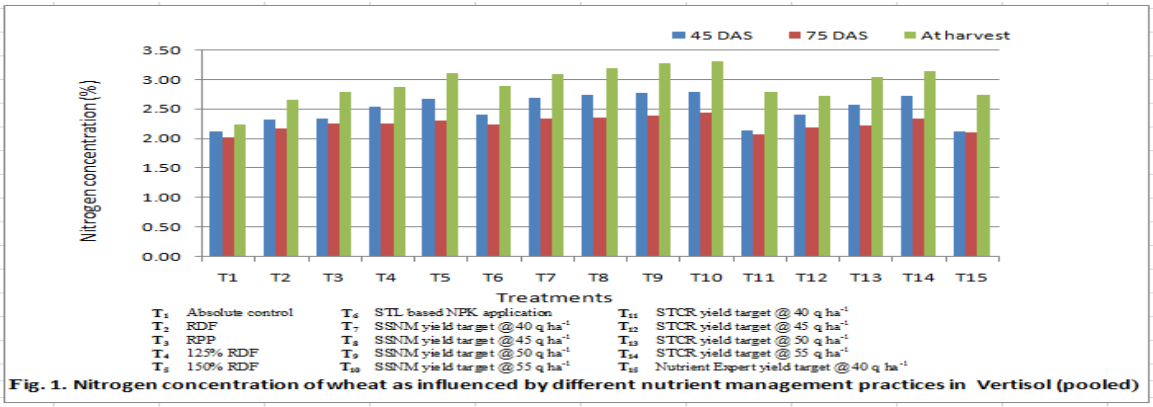

Fig. 1. Nitrogen concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

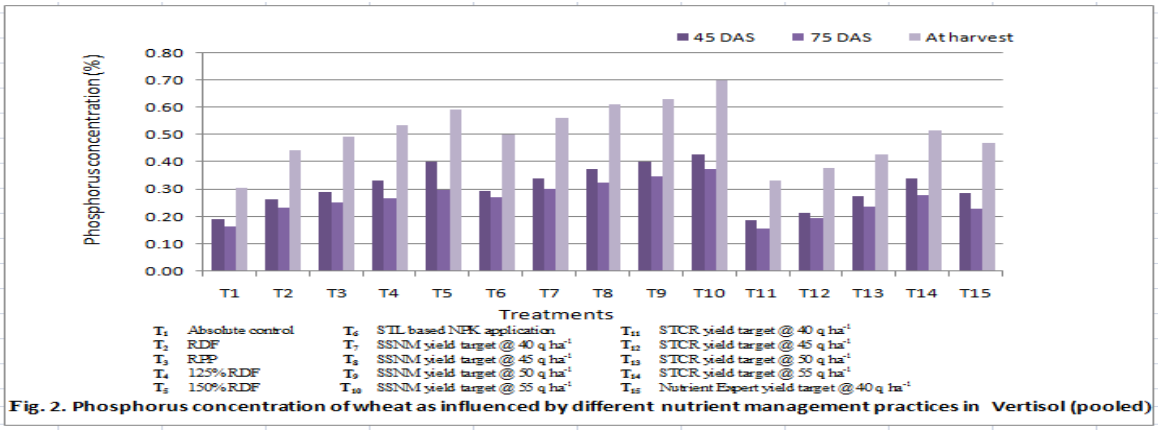

Fig. 2. Phosphorus concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

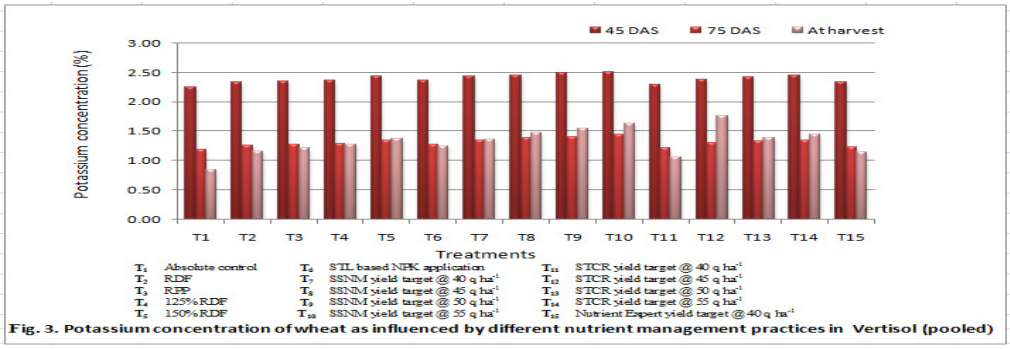

Fig. 3. Potassium concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

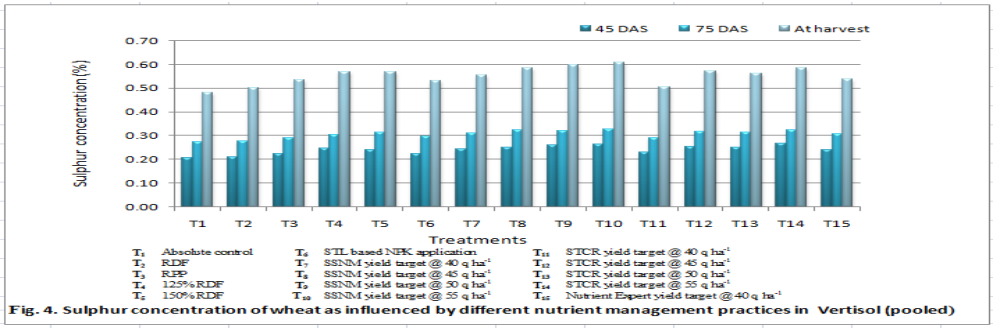

Fig. 4. Sulphur concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

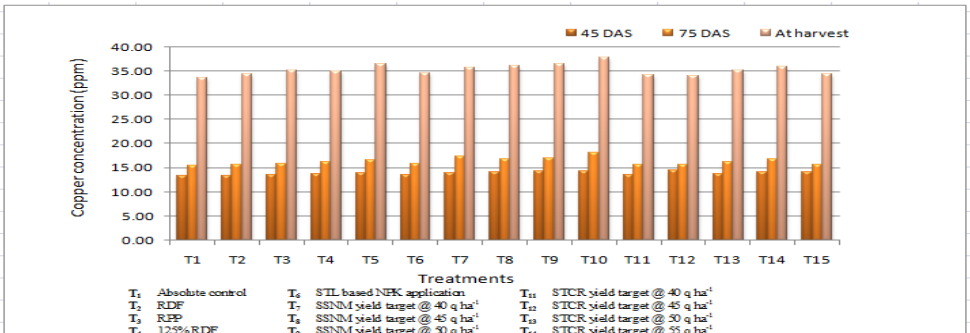

Fig. 5. Copper concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

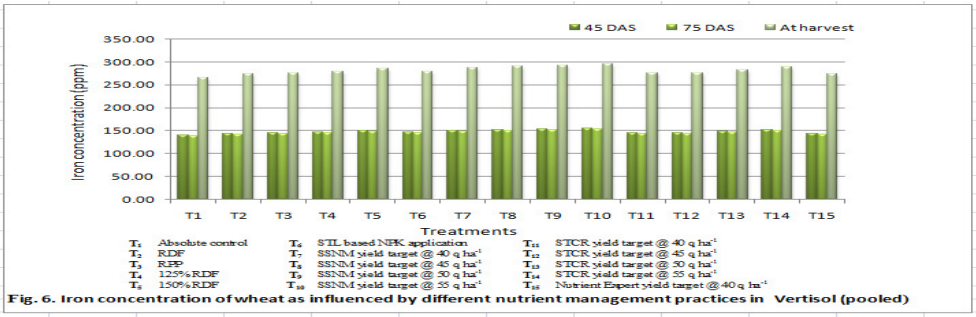

Fig. 6. Iron concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

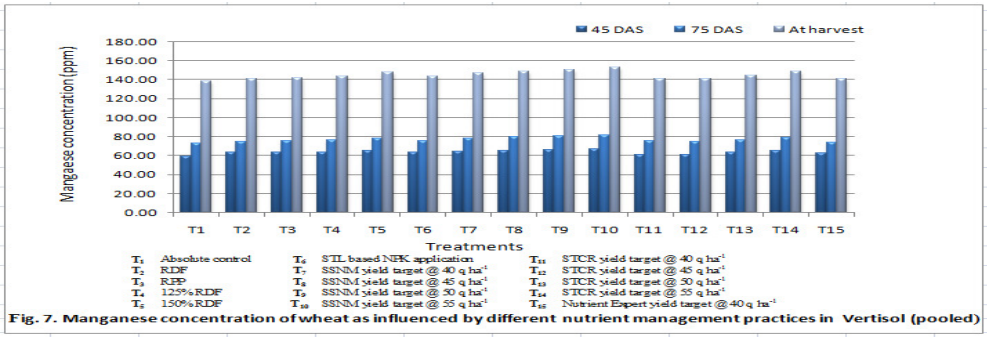

Fig. 7. Manganese concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

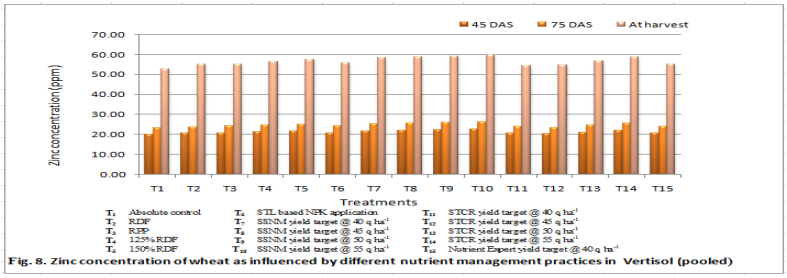

Fig. 8. Zinc concentration of wheat as influenced by different nutrient management practices in Vertisol (pooled)

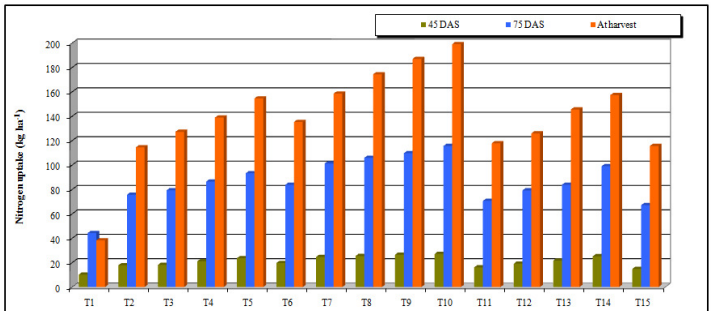

Fig. 9. Uptake of nitrogen by wheat as influenced by different nutrient management practices in Vertisol (pooled)

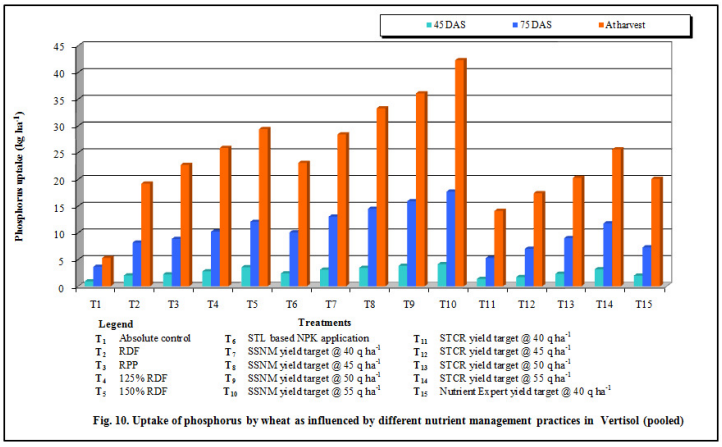

Fig. 10. Uptake of phosphorus by wheat as influenced by different nutrient management practices in Vertisol (pooled)

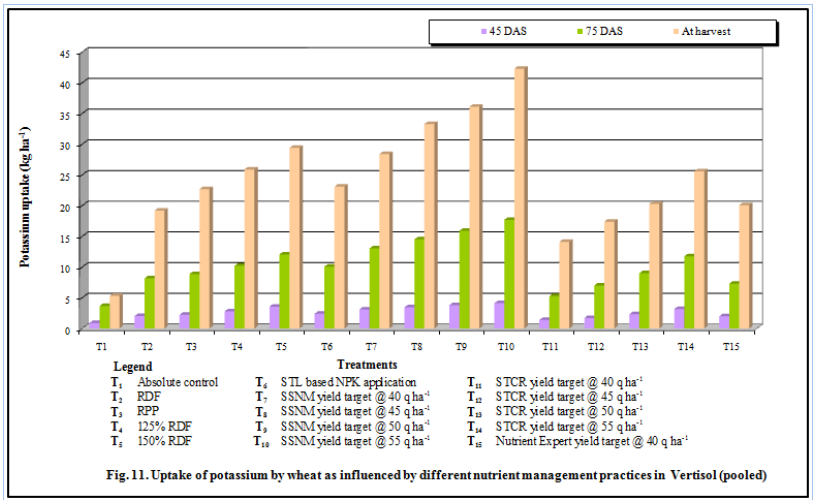

Fig. 11. Uptake of potassium by wheat as influenced by different nutrient management practices in Vertisol (pooled)

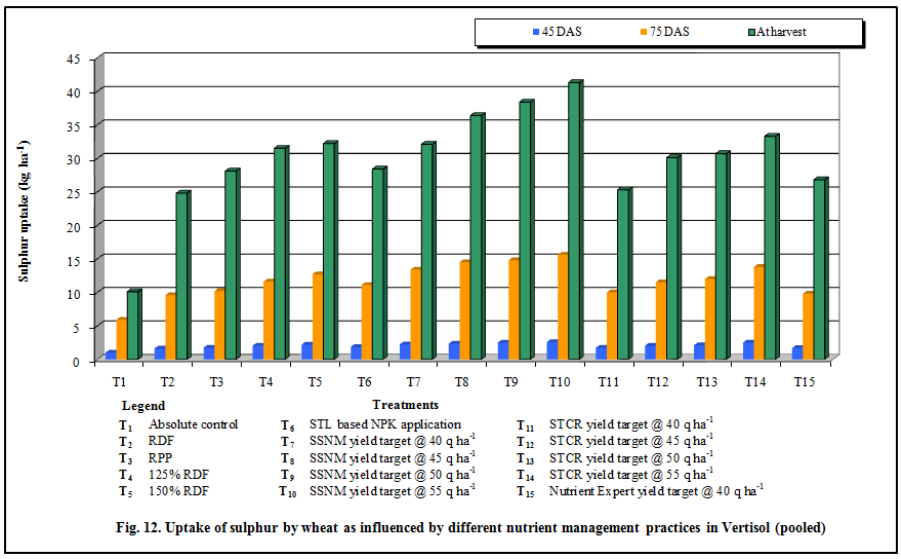

Fig. 12. Uptake of sulphur by wheat as influenced by different nutrient management practices in Vertisol (pooled)

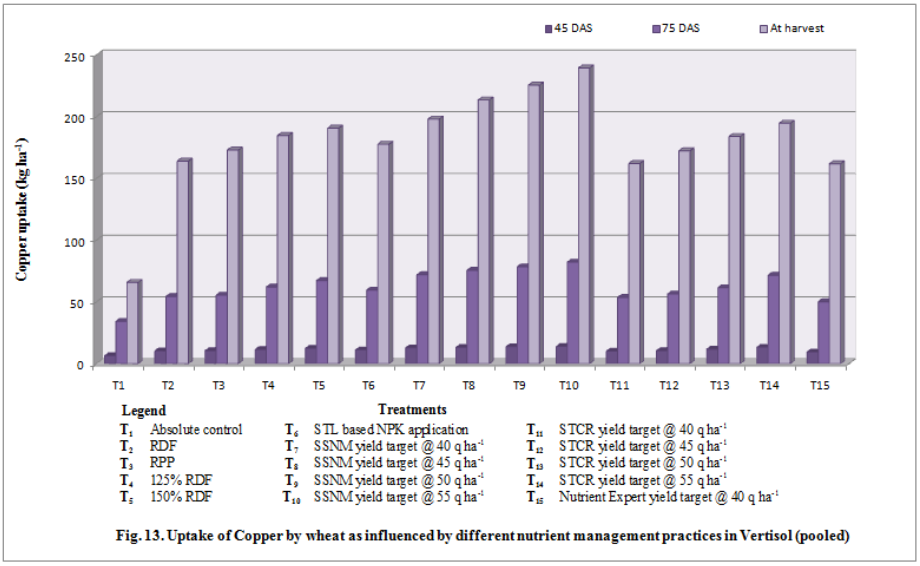

Fig. 13. Uptake of Copper by wheat as influenced by different nutrient management practices in Vertisol (pooled)

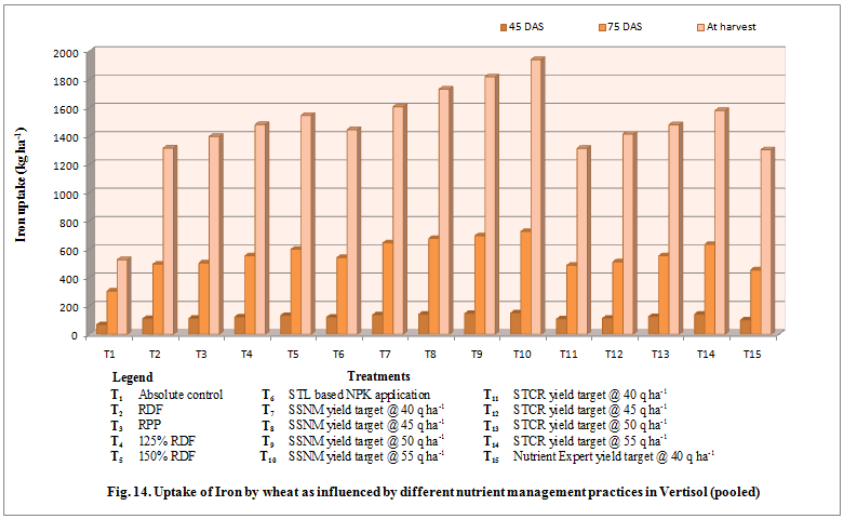

Fig. 14. Uptake of Iron by wheat as influenced by different nutrient management practices in Vertisol (pooled)

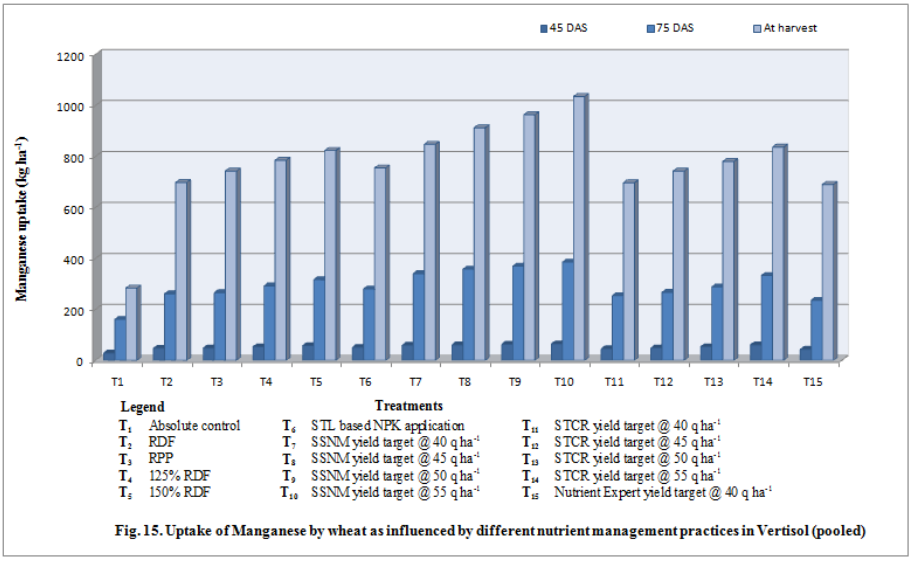

Fig. 15. Uptake of Manganese by wheat as influenced by different nutrient management practices in Vertisol (pooled)

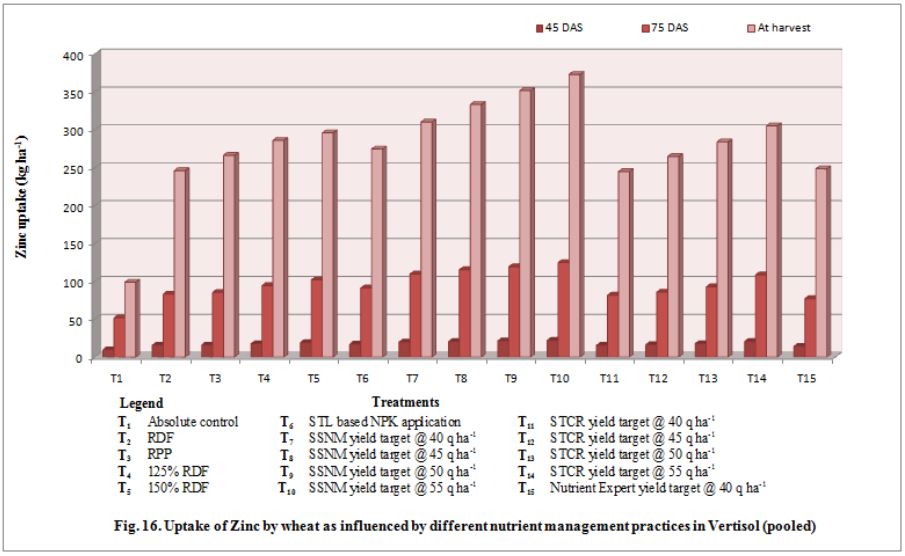

Fig. 16. Uptake of Zinc by wheat as influenced by different nutrient management practices in Vertisol (pooled)

CONCLUSION

Site specific nutrient management approach for yield targeted at 55 q ha^{-1} significantly increased the nutrient concentration and their uptake of major and micronutrients in wheat when compared to other approaches such as soil test laboratory (STL), soil test crop response (STCR) and nutrient expert (NE), 125 and 150 per cent RDF and RPP.

FUTURE SCOPE

Based on the results of present investigation, long term effect of nutrient management through targeted yield approaches on soil fertility and cropping sequence need to be studied.

Conflicts of Interest. None.

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