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K Reddy Tummala
Department of Soil Science and Agriculture Chemistry, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur, Maharashtra, India

Utkarsha Amolic
Department of Soil Science and Agriculture Chemistry, MPKV Rahuri, Maharashtra, India

PR Ramteke
Department of Soil Science and Agriculture Chemistry, Dr. PDKV Akola, Maharashtra, India

Corresponding Author:
K Reddy Tummala
Department of Soil Science and Agriculture Chemistry, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur, Maharashtra, India

Soil fertility and nutrient uptake of wheat (*Triticum aestivum* L.) as influenced by Integrated Nutrient Management in Inceptisol

K Reddy Tummala, Utkarsha Amolic and PR Ramteke

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Abstract
The present investigation was undertaken at Post Graduate Research Farm, College of Agriculture, Kolhapur during rabi 2016 to study the effect of Integrated nutrient management on soil fertility and nutrient uptake of wheat in Inceptisol. The experiment was laid out in a randomized block design with three replications and ten treatments. Studies revealed that the pH, EC, Calcium carbonate equivalent, available N, P and K content of soil after harvest of wheat crop were not affected significantly due to different treatments. However, the organic carbon content of soil after harvest of wheat increased significantly due to application of organic manures. The concentration of nitrogen (N), phosphorus (P) and potassium (K) in grain and stover of wheat were not affected significantly due to integrated nutrient management. The total uptake of nitrogen (N), Phosphorus (P) and potassium (K) were increased significantly due to application of organic manures along with inorganic fertilizers.

Keywords: INM, soil fertility, nutrient uptake

Introduction
Wheat (*Triticum aestivum* L.) is the World's most important widely cultivated food crop. Wheat is the most important staple food crop of India. It is consumed as food by millions of people especially in developing countries. Therefore, it is called as "King of Cereals". It is consumed in various forms by more than one thousand million human beings in the World. In India, it is second most important staple food crop after rice. Beside staple food for human beings, wheat straw is a good source of feed for a large population of cattle in our country and also used for manufacturing of straw boards, papers and other pulp products. In India total area under wheat is 29.8 million hectares and wheat production in 2015-16 was 93.50 Mt., India's share in global wheat production was recorded as 11.78%. Maharashtra ranks 8th amongst top ten largest wheat producing states in India in 2016 which is grown in the basins of rivers like Godavari, Krishna and Tapi (Anonymous, 2016) [1].

Integrated nutrient supply is the systematic approach to nutrient management as the combined application of organic and inorganic sources improves the soil fertility and crop productivity (Shree *et al*. 2014) [9]. Remarkable increase in nutrient uptake and yield by integrated nutrient supply have also been reported by Mohanty *et al*. (2013) [4]. High yielding wheat (*Triticum aestivum* L.) varieties and chemical fertilizers were introduced in India with the advent of green revolution. Since then, there was a continuous increase in fertilizer consumption. Securing the future of our next generation, we have to adopt those agricultural technologies and methodologies which will improve the production of crop without deteriorating soil health. Integrated use of organic manures and inorganic fertilizers has assumed great importance for sustainable production and maintaining soil health. In India, during the past three decades, intensive agriculture involving exhaustive high-yielding varieties of wheat has led to heavy withdrawal of nutrients from the soil. Furthermore, imbalanced use of chemical fertilizers by farmers has deteriorated soil health. There has been a phenomenal increase in their production after mid-sixties with the introduction of high yielding verities. To curb this trend of declining yield, there is a need to adopt the concept of integrated nutrient management. Improving and maintaining soil quality for enhancing and sustaining agricultural production is of utmost importance for India's food and nutritional security.

Though India is a food surplus nation at present with about 200 Mt food grain production per annum, it will require about 7-9 Mt additional food grains each year if the trend in rising population persists. This challenge can be met by greater and more efficient use of fertilizers and organic sources. Adoption of integrated plant nutrient supply and management strategies for enhancing soil quality, input use efficiency and crop productivity is extremely important for food and nutritional security in Indian agriculture. (Swarup, 2010) [11].

In view of this the present investigation was undertaken to study the soil fertility and nutrient uptake of wheat as influenced by integrated nutrient management in Inseptisol of College of Agriculture Farm, Kolhapur.

Material and Methods

The field experiment was carried out during rabi, 2016 in the randomized block design with ten treatments replicated thrice. The sowing of seeds of wheat cv. Phule Samadhan (NIAW1994) was done by line sowing by hand at 2-3 cm depth of soil and with line to line spacing of 22.5 cm to maintain uniform plant population. Treatments superimposed were T1-Absolute control, T2-RDN + RD of P_2O_5 and K_2O, T3-75% inorganic RDN + 25% RDN through FYM + RD of P_2O_5 and K_2O, T4-75% inorganic RDN + 25% RDN through PMC + RD of P_2O_5 and K_2O, T5-75% inorganic RDN + 25% RDN through Vermicompost + RD of P_2O_5 and K_2O, T6-50 % inorganic RDN + 50% RDN through FYM + RD of P_2O_5 and K_2O, T7-50% inorganic RDN + 50% RDN through PMC + RD of P_2O_5 and K_2O, T8-50% inorganic RDN + 50% RDN through Vermicompost + RD of P_2O_5 and K_2O, T9-100 % RDN through organics (33% FYM + 33% PMC + 33% V.C) + RD of P_2O_5 and K_2O, T10-Green manuring in situ of sunnhemp (2:1; wheat: sunnhemp) + RD of P_2O_5 and K_2O. FYM, PMC, Vermicompost were applied as per the treatments 15 days before sowing. Out of total recommended dose of fertilizer (120: 60: 40; N: P_2O_5: K_2O kg ha^{-1}) a basal dose of 60: 60: 40; N: P_2O_5: K_2O kg ha^{-1} was applied through urea, single super phosphate and muriate of potash and different organic manures as per the treatment details, except absolute control. The remaining half dose of nitrogen i.e. 60 kg ha^{-1} was applied at 25 days after sowing through urea except absolute control. The plant and soil samples collected at harvest were analysed for different parameters by adopting standard procedures.

Soil pH was analysed by potentiometry method using 1:2.5 SW ratio (Jackson 1973) [3], EC by conductometry methods (Jackson 1973) [3], organic carbon by wet oxidation method (Nelson and Sommers 1982) [5], per cent CaCO3 equivalent by rapid titration method (Piper 1966) [8], Available Nitrogen by Alkaline permanganate methods (Subbiah and Asija 1956) [10], Available Phosphorus using 0.5M sodium bicarbonate pH 8.5 (Olsen *et al*. 1965) [6], Available Potassium by neutral normal ammonium acetate method (Jackson 1973) [3].

Table 1: Basic soil properties of experimental site

Sr. No	Parameters	Value
1	Soil Texture	Silty clay
2	pH (1:2.5)	7.75
3	EC (dS m^{-1})	0.28
4	Organic carbon (%)	0.46
5	Calcium carbonate equivalent (%)	5.51
6	Available nitrogen (kg ha^{-1})	163
7	Available phosphorus (kg ha^{-1})	23.88
8	Available potassium (kg ha^{-1})	250.1

Table 2: Per cent nutrient content of different organic manures on oven dry basis

Organic manures	N	P	K	S
FYM	0.49	0.18	0.50	0.12
PMC	1.26	1.47	1.54	2.46
Vermicompost	1.26	1.00	1.48	0.54
Sunhemp green manure	2.30	0.50	1.80	0.17

Statistical Analysis

The experimental data were analyzed statistically by applying the technique of "Analysis of variance" and significance was tested by variance ratio i.e. F value at 5 per cent level of significance as described by Panse and Sukhatme (1967) [7]. Standard error of mean (S.Em.) and critical difference (CD) was worked out to evaluate differences between treatment means.

Result and discussion

Effect on soil fertility

The data in respect of effect of integrated nutrient management on different chemical properties of soil after harvest of wheat is presented in Table No 3.

The data revealed that the pH, EC, calcium carbonate and available N, P, and K content of soil after harvest of wheat were not influenced significantly due to different treatments indicating no significant residual effect of manures and fertilizers within one season. The organic carbon per cent in soil after harvest of wheat was increased significantly due to application of organic manures and green manuring. The treatment T10 Green manuring with sunnhemp recorded significantly highest organic carbon (0.60%) content but it was at par with T9 (100% RDN through 33% FYM + 33% PMC + 33% VC). Similar increase in organic carbon status of soil with use of organic manures have been reported by Yadav *et al*. (2009) [12].

Effect on Nutrient Uptake

Effect of Integrated Nutrient Management on Concentration of Nitrogen in Grain and Stover and Total Uptake of Nitrogen by Wheat at Harvest

The data in respect of effect of integrated nutrient management on concentration of nitrogen in grain and stover and total uptake of nitrogen by wheat at harvest is presented in Table No. 4.

The data revealed that there was no significant effect on concentration of nitrogen in grain and stover at harvest of wheat. The total nitrogen uptake in wheat at harvest increased significantly due to application of organic manures along with inorganic fertilizers. The treatment T4 (75% RDN + 25% RD of N through PMC + RD of P_2O_5 and K_2O) recorded significantly highest total nitrogen uptake (102.76 kg ha^{-1}), however it was at par with T5 (75% RDN + 25% RD of N through VC + RD of P_2O_5 and K_2O), T3 (75% RDN + 25% RD of N through FYM + RD of P_2O_5 and K_2O) and T2 (100% + RD of P_2O_5 and K_2O). The significantly highest total nitrogen uptake was obtained due to substitution of 25% inorganic nitrogen with different organic manures *viz*: FYM, PMC, VC. Application of GRDN + GRD of P_2O_5 and K_2O through inorganic fertilizers supplied N to wheat through it's growing period, thus improving the FUE of applied nitrogen. Further substituting 50% inorganic N with organic N through different organic manures significantly reduced the total nitrogen uptake however, the total nitrogen uptake was significantly higher over absolute control. Green manuring of sunnhemp in wheat increased the total nitrogen uptake of wheat significantly over absolute control indicating the favorable effect of green manuring on soil and crop. The significant increase in the uptake of total nitrogen might be

due to combined application of organic manures and inorganic fertilizers due to which there was continuous supply of N throughout growing season. The findings are accordance with those reported by Bahadur *et al*. (2013) [2].

Effect of Integrated Nutrient Management on Concentration of Phosphorus in Grain and Stover and Total Uptake of Phosphorus by Wheat at Harvest

The data in respect of effect of integrated nutrient management on concentration of phosphorus in grain and stover and uptake of phosphorus by wheat at harvest is presented in Table No. 5.

The data revealed that there was no significant effect on concentration of phosphorus in grain and stover of wheat at harvest. The total phosphorus uptake in wheat at harvest increased significantly due to application of organic manures along with inorganic fertilizers. The treatment T4 (75% RDN + 25% RD of N through PMC + RD of P_2O_5 and K_2O) recorded significantly highest uptake of phosphorus (33.88 kg ha^{-1}), however it was at par with T5 (75% RDN + 25% RD of N through VC + RD of P_2O_5 and K_2O), T3 (75% RDN + 25% RD of N through FYM + RD of P_2O_5 and K_2O) and T2 (100% + RD of P_2O_5 and K_2O). The significantly higher total phosphorus uptake was obtained due to substitution of 25% inorganic nitrogen with different organic manures FYM (31.68 kg ha^{-1}), PMC (33.88 kg ha^{-1}), VC (32.87 kg ha^{-1}) over rest of the treatments. Further substituting 50% inorganic N with organic N through different organic manures significantly reduced the total phosphorus uptake however, the total phosphorus uptake was significantly higher over absolute control. Green manuring of sunnhemp in wheat increased the total phosphorus uptake of wheat significantly (16.61 kg ha^{-1}) over absolute control (11.16 kg ha^{-1}) indicating the favorable effect of green manuring on soil and crop. The significant increase in the uptake of total phosphorus might be due to combined application of organic and inorganic fertilizers due to which availability of nutrients increased during crop growth. The findings are accordance with those reported by Bahadur *et al*. (2013) [2].

Effect of Integrated Nutrient Management on Concentration of Potassium in Grain and Stover and Total Uptake of Potassium by Wheat at Harvest

The data in respect of integrated nutrient management on concentration of potassium in grain and stover and total uptake of potassium by wheat at harvest is presented in Table No.6.

The data revealed that there was no significant effect on concentration of potassium in grain and stover at harvest of wheat. The total potassium uptake in wheat at harvest increased significantly due to application of organic manures along with inorganic fertilizers. The treatment T4 (75% RDN + 25% RD of N through PMC + RD of P_2O_5 and K_2O) recorded significantly highest uptake of potassium (114.78 kg ha^{-1}) however it was at par with T5 (75% RDN + 25% RD of N through VC + RD of P_2O_5 and K_2O), T3 (75% RDN + 25% RD of N through FYM + RD of P_2O_5 and K_2O) and T2 (100% + RD of P_2O_5 and K_2O). The significantly highest total potassium uptake was obtained due to substitution of 25% inorganic nitrogen with different organic manures *viz*: FYM, PMC, VC. Green manuring of sunnhemp in wheat increased the total potassium uptake of wheat significantly over absolute control indicating the favorable effect of green manuring on soil and crop. The increase in the uptake of potassium might be due to combined application of organic and inorganic fertilizers due to which availability of nutrients increased due to favorable soil condition. These findings are accordance with those reported by Bahadur *et al*. (2013) [2].

Table 3: Effect of Integrated Nutrient Management on soil fertility parameters at wheat harvest

Treatment	pH (1:2.5)	EC (dS m^{-1})	Calcium carbonate equivalent (%)	Organic carbon (%)	Available nutrients (kg ha^{-1})		
					N	P	K
T_1 (Absolute Control)	7.72	0.28	5.65	0.47	159.81	21.35	250.13
T_2 (RDN + RD of P_2O_5 & K_2O)	7.73	0.27	6.44	0.49	169.34	27.25	272.53
T_3 (75% RDN + 25% RDN through FYM + RD of P_2O_5 & K_2O)	7.77	0.29	5.91	0.51	170.46	27.69	272.53
T_4 (75% RDN + 25% RDN through PMC + RD of P_2O_5 & K_2O)	7.73	0.26	6.17	0.51	174.56	28.74	276.26
T_5 (75% RDN + 25% RDN through VC + RD of P_2O_5 & K_2O)	7.71	0.27	6.05	0.50	172.50	29.49	276.26
T_6 (50% RDN + 50% RDN through FYM + RD of P_2O_5 & K_2O)	7.72	0.28	6.36	0.54	166.49	25.78	265.06
T_7 (50% RDN + 50% RDN through PMC + RD of P_2O_5 & K_2O)	7.74	0.26	6.36	0.55	164.39	26.05	268.80
T_8 (50% RDN + 50% RDN through VC + RD of P_2O_5 & K_2O)	7.76	0.29	6.27	0.54	165.20	26.98	265.06
T_9 (100% RDN through (33% FYM + 33% PMC + 33% VC) + RD of P_2O_5 & K_2O)	7.71	0.27	5.86	0.57	163.35	25.01	261.33
T_{10} (Green manuring*in situ* (2:1;wheat:sannhemp) RD of P_2O_5 & K_2O)	7.73	0.26	5.73	0.60	162.22	24.18	253.86
S.E ±	0.03	0.009	0.20	0.01	3.07	1.84	5.38
CD (P=0.05)	NS	NS	NS	0.04	NS	NS	NS

Table 4: Effect of Integrated Nutrient Management on Concentration of Nitrogen in Grain and Stover and Total Uptake of Nitrogen by Wheat at Harvest

Treatment	Concentration (%)		N Uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
	Grain	Stover	Grain	Stover	
T_1 (Absolute Control)	1.52	0.40	28.19	10.16	38.35
T_2 (RDN + RD of P_2O_5& K_2O)	1.59	0.50	66.23	28.48	94.71
T_3 (75% RDN + 25% RDN through FYM + RD of P_2O_5 & K_2O)	1.60	0.50	66.52	29.65	96.18
T_4 (75% RDN + 25% RDN through PMC + RD of P_2O_5 & K_2O)	1.63	0.51	70.66	32.07	102.76
T_5 (75% RDN + 25% RDN through VC + RD of P_2O_5 & K_2O)	1.62	0.51	68.15	32.84	101.00
T_6 (50% RDN + 50% RDN through FYM + RD of P_2O_5 & K_2O)	1.53	0.45	54.36	22.30	74.66
T_7 (50% RDN + 50% RDN through PMC + RD of P_2O_5 & K_2O)	1.56	0.47	57.45	24.67	82.12
T_8 (50% RDN + 50% RDN through VC + RD of P_2O_5 & K_2O)	1.54	0.46	56.09	23.04	79.13
T_9(100% RDN through (33% FYM + 33% PMC + 33% VC) + RD of P_2O_5 & K_2O)	1.53	0.43	50.45	18.87	69.32
T_{10} (Green manuring *in situ* (2:1;wheat:sannhemp) RD of P_2O_5 & K_2O)	1.52	0.42	40.44	14.52	54.97
S.E ±	0.04	0.03	2.23	2.05	3.72
C.D.(P=0.0.5)	NS	NS	6.64	6.11	11.07

Table 5: Effect of Integrated Nutrient Management on Concentration of Phosphorus in Grain and Stover and Total Uptake of Phosphorus by Wheat at Harvest

Treatment	Concentration (%)		P Uptake (kg ha^{-1})		Total P uptake (kg ha^{-1})
	Grain	Stover	Grain	Stover	
T_1 (Absolute Control)	0.37	0.17	6.87	4.29	11.16
T_2 (RDN + RD of P_2O_5& K_2O)	0.44	0.22	18.05	12.46	30.52
T_3 (75% RDN + 25% RDN through FYM + RD of P_2O_5 & K_2O)	0.45	0.22	18.85	12.83	31.68
T_4 (75% RDN + 25% RDN through PMC + RD of P_2O_5 & K_2O)	0.45	0.23	19.49	14.39	33.88
T_5 (75% RDN + 25% RDN through VC + RD of P_2O_5 & K_2O)	0.45	0.23	18.93	13.94	32.87
T_6 (50% RDN + 50% RDN through FYM + RD of P_2O_5 & K_2O)	0.41	0.19	14.59	9.41	24.00
T_7 (50% RDN + 50% RDN through PMC + RD of P_2O_5 & K_2O)	0.42	0.20	15.43	10.41	25.84
T_8 (50% RDN + 50% RDN through VC + RD of P_2O_5 & K_2O)	0.42	0.20	15.27	9.97	25.24
T_9 (100% RDN through (33% FYM + 33% PMC + 33% VC) + RD of P_2O_5 & K_2O)	0.40	0.18	13.14	7.91	21.06
T_{10} (Green manuring *in situ* (2:1;wheat:sannhemp) RD of P_2O_5 & K_2O)	0.39	0.18	10.40	6.21	16.61
S.E ±	0.02	0.018	1.04	1.14	1.74
C.D.(P=0.0.5)	NS	NS	3.09	3.38	5.17

Table 6: Effect of Integrated Nutrient Management on Concentration of Potassium in Grain and Stover and Total Uptake of Potassium by Wheat at Harvest

Treatment	Concentration (%)		K Uptake (kg ha^{-1})		Total K uptake (kg ha^{-1})
	Grain	Stover	Grain	Stover	
T_1 (Absolute Control)	0.74	1.19	13.70	30.05	43.90
T_2 (RDN + RD of P_2O_5 & K_2O)	0.79	1.25	32.66	71.59	104.26
T_3 (75% RDN + 25% RDN through FYM + RD of P_2O_5 & K_2O)	0.80	1.26	33.25	73.41	106.67
T_4 (75% RDN + 25% RDN through PMC + RD of P_2O_5 & K_2O)	0.81	1.27	35.41	79.37	114.78
T_5 (75% RDN + 25% RDN through VC + RD of P_2O_5 & K_2O)	0.81	1.27	34.15	77.30	111.46
T_6 (50% RDN + 50% RDN through FYM + RD of P_2O_5 & K_2O)	0.76	1.22	27.06	60.36	87.42
T_7 (50% RDN + 50% RDN through PMC + RD of P_2O_5 & K_2O)	0.77	1.23	28.28	64.10	92.38
T_8 (50% RDN + 50% RDN through VC + RD of P_2O_5 & K_2O)	0.77	1.23	28.14	61.67	89.81
T_9 (100% RDN through (33% FYM + 33% PMC + 33% VC) + RD of P_2O_5 & K_2O)	0.75	1.20	24.62	52.90	77.52
T_{10} (Green manuring*in situ* (2:1;wheat:sannhemp) RD of P_2O_5 & K_2O)	0.75	1.20	19.95	52.87	72.82
S.E ±	0.02	0.08	1.72	5.19	5.54
C.D.(P=0.0.5)	NS	NS	5.13	15.42	16.47

Conclusion

There was no significant difference in available N, P and K content after harvest of wheat in soil indicating no residual effect of manures and fertilizers, there was significant increase in organic carbon content (0.60%) in the treatment T10 (Green manuring in situ + RD of P2O5 & K2O) but it was at par with T9 (100% RDN through 33% FYM + 33% PMC + 33% VC + RD of P2O5 & K2O). The highest total uptake of nitrogen, phosphorus and potassium by wheat was observed due to the substitution of 25% RDN through pressmud cake (T4) however it was at par with T5, T3 and T2. The results of the present investigation indicate that it is possible to replace 25% inorganic nitrogen through organic manures *viz*: PMC, VC and FYM with maintaining yield and organic carbon status of soil.

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