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Residual Effect of Integrated Nutrient Management on Yield and Nutrients Uptake of Wheat under Rice-Wheat System

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A B S T R A C T

A field experiment was conducted during *kharif* season at Rajendra Agricultural University, Pusa to assess the residual impact of conjoint use of organics and chemical fertilizers on yield and nutrients uptake of wheat under rice-wheat system. Results revealed that among the organics, FYM 10 t ha^{-1} application, produced highest grain yield (36.38 q ha^{-1}) followed by Straw (32.84 q ha^{-1}), Dhaincha (GM) (28.93q ha^{-1}) and Urd (27.61 q ha^{-1}). Increasing levels of inorganic fertilizers also increased the wheat grain and straw yield with the maximum grain (36.34 q ha^{-1}) and straw (51.95 q ha^{-1}) yield was observed in 100% recommended NPK treatment. Among all the treatments, highest grain yield (41.67 q ha^{-1}) and uptake of major nutrients *i.e.* N (108.37kg ha^{-1}), P (25.45kg ha^{-1}) and K (99.03 kg ha^{-1}) in wheat were observed under combined application of 100% NPK + FYM. Besides this, the fertilizer use efficiency (FUE) for N, P and K was found maximum in the treatment replacing 50% of N through FYM + 50% NPK. Thus, higher yield at balanced nutrition is safe guard for soil fertility and integrated plant nutrient supply system could help in meeting the goals of balanced fertilization as well as ita reliable way for obtaining fairly high productivity with increased FUE and an alternative practice towards sustainable agriculture.

Introduction

Among the cereals, rice and wheat are the world's most important staple food crops and are generally grown in sequence in the South Asia occupying an area of about 13.5 million ha of prime agricultural land in Bangladesh, India, Nepal, and Pakistan, with another 12 million ha in China (Ladha *et al.,* 2000). In India alone, the system occupies about 10.0 million ha in the Indo-Gangetic plains (IGP) mostly located in UP (4.8 m ha), Punjab (1.5 m ha), Bihar (1.6 m ha), MP (1.3 m ha) and Haryana (0.5 m ha) (Singh *et al.,* 1994; Modgal *et al.,* 1995; Ladha *et al.,* 2005) and provides food security for 400 million of people (Ladha *et al.,* 2000). At global level, India ranks as second largest wheat producing nation and contributing approximately 11.9% to the world wheat production from about 12% of global area (USDA, 2010).The area under wheat throughout the world as well as in India has become nearly constant around 217.9 million ha and 26.9 million ha respectively. Wheat contributes about 30% of total grain production in India. Long time studies being carried out at several locations in India indicated that application of all the needy nutrients through chemical fertilizers have deterious effect on soil health leading to unsustainable yields. Looking at the actual scenario in the northern alluvial belt, it seems that available resources and input use may account for higher productivity in Punjab and poor yields in Bihar (Modgal *et al.,* 1995).

These variations in productivity may be due to variations in the agro-ecological conditions, degree of water control, levels of inputs used and farmers' skill. This system is primarily dependent on inorganic fertilizers only. Deficit in availability of fertilizer nutrients is one problem and declining tendency in rice-wheat productivity due to continuous use of only inorganic fertilizers in the system is the other (Ladha *et al.,* 2005; Rahman *et al.,* 2009). In order to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields. The rice-wheat cropping system needs higher inputs and the declining trends in system's productivity due to depletion of organic matter in the soil, which results disturbance in soil aggregation, soil productivity and soil health (Abrol and Gill, 1994; Modgal *et al.,* 1995; Patro *et al.*, 2011) need to be taken care of prudently. Since the farmers of the region are resource poor, therefore, there is a need for complete or partial substitution of inorganic fertilizers, by locally available organic sources for sustaining rice production (Acharya and Mandal, 2010; Brahmachari *et al.*, 2011).

Therefore, there is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizers in conjunction with organic manures coupled with input through biological processes (Prasad *et al.,* 1995; Aulakh, 2010). Moreover, application of imbalanced nutrients could lead to declining nutrient-use efficiency making fertilizer consumption uneconomical and adversely affecting the atmosphere (Aulakh and Adhya, 2005) and groundwater quality (Aulakh *et al.*, 2009) causing health hazards and climate change. Under such a condition, there is need to explore the possibilities of using the expanding native sources of plant nutrient.

The organic sources of nutrients like dhaincha, rice straw and green legumes (Dixit and Gupta, 2000) and organic manure such as FYM (Kumari *et al.,* 2010) are gaining global importance for rice-wheat system. In this context, the present study was undertaken to study the effect of integrated supply of inorganic fertilizers along with some organic sources of nutrients on yield, nutrients uptake by wheat under intensively cultivated rice-wheat cropping systems.

Materials and Methods

Site description

The field experiment was conducted with test crop wheat in rice-wheat copping system on an Inceptisols at North Chhawania of Rajendra Agricultural University, Pusa, Bihar, India (25° 58' 41" N latitude, 85° 40' 24" E longitude and 52.4 m above mean sea level). The climate is hot, humid subtropics with an average annual rainfall of approximately 1380 mm and mean annual minimum and maximum temperatures of 13.5 and 38.2ºC, respectively. The soil is hyperthermic (AericHaplaquept) according to US Soil Taxonomy, Soil Survey Staff (2003) and sandy loam in texture. The pH of the soil at the start of experiment was neutral (pH 8.5) in reaction with sand, silt, and clay values of 57.76, 28.23 and 14.01%, respectively.

The oxidizable organic C, available N, P and K content of the soil (0-0.2 m) are 5.1 g kg^{-1}, 200.32 kg ha^{-1}, 14.46 kg ha^{-1} and 96.18 kg ha^{-1}, respectively. The bulk density and cation exchange capacity values of the initial soil were 1.35 Mg m^{-3} and 31.0 Cmol (p+) kg^{-1}, respectively.

Description of field experiment

Wheat was grown under irrigated condition following the standard package of practices. The popularly grown wheat cultivar *HUW-206*was used for the experiment. The experimental plot was well drained and had uniform topography with assured tube well irrigation facility.

The experiment was laid out in a split plot design with five main plot treatments and five sub-plot treatments in three replications.

The organic sources of nutrients are used in main plots in *kharif* before rice transplanting, while inorganic sources of nutrients were used in sub plot treatments.

The details of main plot treatments were M_1 – green manure [dhaincha (*Sesbania rostrata*)], M_2 – green legume [urd (*Vigna mungo*)], M_3 – FYM @ 10 t ha^{-1}, M_4 - straw @ 5 t ha^{-1} and M_5 - weedy fallow, whereas, the details of sub-plot treatments were S_1 – Control, S_2 – 50% PK, S_3 – 50% NPK, S_4 – 100% PK and S_5 – 100% NPK. The recommended dose of NPK was 120 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare.

Analytical procedure

Grain and straw yield of wheat were recorded from a harvest area of 10 m^2. Plant samples were first washed with running tap water followed by washing with 0.01 N HCl and finally with double distilled water. After that, plant samples were dried in a hot air oven at 50^0C for 48 hours till the constant weight was achieved.

After drying, the samples were ground to fine powder by using stainless steel grinder for further analysis. Total N content of the plant samples as well as organic materials were analyzed by Kjeldahl method using Kel-Plus analyzer (Pelican Equipments, Chennai, India), while total P and K content of the plant samples were analyzed in aqueous extracts prepared after wet-digestion with a di-acid mixture of HNO_3 and $HClO_4$ (9:4 ratio) using UV-Visible spectrophotometer (Systronics 118) and Flame photometer (Systronics 128), respectively (Jackson, 1973).

Statistical analysis

The analysis of variance (ANOVA) of the measured parameters was performed by windows based Statistical Package namely SPSS (ver. 9.3) and the least significant difference (LSD) test was applied to evaluate the significance of the differences between the variables and treatments.

Results and Discussion

The different organic and inorganic treatment applied in rice were evaluated for their residual effect on wheat crop at normal doses of NPK (120:60:40kg/ha N, P_2O_5 and K_2O) fertilizers uniformly applied in *rabi* season.

Wheat crop yield

Grain yield

A perusal of the data in table 1 indicated that the grain of wheat ranged from 19.31 to 41.67 q/ha as influenced by different treatment combinations. The highest grain of wheat 36.38 q/ha was recorded in FYM treatment and was superior over straw (32.84 q/ha), dhaincha (GM) (28.93 q/ha), urd (GL) (27.61q/ha) and weedy fallow (23.58 q/ ha). The residual effect of dhaincha (28.93 q/ha) and urd (27.61 q/ha) were statistically at par with each other. From these observations, it may be inferred that manures applied to the previous crop cold definitely display a significant positive role on the succeeding wheat crop. Many long term experiments suggested the advantageous effect of continuous manuring and rotational practices on maintaining soil fertility and sustaining crop productivity. The same case was found true in the present investigation which showed the residual and cumulative effects of organic manures and inorganic fertilizers on the yield of wheat crop. Similar findings were also reported by Gaur *et al.,* (1984) and Rai *et al.,* (1990). The more prominent role of FYM was ascribed due to more addition of organic nutrients which exhibited the higher residual values as results of slow mineralization. It is beneficial not only in enhancing the yield of rice but also promoting the wheat yield to a little extent and improving the overall productivity of the soil (Tiwari and Pathak, 1979).Inorganic fertilizer given directly to wheat crop showed highly significant influence on grain yield of wheat. The decreasing trend of grain yield of wheat was observed in the order of 36.94 q/ha (100% NPK) >32.05q/ha (50% NPK) > 29.94 q/ha (100% PK) > 26.12 q/ha (50% PK) > 24.89 q/ha (control).However, the interactive residual effect of organic sources in conjunction with fertilizers on grain yield of wheat was found non-significant. Even though the additional; residual advantage in using FYM and straw with chemical fertilizers was apparent as also shown by the higher grain yield recorded in FYM treatment with all the levels of chemical fertilizers. Similar results were also reported by Mandal and Mandal (1990). They observed that irrespective of the nutrients level, combined application of FYM and NPK produced significantly higher yield than NPK alone. In another experiment in china (Li *et al.,* 2010) concluded that INM was the most suitable approach for profitable crop production in sustained manner.

Straw yield

Similar to grain yield presented in table 1 the stare yield of wheat varied from 26.16 to 61.76 q/ha due to the impact of various treatment combinations. The maximum straw yield (48.16 q/ha) was recorded with FYM treatment which was followed by straw (42.13 q/ha), dhaincha (GM) (39.39 q/ha) and weed fallow (31.69 q/ha) treatment. However, the residual effect of organic sources as shown by dhaincha (GM) (39.39 q/ha) and urd (GL) (38.18 q/ha) treatments was statistically at par with each other. The effect of all organic sources on straw yield of wheat can be shown in following order as: FYM > straw > dhaincha = urd> weedy fallow combinations. These results further indicated that about 25-30 per cent of N content in FYM could be absorbed by rice plant during the first croup. Consequently, accumulated N and other nutrients in soil were gradually mineralized and utilized by successive crop (Gaur *et al.,* 1984). The results showing effect of NPK fertilizer applied tow heat crop indicated that the maximum straw yield (51.95 q/ha) with 100% NPK was achieved and followed by 50% NPK (43.26 q/ha) with 100% PK (39.60 q/ha), 50% PK (32.84 q/ha) and control (31.91 q/ha) treatment. Contrary to the results obtained in grain yield here interactive residual effect of organic sources and inorganic fertilizers were found to be significant. The higher straw yield (61.76 q/ha) was recorded in FYM with 100% NPK treatment combinations while, minimum (25.16 q/ha) was recorded in weedy fallow with control treatment combination. However, the straw yield in FYM and straw combination with all NPK levels differed statistically to each other except with 100% PK treatment combination. It was also observed that dhiancha and urd treatment gave statistically similar yield at all the levels of inorganic fertilizers combinations except 100% NPK. Similar results were also observed by Meelu and Rekhi (1981) & Sharma and Mitra (1990).

Table.1 Influence of organic and inorganic fertilizers on the yield of wheat in rice - wheat system

Inorganic fertilizer levels	Grain yield (q/ha)						Straw yield (q/ha)					
	Organic source						Organic sources					
	Dhaincha (GM)	Urd (GL)	FYM	Straw	Weedy fallow	Mean	Dhaincha (GM)	Urd (GL)	FYM	Straw	Weedy fallow	Mean
Control	**24.08**	**22.08**	**31.65**	**27.32**	**19.31**	**24.89**	**30.26**	**29.14**	**42.25**	**32.74**	**25.16**	**31.96**
50% PK	**24.56**	**23.87**	**33.18**	**27.68**	**21.31**	**26.12**	**31.34**	**29.92**	**41.50**	**34.43**	**26.98**	**32.84**
50% NPK	**30.78**	**29.31**	**38.53**	**35.91**	**25.71**	**32.05**	**43.26**	**42.87**	**50.85**	**45.46**	**33.85**	**43.26**
100% PK	**29.05**	**27.53**	**36.87**	**34.02**	**22.23**	**29.94**	**38.35**	**41.67**	**44.44**	**42.21**	**31.34**	**39.60**
100%NPK	**36.19**	**35.24**	**41.67**	**39.27**	**29.34**	**36.34**	**53.74**	**47.32**	**61.76**	**55.82**	**41.12**	**51.95**
Mean	**28.93**	**27.61**	**36.38**	**32.84**	**23.58**		**39.39**	**38.18**	**48.16**	**42.13**	**31.69**	
Sources		S.Em.±		LSD (P<0.05)			S.Em.±		LSD(P<0.05)			
Organic manures (M)		0.43		1.40			0.63		2.04			
Inorganic fertilizer (S)		0.56		1.61			0.61		1.76			
Interaction (M x S)		1.21		NS			1.38		4.06			

Table.2 Influence of organic and inorganic fertilizers on the nitrogen uptake by wheat in of rice-wheat system

Inorganic fertilizer levels	Total N- uptake (kg/ha) by wheat					
	Organic sources					
	Dhaincha (GM)	Urd (GL)	FYM	Straw	Weedy fallow	Mean
Control	46.82	43.15	66.78	50.93	32.47	48.03
50% PK	49.29	46.51	70.99	52.67	35.53	51.00
50% NPK	68.05	63.14	88.28	72.61	47.06	67.83
100% PK	61.40	59.29	80.50	66.49	40.11	61.56
100 % NPK	94.51	82.76	108.37	87.92	62.24	87.16
Mean	64.01	58.97	82.98	66.13	43.48	
Sources		**S.Em. ±**	**LSD (P<0.05)**			
Organic manures (m)		0.82	2.67			
Inorganic fertilizer (s)		1.09	3.13			
Interaction (m x s)		2.34	NS			

Table.3 Influence of organic and inorganic fertilizers on phosphorous uptake by wheat in of rice-wheat system

Inorganic fertilizer levels	Total P- uptake (kg/ha) by wheat					
	Organic sources					
	Dhaincha (GM)	Urd (GL)	FYM	Straw	Weedy fallow	Mean
Control	11.66	10.39	16.01	11.37	7.75	11.43
50% PK	12.79	11.72	16.95	12.58	9.40	12.69
50% NPK	16.06	15.56	20.45	17.31	11.77	16.34
100% PK	15.23	15.01	19.19	16.19	10.63	15.34
100 % NPK	21.37	19.29	25.45	21.38	14.84	21.78
Mean	15.52	14.39	19.61	15.56	10.88	
Sources		**S.Em. ±**	**LSD (P<0.05)**			
Organic manures (m)		0.37	1.21			
Inorganic fertilizer (s)		0.31	0.88			
Interaction (m x s)		0.72	NS			

Table.4 Influence of organic and inorganic fertilizers on potassium uptake by wheat in rice-wheat system

Inorganic fertilizer levels	Total K- uptake (kg/ha) by wheat					
	Organic sources					
	Dhaincha (GM)	Urd (GL)	FYM	Straw	Weedy fallow	Mean
Control	42.25	38.89	63.06	51.91	32.19	45.66
50% PK	48.78	44.86	68.35	57.41	35.86	51.05
50% NPK	66.64	61.97	83.98	75.57	48.23	67.27
100% PK	60.18	62.58	75.46	71.19	44.58	62.80
100 % NPK	84.22	75.51	99.03	91.34	63.36	82.89
Mean	60.43	56.76	77.98	69.43	44.84	
Sources		**S.Em. ±**	**LSD (P<0.05)**			
Organic manures (m)		0.76	2.48			
Inorganic fertilizer (s)		0.84	2.40			
Interaction (m x s)		1.84	NS			

Fig.1 N, P and K uptake in wheat as influenced by organic manures

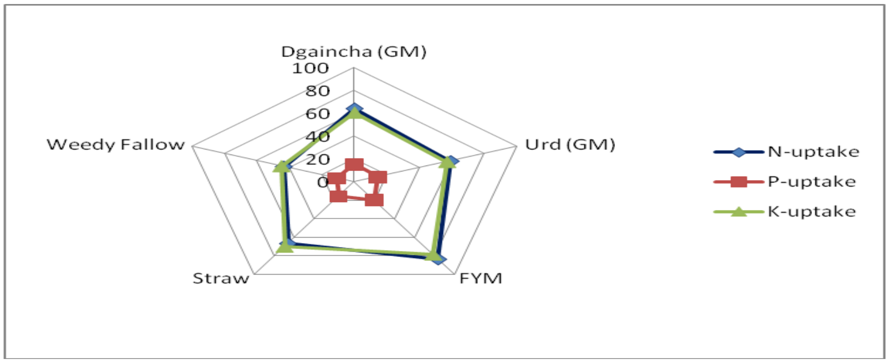
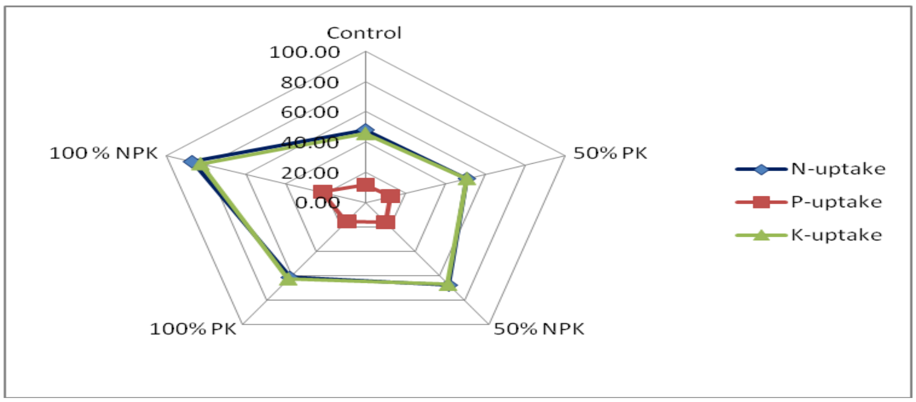


Fig.2 N, P and K uptake in wheat as influenced by inorganic fertilizers



Nutrient uptake in wheat

Total- N uptake

The total N- uptake by wheat ranged from 32.47 to 108.37 kg/ha as influenced by different treatment combinations. The results of total N- uptake in wheat are also presented in table 2 and figure (1 & 2) the data revealed that among the organic sources there were significant differences found in the total-N uptake by wheat crop. Higher N- uptake was recorded (82.98 kg/ha) with FYM treatment, which showed significant superiority over straw (66.13 kg/ha), dhaincha (64.01 kg/ha), urd (58.59 kg/ha) and weedy fallow (43.48 kg/ha) incorporations. The contribution of FYM and wheat straw increased the uptake of nitrogen (Sharma and Mitra, 1991).

The impact of different levels of NPK fertilization resulted in highly significant increase in total N-uptake of wheat over control treatment. The highest total N- uptake (87.16 kg/ha) was recorded with 100% NPK treatment which was followed by 50% NPK (67.83 kg/ha), 100% PK (61.56 kg/ha), 50% PK (51.00 kg/ha) and control (48.03 kg/ha) treatments. However, the interactions results due to the contribution of organic and inorganic did not show statistically significant. Nevertheless, the maximum total N- uptake was recorded as 108.37 kg/ha under FYM and 100% NPK treatment combination which was followed by dhaincha (94.51 kg/ha), straw (87.92 kg/ha), urd 82.76 kg/ha and weedy fallow (62.24 kg/ha) treatments as the same level of chemical fertilizers. Those results showed that the mineralization of residual FYM in wheat crop contributed the highest amount of N content in wheat grain. While, most of the parts of dhaincha (GM) and urd (GL) were already and quickly mineralised and taken by first rice crops. Sharma and Mitra, (1991) also reported that the decomposition process of organic sources which decreased the loss of applied nutrients and thus increased the release of nutrients to the plants.

Phosphorus uptake

Total -P uptake

Total -p uptake by wheat crop ranged from 7.75 to 25.45 kh/ha due to the influenced of various treatment combinations. Further the perusal of data in table 3 and figure (1 & 2) revealed that residual effect of organic sources significantly influenced the total phosphorus uptake in wheat. The total –Puptake in weedy fallow (10.88 kg/ha) was increased to 14.39 kg/ha, 15.52 kg/ha, 15.56 kg/ha and 19.61 kg/ha due to residual effect if urd (GL) dhaincha (GM), straw and FYM incorporations, respectively. These data also indicated that total p- uptake with straw (15.56 kg/ha), dhaincha (15.52 kg/ha) and urd (14.39 kg/ha) treatments were statistically similar. These results apparently showed that organics applied during the kharif season left a substantial quantity of nutrients even under high temperature, humid and tropical conditions which might be subsequently utilized by the succeeding *rabi* crop like wheat. It may also be possible that organic matter left in the soil might enhanced the uptake of applied as well as native nutrients by the crop through it influence on their availability in the soil (Rokima 1985).The residual impact of FYM, straw, dhaincha and urd incorporations on phosphorus by wheat grain might be due to the decomposition of these organics, which released more organic anions and hydroxyl acids. These acids helped in complexing or chelating Fe^{3+}, Al^{3+} and Ca^{2+} and preventing their reactions with phosphate ions to form in soluble phosphates and thus, more phosphorus might have available to the plants (Bindra and Thakur, 1996).

It was also obvious that maximum dose of NPK fertilizers resulted in highest removal of nutrients. It was also observed that there was an increase in total phosphorus uptake at 100% NPK, 50%NPK 100% PK, 50% PK levels over the control (11.43 kg/ha) as shown by total p- uptake values by wheat as 21.78 kg/ha, 16.34 kg/ha, 15.34 kg/ha and 12.69 kg/ha, respectively. Thus these results emphasized that higher phosphorus uptake by wheat crop was recorded with higher fertility levels, which could sufficiently meet nutritional requirement of the corps as well as increasing NPK levels due to production of higher amount of biomass. These results are strictly in line with the findings of Dwivedi (1997). However, the interactive effects between organic sources and inorganic fertilizer were found to be statistically non-significant. Nevertheless, the highest total p-uptake (25.45 kg/ha) by wheat crop was recorded under FYM and 100% NPK treatment combination which was followed by straw (21.38 kg/ha), dhaincha (21.37 kg/ha), urd (19.29 kg/ha) and weedy fallow (14.84 kg/ha) with the same level of fertilizers combinations.

Potassium uptake

Total - K uptake

The inferences of the data estimated for total k- uptake in wheat crop revealed that it was significantly influenced by residual effects of different organic sources and chemical fertilizers. Total k-uptake varied from 32.19 to 99.03 kg/ha in wheat crop (Table 4 and figure 1 & 2) the residual impact of various organic regarding the total potassium uptake by wheat crop might be shown in the following order. FYM (77.98 kg/ha) > straw (69.43 kg/ha) > dhaincha (60.43) >urd 56.76 kg/ha > weedy fallow (44.84 kg/ha). This trend was similar to the trend shown by grain and straw yield of wheat under the same treatment. Hence, higher yields under 100% NPK level of fertilizers along with organic sources were consequently accompanied with larger amount of nutrients removal by the crop. These results inferred that conjoint application of FYM, straw, dhaincha (GM) and urd (GL) and NPK fertilizers further increased the k-uptake as compared to the application of NPK alone. This might be due to the increased efficiency of the fertilizers in combination with organics as K-uptake is concerned. This also might be happened because of its effect on the formation of active and prolific roots resulting in increased absorption of nutrients. Besides this, significantly highest total k-uptake by wheat crop (82.69 kg/ha) was recorded with 100% recommended NPK treatment. The trend of total k-uptake by wheat crop can be represented in the following order of superiority as: 100% NPK (82.69 kg/ha) > 50% NPK (67.27 kg/ha) > 100% PK (62.80 kg/ha) > 50% PK (51.05 kg/ha) > control (45.66 kg/ha) treatments. Further observations revealed that total uptake of potassium increased with progressive increase in the supply of NPK to the crop because of higher availability of these nutrients Santhy *et al.*, (1998). However, interactions between residual effect of organic and inorganic sources on potassium uptake by wheat were did not turn out to be statistically significant

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