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ASSESSMENT OF NUTRIENT DYNAMICS OF DIVERSIFIED RICE-WHEAT CROPPING SEQUENCES UNDER INTEGRATED FARMING SYSTEM OF MIDDLE IGP

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Abstract

A field experiment was conducted with 10 crop sequences as treatments to find out nutrient dynamics and nutrient uptake pattern. This study was laid out in randomized block design with three replications. Among the different cropping sequence taken under study, sudan fodder- berseem- cowpea fodder recorded highest nitrogen (443.6 kg/ha), phosphorus (146.8 kg/ha) and potassium (306.3 kg/ha) uptake followed by cowpea fodder- berseem- maize fodder with 411, 105.9 and 274 kg/ha nitrogen, phosphorus and potassium, respectively. Both these crop sequences showed negative nitrogen balance in soil. Meanwhile potassium balance was negative for most of the sequences. However, high value rice- capsicum - vegetable cowpea registered lowest nitrogen (134.5 kg/ha) and potassium uptake (129.20 kg/ha) leading to a positive nitrogen and potassium balance.

Introduction

Rice-wheat is the most conventional and dominant cropping sequence in the Gangetic plains region of India (Chauhan *et al.* 2012), which occupies 65 to 70% of the total cultivated area in eastern Uttar Pradesh due to its higher and assured productivity (Singh *et al.* 2013). The system is believed to be the basis for food grain security in the country. Rice and wheat productivity, particularly in rice-wheat system in India, in general, are low. Moreover, the continuous practice of rice–wheat system in the Indo Gangetic Plains (IGP) for over four decades has caused a significant risk to crop production and sustainability in that area (Bhatt *et al.* 2016). Over the years, productivity of this cropping system decreased due to plateauing yield, declining factor productivity and degradation of soil health and fertility (Sharma and Bhushan 2001, Nath *et al.* 2017). Soils in the IGP zone have low levels of soil organic matter (SOM) and are being continually stripped off their finite nutrient reserves by these crops (Ladha *et al*. 2004) because it is a common practice of farmers in the IGP to remove wheat and rice straw from fields for use as cattle feed and a variety of other uses *viz.* livestock bedding, house thatching, and bio-fuel (Chauhan *et al.* 2012). Rice-wheat sequence removes significant amount of major, secondary and micronutrients. It has been reported that rice-wheat cropping system depletes the key nutrients such as nitrogen, phosphorus, potassium, and sulphur from the soil, resulting in a nutritional imbalance and deterioration in soil quality (Alam *et al*. 2013). A ton of wheat grains is expected to remove 24.5, 3.8, and 27.3 kg of nitrogen, phosphorus, and potassium, respectively, whereas a ton of rice grains removes 20.1, 4.9, and 25.0 kg of nitrogen, phosphorus, and potassium, respectively (Chauhan *et al*. 2012). This problem is intensified by the use of less/no organic matter/crop residue incorporation, lack of crop diversification, and imbalanced as well as irrational fertilization and these are the major concern for sustainability in agriculture (Verma *et al.* 2018).

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Hence, efforts are needed to diversify the rice-wheat system mainly in IGP. With these facts in view, an experiment was conducted to study the possibility of diversifying the traditional rice-wheat cropping system under ‘integrated farming system’ of Varanasi (middle IGP) with different legumes, oilseeds, fodders and high value vegetable crops and to study their nutrient uptake pattern as well as nutrient dynamics in the soil.

Materials and Methods

A field experiment was carried out at the Agricultural research farm, Banaras Hindu University, Varanasi (25°15′17″ N, 82°59′27″ E and 74.4 m above mean sea level) to study the diversification of existing rice-wheat system and determining the nutrient dynamics of diversified crop sequences. In this experiment ten crop sequences were studied and as per the treatments, the crops are planted in rainy, winter and summer seasons. The treatments consisted of rice - wheat - fallow (S_1), rice - mustard -fallow (S_2), *Sesbania* (G.M.)*rice -lentil -black gram (S_3), *Sesbania* (G.M.)* rice - vegetable pea - black gram (S_4), *Sesbania* (G.M.)* rice - mustard - black gram (S_5), *Sesbania* (G.M.)* rice - mustard - green gram (S_6), Sudan fodder - berseem - cowpea fodder (S_7), cowpea fodder - berseem - maize fodder (S_8), high value rice - potato - lady's finger (S_9), high value rice - capsicum - vegetable cowpea (S_{10}). In sequence S_3 to S_6, *Sesbania*@6 t/ha was incorporated as a green manure crop before rice transplanting. The experiment was carried out in randomized block design with three replications in slightly alkaline (pH- 7.7) sandy clay loam soil having 1.45 g/cc bulk density. The experimental soil was medium in available phosphorus (13.7 kg/ha) and potassium (211.8 kg/ha) but low in organic carbon (4.3 g/kg) and available nitrogen (196.5 kg/ha). Nitrogen, phosphorus and potassium were supplied through urea, di-ammonium phosphate and muriate of potash, respectively. The recommended dose of fertilizer that was applied to the field is presented in Table 1. Nutrient content and uptake of different crops in different cropping sequences were computed using standard procedure.

Results and discussion

Among the rainy season crops in different sequences, fodder crops *viz.* Sudan and cowpea being comparable recorded significantly higher nitrogen uptake than rice in different sequences (Table 2). This might be due to the better productivity of fodder crops and higher nitrogen content of cowpea fodder. Rice taken after *Sesbania* green manuring in sequences (S_3, S_4, S_5,S_6), in general, resulted in higher nitrogen uptake than rice in rest of the sequences but the differences were not significant. *Sesbania* being legume green manure crop, its incorporation improves physical condition and nutrient supplying capacity of soil; as this was the first year trial, in subsequent years, better results can be expected.

With regards to the phosphorus uptake, rice in different sequences and Sudan fodder in S_7 though remained at par, recorded significantly higher P uptake than cowpea fodder. However, the difference between rice (HUR 3022) in S_1 and high value rice (Rajendra Kasturi) in S_9 was significant which can be ascribed to the lower productivity of the later. Potassium uptake was significantly higher in Sudan fodder followed by rice in different sequences and the lowest value was noticed in cowpea fodder probably due to its low productivity and lower K content. These results corroborate the findings of Singh *et al.* (2008).

There was a marked variation in nutrient uptake by cropsin winter season where the mean temperature varied from 17 to 24°C. Nitrogen uptake was the maximum in berseem in sequences S_7 and in S_8 (Table 2). This might be due to higher biomass production of berseem accompanied with higher nitrogen content in economic product. This was also true for the highest potassium

Table 1. Fertilizer rate, time and method of application to different crops in cropping sequences

Season	Crops	Variety	Fertilizer dose (kg/ha)			Time and method of fertilizer application
			N	P	K	
Kharif	Rice	HUR 3022	120	60	60	½ N + full P, K as basal. ½ N top dressed in two equal splits. [S_3, S_4, S_5, S_6 : Green manuring was done with *Sesbania* @ 10 t/ha]
	High value rice	RajendraKasturii	120	60	60	½ N + full P, K as basal. ½ N top dressed in two equal splits.
	Sudan fodder	MFSH 4	120	60	60	½ N + full P, K as basal. ½ N top dressed in two equal splits.
	Cowpea fodder	Hariyali	18	46	40	Full basal
Rabi	Wheat	HUW234	120	60	60	½ N + Full P, K as basal. ½ N top dressed in two splits.
	Mustard	RH 749	120	60	60	½ N + full P, K & S as basal and ½ N top dressed after 1st irrigation.
	Potato	Kufrikhyati	120	60	60	½ N + full P, K as basal and ½ N top dressed at earthing up.
	Lentil	Local variety	18	46	40	Full basal
	Vegetable pea	Kasha nandini	18	46	40	Full basal
	Berseem	Premier	25	60	60	Full basal
	Capsicum	F1 hybrid	100	50	50	½ N + Full P, K as basal. ½ N top dressed in two splits.
Summer	Green gram	HUM 16	18	46	40	Full basal
	Black gram	Azad 3	18	46	40	Full basal
	Cowpea	Kasha kanchan	18	46	40	Full basal
	Lady finger	Lucky 267	120	60	60	½ N+full P&K Basal + ½ N top dressed at one month stage.
	Maize fodder	African tall	120	60	60	½ N+full P&K Basal + ½ N top dressed at one month stage.

Table 2. Nutrient uptake by different *kharif*, *rabi*, and summer crops of different cropping sequence.

Treatments	Kharif crops			Rabi crops			Summer crops		
	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Rice-wheat-fallow (S1)	76.47^{B}	15.60^{A}	90.86^{B}	96.58^{B}	16.34^{A}	93.93^{C}	-0.00^{G}	0.00^{F}	0.00^{G}
Rice-mustard-fallow (S2)	75.88^{B}	14.70^{AB}	92.83^{B}	92.20^{B}	10.14^{E}	53.82^{D}	-0.00^{G}	0.00^{F}	0.00^{G}
Sesbania (G.M.)* Rice-lentil-black gram (S3)	84.14^{B}	15.43^{AB}	92.52^{B}	67.33^{C}	7.86^{F}	28.49^{E}	64.32^{D}	40.00^{D}	26.65^{D}
Sesbania (G.M.)* Rice-veg. pea-black gram (S4)	80.74^{B}	14.91^{AB}	89.85^{B}	57.48^{C}	6.70^{F}	28.46^{E}	74.26^{C}	46.33^{C}	29.20^{D}
Sesbania (G.M.)* Rice-mustard-black gram (S5)	77.45^{B}	14.71^{AB}	94.28^{B}	95.40^{B}	11.67^{C}	54.87^{D}	60.82^{D}	39.17^{D}	25.23^{D}
Sesbania (G.M.)* Rice-mustard- green gram (S6)	82.40^{B}	14.98^{AB}	95.77^{B}	97.56^{B}	11.41^{CD}	57.32^{D}	46.90^{E}	46.90^{C}	11.12^{F}
Sudan fodder-berseem -cowpea fodder (S7)	127.44^{A}	15.32^{AB}	127.44^{A}	195.13^{A}	10.48^{DE}	103.35^{B}	120.98^{A}	121.33^{A}	75.54^{B}
Cowpea fodder-berseem -maize fodder (S8)	129.92^{A}	7.44^{C}	53.07^{C}	194.21^{A}	10.96^{CDE}	114.83^{A}	87.52^{B}	87.50^{B}	106.55^{A}
High value rice-potato-lady's finger (S9)	76.08^{B}	13.83^{B}	95.70^{B}	41.33^{D}	13.29^{B}	17.78^{F}	77.91^{C}	38.00^{D}	50.12^{C}
High value rice-capsicum- vegetable cowpea (S10)	76.10^{B}	14.11^{AB}	95.43^{B}	31.03^{D}	3.41^{G}	17.77^{F}	27.41^{F}	27.43^{E}	15.99^{E}
CD (P=0.05)	10.31	1.64	10.18	11.62	1.16	6.82	7.67	5.78	4.68

Table 3. Nitrogen, phosphorus and potassium balance of different crop sequences.

Treatments	N applied (kg/ha)	N removed (kg/ha)	N balance (kg/ha)	P applied (kg/ha)	P removed (kg/ha)	P balance (kg/ha)	K applied (kg/ha)	K removed (kg/ha)	K balance (kg/ha)
Rice-wheat-fallow (S_1)	240	173.04^{F}	67	120	31.94^{F}	88.1	120	184.79^{C}	-64.8
Rice-mustard-fallow (S_2)	240	168.09^{F}	71.9	120	24.85^{G}	95.2	120	146.64^{E}	-26.6
Sesbania (G.M.)* Rice-lentil-black gram (S_3)	156	215.80^{CDE}	-59.8	152	63.29^{D}	89.4	140	147.67^{E}	-7.7
Sesbania (G.M.)* Rice-veg. pea-black gram (S_4)	156	212.47^{DE}	-56.5	152	67.64^{CD}	85.9	140	147.51^{E}	-7.5
Sesbania (G.M.)* Rice-mustard-black gram (S_5)	258	233.67^{C}	24.3	166	65.63^{D}	100.4	160	174.37^{CD}	-14.4
Sesbania (G.M.)* Rice-mustard- green gram (S_6)	258	226.86^{CD}	31.1	166	73.29^{C}	92.7	160	164.21^{D}	-4.2
Sudan fodder-*berseem* -cowpea fodder (S_7)	163	443.56^{A}	-280.6	166	146.78^{A}	19.2	160	306.33^{A}	-146.3
Cowpea fodder-*berseem* -maize fodder (S_8)	163	411.65^{B}	-248.6	166	105.92^{B}	60.1	160	274.44^{B}	-114.4
High value rice-potato-lady's finger (S_9)	360	195.32^{E}	164.7	180	65.08^{D}	119.9	180	163.60^{D}	16.4
High value rice-capsicum- vegetable cowpea (S_{10})	236	134.54^{G}	101.5	156	44.93^{E}	111.1	150	129.20^{F}	20.8
LSD	-	20.941	-	-	6.4166	-	-	15.24	-

uptake by berseem in sequences S_8 and S_7. Although wheat and mustard in different sequences remained at par with each other, they showed higher nitrogen uptake over legume crops such as Lentil (S_3) and vegetable pea (S_4) mainly due to their exhaustive nutrient removal (Ramanjaneyulu *et al.* 2012). With respect to P uptake of winter crops, wheat in sequence S_1 showed significantly higher P uptake than rest of the crops followed by potato (S_9) and mustard (S_5). However, the lowest nitrogen, phosphorus and potassium uptake by capsicum (S_{10}) was probably because of lower nutrient contents as well as low productivity. The findings of Banjara *et al.* (2021) confirm these results.

It is apparent from the data presented in Table 2 that nitrogen and phosphorus uptake by summer crops were significantly higher in cowpea fodder (S_7) followed by maize fodder in sequence S_8. Maize fodder also showed significantly higher potassium uptake than other summer crops. This could be ascribed to the higher biomass production of fodder crops and higher K content of maize fodder. Nutrient uptake was calculated by adding nutrient uptake of economic product with nutrient uptake of straw/stover. However, except for black gram in sequence S_3, S_4, S_5 and lady's finger in sequence S_9, the stover/ straw product of other summer crops were incorporated in the soil. So, straw yield of only black gram and lady's finger was taken into consideration for nutrient uptake estimation. Hence, the nutrient uptake was significantly lower in green gram in sequence S_6 and vegetable cowpea in sequence S_{10} compared to lady’s finger in S_9 and black gram (S_3, S_4, S_5) where straw/stover incorporation was not done. However, it was also noticed that vegetable cowpea in sequence S_{10} registered lowest phosphorus uptake, whereas green gram in S_6 showed lowest potassium uptake. Sharma *et al.* (2009) also found similar results.

Sudan fodder- berseem- cowpea fodder (S_7) showed distinct superiority over other crop sequences as it recorded significantly higher uptake of nitrogen, phosphorus and potassium than rest of the sequences. This was followed by cowpea- berseem- maize fodder sequence (S_8) that also resulted in significantly higher N, P and K uptake than other sequences. This may be attributed to the higher production potential of fodder crop sequences. The next in order were sequences involving mustard for N and P uptake. Whereas, for system K uptake, it was rice-wheat sequence (S_1) closely followed by green manure rice- mustard-black gram (S_5). This could be assigned to the higher nutrient content of mustard for system N and P uptake and comparatively higher K content of rice and wheat straw for system K uptake in sequences S_1 and S_5. Nevertheless, due to low biomass production of capsicum, sequence S_{10} showed lowest uptake of N, P and K. Sharma *et al.* (2008) also found similar results.

Highly negative nitrogen balance was noticed in fodder based sequences *viz.* sudan- berseem- cowpea and cowpea- berseem- maize fodder (Table 3) as the higher nitrogen removal leads to more canopy growth and more biomass production (Sharma and Sharma 2002, Yadav *et al.* 2013). The nitrogen balance was also negative (Table 3) in sequence S_3 and S_4 mainly because the biological nitrogen fixation by legume crops and nitrogen applied in soil through incorporation was not taken into consideration in applied nitrogen. In all the crop sequences, phosphorus balance was positive *i.e.* P removed by the sequences was less than the P applied due to its fixation in the soil. But the highest gap between addition and removal was found in potassium. The higher negative K balance in all the sequences is attributed to the excessive K uptake in comparison to K applied. These findings are in agreement with the findings of Sharma *et al.* (2014).

Thus, it maybe concluded that cropping sequence with 300% cropping intensity showed significantly higher nutrient uptake compared to traditional rice-wheat and rice-mustard cropping systems. Among the ten different cropping sequences, Sudan fodder- berseem- cowpea (S_7) registered significantly higher nutrient uptake followed by cowpea fodder- berseem- maize fodder. The higher biomass production of fodder based sequences resulted in enhanced uptake of nitrogen and potassium in comparison to applied N and K. However, for all the sequences, the phosphorus uptake was less as compared to applied P that resulted in positive balance for all the sequences. Notwithstanding, the fact that major portion of this P is in the fixed form which highly insoluble and generally not available to the plants.

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