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Nutrient uptake and nutrient balance as influenced by different rice based cropping patterns in Assam

A. M. DEKA, H. KALITA, N. BORAH AND A. S. N. ZAMAN

Regional Agricultural Research Station, Assam Agricultural University
Shillongani, Nagaon-782002, Assam

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ABSTRACT

A field experiment was conducted at Regional Agricultural Research Station, Shillongani, Nagaon, Assam during kharif, rabi and summer seasons in three crop sequence during 2014-15 and 2015-16 to study the effect of rice based cropping system on nutrient uptake and balance. The treatments of the experiment comprised three dates of Sali rice transplanting viz., 20 June, 5 July and 20 July and two methods of cultivation viz. conventional and SRI with four relay crops viz. lentil, pea, toria and niger. During summer, fodder maize and green gram in 1:1 row ratio was grown as intercrops in each plot. The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.61), medium in available N (296 kg ha^{-1}) and K_2O (195 kg ha^{-1}) and low in available P_2O_5 (21 kg ha^{-1}). Rice transplanting on 20 June recorded significantly higher grain yield of rice, relay crops and summer intercrops. System of Rice Intensification (SRI) recorded significantly higher grain yield of rice (60.34 q ha^{-1}),relay and intercrops as compared to conventional method. The treatment combination "rice transplanted on 20 June under SRI method relayed by pea and followed by summer inter crops of fodder maize and green gram" was more efficient in showing better response to applied nutrients and thereby resulting in the highest N, P and K uptake and the lowest available N, P_2O_5 and K_2O content in soil during the entire period of two-year experimentation.

***Keywords* :** Grain yield, nutrient balance, nutrient uptake and rice-based cropping pattern

The demand for cereals, pulses and oilseeds is increasing due to increasing population pressure. To increase their production and thereby to meet the future demands, the cultivated land area cannot be increased directly. In such cases, inclusion of pulses and oilseeds through multiple cropping in rice based cropping patterns of Assam are of prime importance (Deka *et al.,* 2013). Moreover, continuous mono cropping of rice has led to decline or stagnation of productivity due to emergence of multiple nutrient deficiency and deterioration of soil physico-chemical properties besides increase pressure of insect pest and diseases. This problem can be partly overcome by shifting from continuous rice production or rice- fallow system to growing of rice-legume/pulse cropping pattern. Since, legumes or pulses fix atmospheric nitrogen, it partly meets the N requirement of the crop and the residual N is utilized by the subsequent crops. Pulses play an important role in sustainable agriculture by improving soil health and conserving soil and water (Ali, 2015). Pulses help in sustaining the rice-based cropping systems by breaking insect-pest and disease cycles associated with sole rice eco- systems, also enhance the microbial activity and thereby increase the nutrient availability in the soils after rice (Subbarao *et al*., 2001). Moreover, growing of crops in sequence plays an important role in sustainable agriculture by improving soil health and conserving soil and water through decomposition of crop residues (Ali, 2015). In state like Assam rice lands are the only target for crop intensification. Hence an experiment was designed to study the effect of three crop rice based sequential cropping on crop yield as well as soil health.

Email : anjumaladeka.sms@gmail.com

METERIALS AND METHODS

A field experiment was carried out during the *kharif*, *rabi* and summer seasons of 2014-15 and 2015-16 at Research Farm of Regional Agricultural Research Station, Shillongani, Nagaon, Assam (26^0 N latitude, 90^{0}45′E longitude and at an altitude of 50.2 m above from the mean sea level). The climate of this region is sub-tropical with hot humid summer and relatively dry and cold winter. The crop experienced favourable weather conditions in both the years of experimentation. Total amount of rainfall received during the crop growth period were 1771.7 mm during 2014-15 and 1935.6 mm during 2015-16 (Source: Gramin Krishi Mausom Sewa, RARS, Shillonani, Nagaon).The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.61), medium in organic carbon (0.84 %), available N (296 kg ha^{-1}) and available K_2O (195 kg ha^{-1}) and low in available P_2O_5 (21 kg ha^{-1}). All the plots were fertilized with recommended dose of fertilizers as per the crops grown in different seasons.

The treatments of the experiment comprised three dates of *Sali* rice transplanting *viz.* 20th June, 5th and 20th July and two methods of cultivation *viz.,* conventional and SRI (system of rice intensification) with four relay crops *viz.* lentil, pea, *toria* and niger. The experiment was laid out in a factorial randomized block design for the treatments in rice during *kharif* season and a split plot design for treatments of relay crops in *rabi* season assigning dates of transplanting and method of cultivation in the main plots and relay crops in sub-plots with three replications. During summer, fodder maize and green gram in 1:1 row ratio was grown as intercrops in each plot.

Winter rice variety 'Ranjit', lentil variety 'PL 406', pea var 'Aman', *toria* var. 'TS 38', niger var. 'NG 1', green gram var. 'Pratap' and fodder maize var. 'African Tall' were used for the study. The seeds of all the *rabi* crops *viz*., lentil, pea, *toria* and niger were broadcast @ 45 kg ha^{-1}, 80 kg ha^{-1}, 13 kg $ha^{-1}$and 16 kg ha^{-1}, respectively, in the standing rice crop at soil moisture saturation. Based on proper soil moisture content, the relay crops were sown on 1st November, 2014 and 26th October, 2015. Rice was harvested from net plot while relay and inter crops were harvested from gross plot. All the crops were harvested at their physiological maturity stage. Soil samples were collected before sowing and at the end of second year to analyse for chemical properties following standard procedures. The plant samples (both seed and stover) of rice, relay and inter crops were collected separately after threshing and dried in oven at 65^0C for 72 hrs. The oven-dried samples were finely ground and chemically analysed for N content by modified Kjeldahl method, P colorimetrically by tri-acid digestion and yellow colour method and K by flame photometer as described by (Jackson, 1973). The uptake of nutrients was calculated by multiplying the dry matter yield with respective percentage of nutrients.

Nutrient uptake (kg ha^{-1}) =

$$\frac{\text{Nutrient content}(\%) \times \text{grain or straw yield} (\text{kg ha}^{-1})}{100}$$

Nutrients (NPK) balance of cropping systems was calculated from total nutrient added to the whole system and total nutrient uptake by the whole cropping sequence during both the years as well as soil available nutrients status at the end of last crop harvest.

Nutrient balance= (a+b) - (c+d)

Where,

a = Initial available soil NPK; b= NPK- added in two years;

c = NPK-uptake by whole system; d= Soil NPK status at the end of two years

The data pertaining to each of the characters of the experimental crops were tabulated and finally analyzed statistically. Analysis of variance for Factorial RBD and SPD were worked out as per the standard procedure described by Panse and Sukhatme (1985) and the significance or non-significance of the variances due to treatment effects was tested by 'F' test. Critical difference was calculated wherever 'F' test was significant.

RESULTS AND DISCUSSION

Grain yield of rice

Different dates of transplanting had significant effect on grain yield of rice (Fig. 1). The highest grain yield in both the years and pooled was recorded under 20 June which was at par with that of 5 July transplanting and were significantly higher than that of 20 July. Higher grain yield at early transplanting was owing to relatively early crop establishment and better yield attributes. The result corroborates the findings of Ashem *et al.*, 2010 and Changmai, 2015. The grain yield of rice under SRI method was found significantly higher than the conventional method. This finding is in conformity with that of Singh *et al*., 2013 and Ranjitha and Reddy, 2014.

Grain yield of relay crops

Dates of rice transplanting had significant effect on seed yield of all relay crops *viz.,* lentil, pea, *toria* and niger during both the years (Table 1). The highest seed yield of relay crops was found in 20th June transplanted rice followed by 5 and 20 July transplanted rice. The higher seed yield in 20th June transplanted rice was owing to higher plant population m^{-2} at relay crop harvest and higher yield attributes of relay crops associated with early transplanted rice (Gupta and Bhowmick, 2005; Tripathi, 1986) which might be due to more favourable growing condition for all relay crops with early dates of rice transplanting resulted from less days of association of relay crops with rice (Duary *et al*., 2004).

Relay crops had significant effect on green fodder yield of maize during both the years. The highest green fodder yield of maize was noted when maize fodder was grown after lentil which was at par with that after pea and *toria* and was significantly higher than that after niger (Fig. 2). This was due to higher plant height of maize associated with lentil and pea (Matusso *et al*., 2014).

The seed yield of green gram differed significantly due to the effect of different relay crops in both the years (Fig. 3). The highest seed yield of green gram was recorded when green gram was grown after *toria* which was at par with niger and both were significantly higher than after lentil and pea in both the years. Higher grain yield of green gram after toria and niger was owing to early sowing of green gram and early crop establishment due to early harvest of *toria* and niger. While sowing of green gram was delayed due to late harvest of lentil and pea which resulted in delayed picking of pods and coincidence with pre-momsoon rainfall during the later crop growth stage resulting in poor seed formation and thereby ultimately lower yield.

Available N, P_2O_5 and K_2O content in soil

The dates of rice transplanting had significant effect on available N, P_2O_5 and K_2O content in soil recorded at

Table 1: Grain yield (q ha^{-1}) of relay crops as influenced by date of transplanting and method of cultivation of rice

Treatment	C_1: Lentil		C_2: Pea		C_3: Toria		C_4: Niger	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Date of rice transplanting (D)								
D_1: 20th June	9.86	10.60	16.41	18.51	8.71	7.41	5.49	4.60
D_2: 5th July	9.58	10.43	16.13	18.02	8.12	7.36	5.46	4.30
D_3: 20th July	8.50	8.95	15.71	17.32	7.17	6.53	4.82	3.51
SEm (±)	**0.07**	**0.17**	**0.16**	**0.19**	**0.29**	**0.44**	**0.17**	**0.17**
LSD (0.05)	**0.23**	**0.56**	**0.52**	**0.61**	**0.91**	**1.38**	**0.54**	**0.56**
Method of rice cultivation (M)								
M_1: Conventional	9.26	9.97	16.09	17.97	8.27	7.12	5.23	4.06
M_2: SRI	9.37	10.02	16.07	17.93	7.73	7.08	5.29	4.23
SEm (±)	**0.06**	**0.14**	**0.13**	**0.16**	**0.26**	**0.34**	**0.14**	**0.15**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction (D × M)								
SEm (±)	**0.10**	**0.25**	**0.22**	**0.27**	**0.55**	**0.66**	**0.25**	**0.25**
LSD (0.05)	**0.32**	**0.79**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 2: Available N, P_2O_5 and K_2O content in soil at the end of two year-crop cycle as influenced by different treatments

Treatment	Available N(kg ha^{-1})	Available P_2O_5(kg ha^{-1})	Available K_2O (kg ha^{-1})
Date of rice transplanting (D)			
D_1: 20th June	249.88	15.16	137.82
D_2: 5th July	253.70	15.69	139.48
D_3: 20th July	268.72	17.58	144.13
SEm (±)	**0.14**	**0.17**	**0.04**
LSD (0.05)	**0.45**	**0.53**	**0.13**
Method of rice cultivation (M)			
M_1: Conventional	258.10	16.32	141.23
M_2: SRI	256.77	15.97	139.72
SEm (±)	**0.12**	**0.14**	**0.03**
LSD (0.05)	**0.37**	**NS**	**0.11**
Relay crops (C)			
C_1: Lentil	259.45	15.16	136.13
C_2: Pea	193.59	13.97	126.56
C_3: Toria	285.63	17.25	147.89
C_4:Niger	291.06	18.20	151.33
SEm (±)	**0.09**	**0.15**	**0.05**
LSD (0.05)	**0.27**	**0.42**	**0.14**

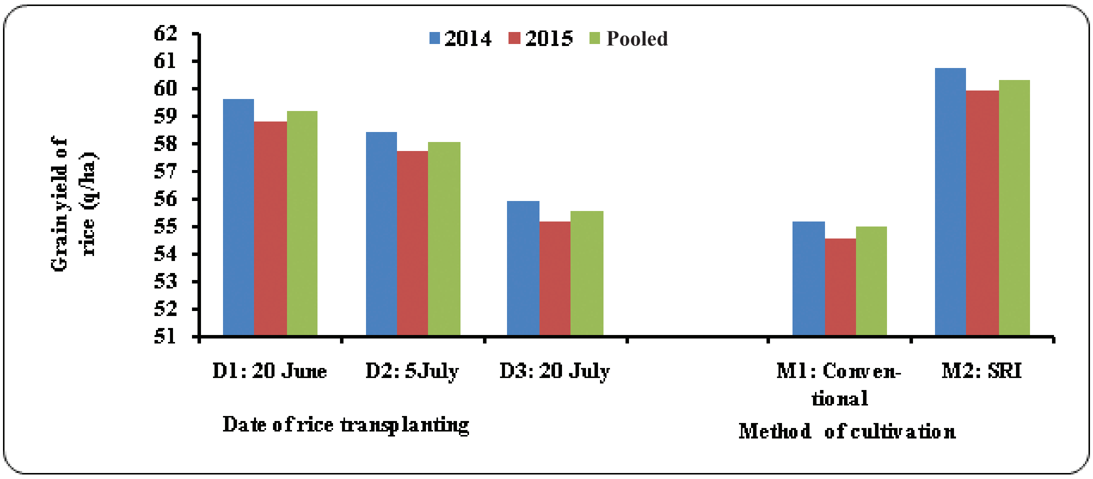

Fig.1: Grain yield of rice (q ha^{-1}) due to different treatments during 2014 and 2015

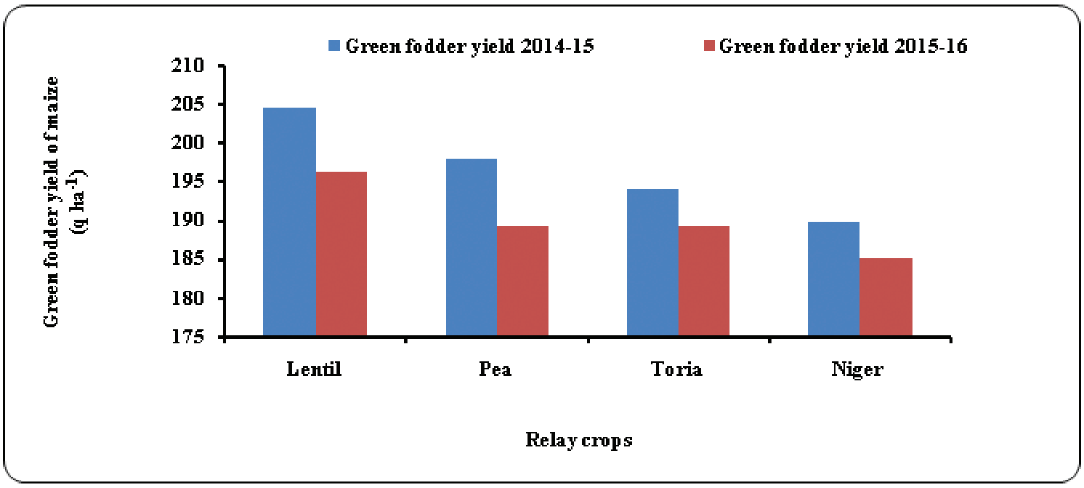

Fig. 2: Green fodder yield of maize (q ha^{-1}) due to relay crops during 2014-15 and 2015-16

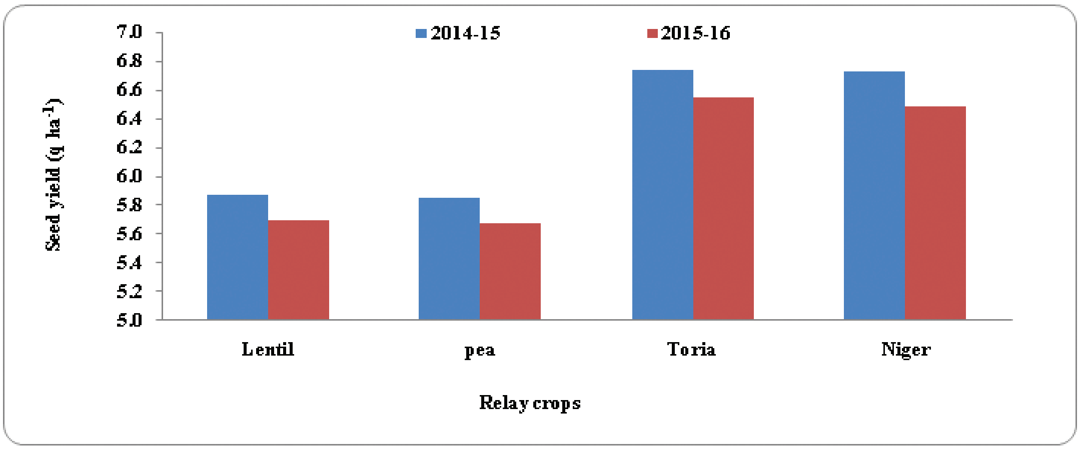

Fig. 3: Seed yield of green gram (q ha^{-1}) due to relay crops during 2014-15 and 2015-16

Table 3: Effect of treatment combinations on NPK- balance (kg ha^{-1}) in soil at the end of two year- crop cycle

Treatments	Initial available soil (a)			N- added in two years(b)			Initial N + added (c) = (a)+(b)		
	N	P	K	N	P	K	N	P	K
$D_1M_1C_1S$	296.29	9.24	162.29	359	98.90	191.68	655.29	108.14	353.97
$D_1M_1C_2S$	296.29	9.24	162.29	359	103.72	187.52	655.29	112.96	349.81
$D_1M_1C_3S$	296.29	9.24	162.29	359	96.72	204.18	655.29	105.96	366.47
$D_1M_1C_4S$	296.29	9.24	162.29	359	87.98	187.52	655.29	97.22	349.81
$D_1M_2C_1S$	296.29	9.24	162.29	394	116.58	237.5	690.29	125.82	399.79
$D_1M_2C_2S$	296.29	9.24	162.29	394	121.40	233.34	690.29	130.64	395.63
$D_1M_2C_3S$	296.29	9.24	162.29	394	114.40	250	690.29	123.64	412.29
$D_1M_2C_4S$	296.29	9.24	162.29	394	105.66	233.34	690.29	114.90	395.63
$D_2M_1C_1S$	296.29	9.24	162.29	359	98.90	191.68	655.29	108.14	353.97
$D_2M_1C_2S$	296.29	9.24	162.29	359	103.72	187.52	655.29	112.96	349.81
$D_2M_1C_3S$	296.29	9.24	162.29	359	96.72	204.18	655.29	105.96	366.47
$D_2M_1C_4S$	296.29	9.24	162.29	359	87.98	187.52	655.29	97.22	349.81
$D_2M_2C_1S$	296.29	9.24	162.29	394	116.58	237.5	690.29	125.82	399.79
$D_2M_2C_2S$	296.29	9.24	162.29	394	121.40	233.34	690.29	130.64	395.63
$D_2M_2C_3S$	296.29	9.24	162.29	394	114.40	250	690.29	123.64	412.29
$D_2M_2C_4S$	296.29	9.24	162.29	394	105.66	233.34	690.29	114.90	395.63
$D_3M_1C_1S$	296.29	9.24	162.29	359	98.90	191.68	655.29	108.14	353.97
$D_3M_1C_2S$	296.29	9.24	162.29	359	103.72	187.52	655.29	112.96	349.81
$D_3M_1C_3S$	296.29	9.24	162.29	359	96.72	204.18	655.29	105.96	366.47
$D_3M_1C_4S$	296.29	9.24	162.29	359	87.98	187.52	655.29	97.22	349.81
$D_3M_2C_1S$	296.29	9.24	162.29	394	116.58	237.5	690.29	125.82	399.79
$D_3M_2C_2S$	296.29	9.24	162.29	394	121.40	233.34	690.29	130.64	395.63
$D_3M_2C_3S$	296.29	9.24	162.29	394	114.40	250	690.29	123.64	412.29
$D_3M_2C_4S$	296.29	9.24	162.29	394	105.66	233.34	690.29	114.90	395.63

Note: Date of transplanting (D) = D_1: 20 June, D_2: 5 July, D_3: 20 July; Method of cultivation (M) = M_1: Conventional method, M_2: SRI method; Relay crops (C) = C_1: Lentil, C_2: Pea, C_3: Toria, C_4: Niger; Summer crops (S) = Fodder maize and green gram intercropping in 1:1 ratio

the end of two year-crop cycle (Table 2).The lowest available N, P_2O_5 and K_2O in soil at the end of the experimentation *i.e.* June 2016 was recorded under 20 June transplanting, which gradually and significantly increased with the delay of rice transplanting and recording the highest value under 20 July transplanting. It was observed that the N, P and K uptake by all the crops in whole cropping system was maximum under 20 June transplanted rice as compared to later dates of transplanting which might have led to lower available soil N, P_2O_5 and K_2O contents after harvest of the last crop in second year (Table 2).

Method of rice cultivation had significant effect on the available N and K_2O content in soil at the end of cropping sequence. Significantly higher values of available N and K_2O content (258.10 and 141.23 kg ha^{-1}, respectively) in soil was found under conventional method as compared to SRI method of rice cultivation. The lower available soil N, P_2O_5 and K_2O content (256.77, 15.97 and 139.72 kg ha^{-1}, respectively) was recorded under SRI method of rice cultivation might be due to higher grain or seed yield, straw or stover or fodder yield resulting in higher uptake of N, P and K by the crops of different seasons under the treatment of SRI method of rice cultivation as compared to conventional method. Similar findings were also reported by Singh *et al*. (1999) and Manna *et al*. (2006).

The effect of relay crops was found statistically significant on the available N, P_2O_5 and K_2O content in soil after harvest of the last crop in second year. All the treatments were significantly different from each other. Among the relay crops, the niger plots recorded the highest available soil N, P_2O_5 and K_2O content (291.06, 18.20 and 151.33 kg ha^{-1}, respectively) followed by *toria* and this might be due to lower uptake of N, P and K because of lower yield of crops in the system associated with niger and *toria* relay crop treatments as compared to lentil and pea. Again, the lowest amount of available N, P_2O_5 and K_2O content (193.59, 13.97 and 126.56 kg ha^{-1}, respectively) recorded in pea plots followed by lentil plots might have resulted to higher nutrient uptake by the crops in the system associated with pea and lentil as

Table 4: Effect of treatment combinations on NPK- balance (kg ha^{-1}) in soil at the end of two year- crop cycle

Treatments	NPK-uptake by whole system (d)			Soil NPK status at the end of two years(e)			NPK-balance (g)=(a+b)-(c+d)		
	N	P	K	N	P	K	N	P	K
$D_1M_1C_1S$	367.80	94.02	292.71	262.04	6.58	113.66	+25.45	+7.54	-52.40
$D_1M_1C_2S$	438.73	103.09	331.88	196.05	6.04	105.21	+20.50	+3.82	-87.29
$D_1M_1C_3S$	301.05	80.85	245.44	289.34	7.46	124.17	+64.89	+17.64	-3.14
$D_1M_1C_4S$	274.03	73.34	230.78	291.29	7.95	124.69	+89.96	+15.92	-5.66
$D_1M_2C_1S$	412.75	108.96	318.73	241.37	5.71	109.98	+36.17	+11.14	-28.93
$D_1M_2C_2S$	488.45	121.05	362.52	179.46	5.38	103.81	+22.37	+4.20	-70.70
$D_1M_2C_3S$	339.82	92.45	267.43	283.44	6.56	115.61	+67.03	+24.63	+29.25
$D_1M_2C_4S$	311.73	84.69	253.13	286.63	7.28	121.66	+91.92	+22.92	+20.85
$D_2M_1C_1S$	380.29	99.23	297.71	250.86	6.33	112.74	+24.13	+2.58	-56.48
$D_2M_1C_2S$	451.58	109.81	338.50	185.54	5.79	104.48	+18.16	-2.65	-93.17
$D_2M_1C_3S$	307.83	83.16	247.49	281.73	7.35	124.32	+65.73	+15.45	-5.34
$D_2M_1C_4S$	278.75	74.99	232.00	286.62	7.80	126.37	+89.91	+14.42	-8.57
$D_2M_2C_1S$	383.62	97.05	301.47	249.69	6.48	111.00	+56.98	+22.28	-12.68
$D_2M_2C_2S$	453.52	105.34	340.04	183.34	5.97	104.21	+53.43	+19.33	-48.62
$D_2M_2C_3S$	317.45	83.88	255.32	279.77	7.30	122.36	+93.07	+32.46	+34.61
$D_2M_2C_4S$	291.51	76.66	241.92	281.48	7.78	124.35	+117.30	+30.45	+29.35
$D_3M_1C_1S$	346.53	83.41	271.15	271.67	7.28	116.30	+37.08	+17.44	-33.48
$D_3M_1C_2S$	426.65	92.69	316.51	205.54	6.66	107.06	+23.09	+13.61	-73.76
$D_3M_1C_3S$	296.85	72.78	234.69	282.93	8.01	126.40	+75.51	+25.16	+5.37
$D_3M_1C_4S$	267.09	65.48	220.26	293.57	8.24	126.86	+94.62	+23.49	+2.68
$D_3M_2C_1S$	342.23	83.91	271.51	281.04	7.33	116.94	+67.01	+34.57	+11.34
$D_3M_2C_2S$	422.35	92.04	315.32	211.65	6.74	108.02	+56.29	+31.85	-27.71
$D_3M_2C_3S$	287.33	73.01	236.37	296.57	8.51	126.56	+106.39	+42.11	+49.36
$D_3M_2C_4S$	263.87	66.91	221.24	306.78	8.63	132.69	+119.64	+39.35	+41.69

relay crops. This result was also in agreement with the findings of Singh *et al*. (1999), Kadam *et al*. (2010), Vidyavathi *et al*. (2011) and Das *et al.* (2010).

Nutrient (NPK) uptake and balance

Total uptake of N by whole cropping system varied between 488.45 kg ha^{-1}and 263.87 kg ha^{-1}, that of P between 121.05 kg ha^{-1} and 72.78 kg ha^{-1} and K between 362.52 kg ha^{-1} and 220.26 kg ha^{-1} (Table 4) among the different treatment combinations. The highest N, P and K-uptake (488.45, 121.05 and 362.52 kg ha^{-1}, respectively) and thereby lowest available soil N, P and K (179.46, 5.38 and 103.81 kg ha^{-1}, respectively) in the whole cropping system was recorded by the treatment combination of 20 June (D_1) transplanting under SRI method of rice cultivation (M_2) involving rice- pea (C_2) relay system ($D_1M_2C_2S$) followed by rice-lentil relay under the same rice treatment combination. The higher NPK uptake in the treatment combination involving pea relay crop was the resultant of higher seed and stover yield of pea in the system. It is noticed that in all the treatment combinations involving pea were more efficient in utilizing the soil available N, P_2O_5 and K_2O; applied N, P_2O_5 and K_2O resulting in higher uptake of nutrients by the crops in the system and lower N, P_2O_5 and K_2O content in soil after harvest of last crop of second year under these treatment combinations followed by the treatment combinations involving lentil. Similar findings were also reported by Sathish *et al.* (2011), Kalhapure *et al.* (2014) and Kumar *et al.* (2012).

The positive N balance in all the treatment combinations indicated that all the treatment combinations were responsible for mining of N from soil. However, more mining was observed in the treatment combination involving pea and lentil which might be due to the availability of more N in soil as a result of the positive effect of these two leguminous crops on improvement of soil fertility through biological N-fixation (Kumar *et al.,* 2012). Since, the total NPK uptake by whole system was more in the treatment combinations with pea and lentil relay crops. Lower P-balance in the treatment combination involving pea relay crop as compared to lentil might be due to more efficient utilization of P by pea and thereby higher pea yield than lentil. The positive P balance found in almost all the treatment combinations might be due to positive effect of growing crops in sequence and incorporation of crop residues into the soil which resulted in increased soil microbial population and organic matter (Subbarao *et al*., 2001). Some treatment combinations showed positive K- balance and some negative K-balance. The negative K balance indicated higher removal of K through harvested crop produce and residues in the crop sequences. However, incorporation of crop residues (mainly green gram residues after picking of pods) into the soil would help in replenishing the K status in the soil and thereby help in maintaining K status in the soil.

Based on the results of two years study, it may be concluded that the crop sequence "rice (transplanted on June 20 under SRI method) – field pea (relay crop) - maize (fodder crop) + green gram intercrops" was more efficient in utilizing the soil available nutrients resulting in the highest N, P and K removal and therefore the lowest available soil nutrient status after two-year cycle. So far as productivity and profitability is concerned this crop sequence may be recommended for the rice farmers of the region in loamy soils under medium land situation. Higher productivity related to higher nutrient removal warrants further study with organics for both sustained production and soil health.

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