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Integrated based Nutrient Management on Nutrient Content and Nutrient Availability under Aromatic Rice-(Aromatic)-Lentil Cropping System

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Abstract

Management of nutrients by integrating is becoming an important issue after targeting on justifiable crop production. With this view point, a field experiment was undertaken at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during the *kharif* and *rabi* season of 2016-17 and 2018-19 to investigate the effects of integrated sources of nitrogen management in the performance of rice varieties (aromatic) and their lingering effects on the sequential lentil crop. Among the two varieties, nutrient content studies revealed that variety Gobindobhog recorded the highest nitrogen, phosphorus and potassium content compared to Kalonunia variety relating to root, shoot and grain. Conversely, the plot transplanted with Kalonunia had a higher residual effect on the yield attributes and yields of the succeeding lentil crop. In this experiment pooled analysis showed that the plot treated with 50% N using fertilizer + 50% N using vermicompost (T_6), 50% N using fertilizer + 25% N using vermicompost + 25% N using FYM (T_8) and 75% N using fertilizer + 25% N using vermicompost (T_9) recorded highest or at par nutrient content of rice plant. For the lentil plant, the plot receiving the residual effect of 50% N using fertilizer + 25% N using vermicompost + 25% N using FYM (T_8) observed maximum nutrient content. The lowest was recorded in control plot. Highest yield efficacy of aromatic rice was found in the plot treated with 50% N using fertilizer + 50% N using vermicompost (T_6) and highest lentil yield was recorded in a plot fertilized with 50% N using fertilizer + 50% N using FYM (T_7), respectively.

Keywords: Aromatic rice, Farm yard manure (FYM), Residual effect, Rice-Lentil cropping system, Vermicompost

Introduction

Rice crop which involved in poaceae family is occupying an area of 162 million hectares worldwide with a productivity of 719.7 MT. In discussion about area and production, India is the country that grows the most rice globally, ranking second only to China among rice-growing nations. India's average productivity is 2.82 tonnes hectare^{-1}, yielding approximately 110.15 million tonnes from 43.19 million tonnes hectares^{-1} (Anonymous, 2017). In regards of the export of rice, India is also one of the major countries which play an important role in export of rice. India is currently the nation that exports the most rice worldwide (Ramakrishna and Degaokar, 2016). The superior quality characteristics of aromatic or scented (fragrant) rice place it at the top of the rice varieties, offering significant export potential. Aromatic rice is a major agricultural commodity that is exported.

In the Indian society, aromatic rice is regarded as most important not because of its outstanding quality but they also are considered as propitious. At every stage of aromatic rice, *i.e.*, flowering stage, harvesting stage, in storage even

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during milling and cooking, they produce specific fragrance in the aromatic rice field (Oad *et al*., 2006). Considering the growing demand of aromatic rice in present day, there is a vast scope to bring more area under these aromatic rice varieties in this part. Aromatic rice varieties of North Bengal and other parts of North Eastern states play a fundamental role in global rice trade (Mondal and Dutta, 2014). In local aromatic rice, the lower productivity is due to unsuitable agronomic management of nutrients, wherein the choice of a suitable variety with stable nutrient supervision may play an essential role. The lower productivity of local aromatic rice is caused by various constraints, including improper time of sowing, insufficient as well as excessive use of nutrients.

Selection of the appropriate variety and proper nutrient management are important factors for maximizing quality rice production. Due to declining soil health and rising inorganic fertilizer costs, there is a greater emphasis on the viability and application of organic sources as inexpensive organic manures to partially supplement the crop's nitrogen needs. Addition of organic residues, FYM, green manuring, *etc*. improves soil health and crop yield (Rajendiran *et al*., 2020). Integrated nutrient management (INM) techniques improve the productivity of the previous crop and have a positive knock-on effect on the one that follows. Nitrogen fertilizer is one of the main inorganic fertilizers thought to have a significant impact on the quantity and quality of aromatic rice. A nitrogen deficiency may also have an impact on rice yield, while an excessive nitrogen application may cause plants to lodge and reduce yield. Therefore, the best course of action for enhancing growth and achieving a satisfactory yield of aromatic rice in West Bengal's *terai* zone may be the prudent use of nitrogen fertilizer mixed with organic manures.

In intensive cropping system organic manure such as farm yard manure (FYM), vermicompost, *etc*. perform an essential function in maintenance of soil biological, physical and chemical properties and supplementation of the crop with macro and micronutrients. Organic manure applied to the previous crop, leaves some remaining into the soil up to a certain extent (Mahata *et al*., 2018). The residual effect of organic manures raises soil biomass by promoting microbial activity in the soil. Growing a subsequent pulse crop, such as lentils, seems appropriate to take advantage of residual fertility after rice harvest and to enrich the soil during the dry season (Bandyopadhyay *et al*., 2018). In addition, Shenoy (2020) opined that management of nutrients in an integrated manner and cropping system incorporation of legumes are profitable for rice production. Thus, an effort was made to examine the consequences of various nitrogen sources on the ensuing lentil crop in the long run.

Materials and Methods

During 2016-17 and 2018-2019, a field study was undertaken at the experimental field of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal to study the direct and residual outcome of management of nutrients in an integrated manner on the content of available nutrients and their yield effect of aromatic rice cultivars and succeeding lentil crop under rice (aromatic)-lentil cropping system. Split plot design was used for the study amd was replicated thrice. In the main plots, treatments comprised of 2 varieties (V_1: 'Kalonunia' and V_2: 'Gobindabhog') and 12 nitrogen management methods in subplots (T_1: control, T_2: 100% N using fertilizer, T_3: 25% N using fertilizer + 75% N using VC, T_4: 25% N using fertilizer + 75% N using FYM, T_5: 25% N using fertilizer + 37.5% N using VC + 37.5% N using FYM, T_6: 50% N using fertilizer + 50% N using VC, T_7: 50% N using fertilizer + 50% N using FYM, T_8: 50% N using fertilizer + 25% N using VC + 25% N using FYM, T_9: 75% N using fertilizer + 25% N using VC, T_{10}: 75% N using fertilizer + 25% N using FYM, T_{11}: 75% N using fertilizer + 12.5% N using VC + 12.5% N using FYM, T_{12}: 50% N using VC + 50% N using FYM). For soil available nitrogen, alkaline potassium permanganate method was used (Subbiah and Asija, 1956), to estimate available nitrogen. 5 g soil sample was digested with 25 ml potassium permanganate and 25 ml alkali; ammonia was extracted on other end in dissolved form of boric acid after six minutes, which then was titrated with acid to obtain the amount of acid to neutralize alkali, thereafter was further calculated for available nitrogen. Total nitrogen content was estimated through CHNS instrument in percentage. Available phosphorus was extracted using Bray and Kurtz (1945) method based on low pH of the soil. Soil was dissolved by ammonium fluoride and hydrochloric acid mix extractant in 1:10 ratio, shaken in mechanical shaker for exactly five minutes then filtered with Whatman filter paper No. 42. After adding 5 ml of the collected aliquot to 15 ml of boric acid and 8 ml of reagent (ammonium molybdate, antimony potassium tartarate, and glucose), the mixture was diluted with 50 ml of distilled water. Solution was shaken until colour appears blue, after which intensity of colour was measured in spectrometer at 780 nm. Readings were further calculated for available phosphorus. For available potassium of soil, $NH_4C_2H_3O_2$ solution with pH - 7.0 in ratio of 1:10 was used to treat the soil sample, and shaking was done for 1 hour, and filtered, the leachate was used to determine the K^+ content which was measured using a Flame photometer (Baruah and Barthakur, 1997). Soil was dissolved in ammonium acetate extractant in 1:5 ratio, shaken for exactly five minutes, then filtered with Whatman filter paper No. 1. Aliquot was diluted with distilled water in 1:1 or 2:3 ratio, as required and absorbance values were noted for each sample. Readings were further calculated for available potassium.

For the assessment of total N, the plant sample was digested in concentrated sulphuric acid with a digestion mixture which comprises of potassium sulphate (20 parts) with copper sulphate, mercury oxide and Se powder in the ratio of 20:3:1 (1 part). Micro-Kjeldahl method is used for analysing of N just after digestion (Jackson, 1973). In order to compute total P and K, the wet digestion of plant sample was carried out in diacid mixture consisting of HNO_3 and $HClO_4$ in the ratio of 4:1 and volume make-up was done upto 100 ml. Jackson (1973) also described that total P digestion was done using vanado-molybdo-phosphoric yellow color method using spectrophotometer at 420 nm; whereas total K by flame-photometer method. For individual major nutrient, the total uptake by each crop at harvest was estimated on dry weight basis, *i.e.*, the total dry matter of the crop was multiplied with its corresponding nutrient content.

Results and Discussion

Effects of Integrated based Nutrient Management on the N, P and K Content of Aromatic Rice

Data provided in table 1, revealed that the difference in N content in shoot, root and grain of rice of the two varieties were found to be significant. The pooled analysis of N content in the shoot (77.15 kg ha^{-1}), root (13.83 kg ha^{-1}) and grain (56.32 kg ha^{-1}) portion was higher in Gobindobhog than that of Kalonunia, *i.e.*, shoot (69.72 kg ha^{-1}), root (13.29 kg ha^{-1}) and Grain (52.14 kg ha^{-1}), respectively. The Phosphorus content in the rice shoot and grain had varied significantly except the root extract in rice. Similarly, the K content in rice shoot, root and grain was significantly influenced by the varieties. Analysis of pooled data showed that higher K content was observed in Gobindobhog, *i.e.*, shoot (64.18 kg ha^{-1}), root (12.00 kg ha^{-1}) and grain (47.55 kg ha^{-1}) than that of Kalonunia (shoot, 60.16 kg ha^{-1}; root, 11.48 kg ha^{-1}; grain, 43.86 kg ha^{-1}, respectively).

Table 1: Effects of integrated nutrient management on the SPAD value of aromatic rice varieties

Treatments	Pooled (2016-17 and 2018-2019)			
	30 DAT	60 DAT	90 DAT	120 DAT
Main plot treatments				
Kalonunia	38.18	42.71	34.25	31.97
Gobindobhog	39.71	43.51	34.99	32.75
SEm ±	0.22	0.29	0.53	0.12
CD (*P*=0.05)	1.33	1.77	3.22	0.70
Sub-plot treatments				
T_1	36.09	40.25	30.70	27.56
T_2	38.51	43.13	33.81	31.74
T_3	38.45	43.21	34.72	32.87
T_4	37.48	41.97	32.80	30.79
T_5	38.83	43.27	36.43	33.16
T_6	40.82	44.34	36.99	34.78
T_7	38.91	43.94	34.91	32.37
T_8	41.40	44.03	35.13	34.40
T_9	41.31	44.65	37.06	34.73
T_{10}	38.58	43.24	33.82	31.36
T_{11}	39.30	43.40	35.65	33.71
T_{12}	37.68	41.90	33.49	30.86
SEm ±	0.93	0.48	0.90	0.98
CD (*P*=0.05)	2.64	1.37	2.56	2.78
Interaction effect (A×B)				
SEm ±	1.31	0.68	1.27	1.38
CD (*P*=0.05)	NS	NS	NS	NS

Maximum nitrogen N content by the rice shoot were recorded significantly with the residual effect of 75% N using fertilizer + 25% N using vermicompost (T_9, 77.45 kg ha^{-1}) followed by T_6 (77.37 kg ha^{-1}). Pooled data reflected 18.7% increase with T_9 over control. The treatment T_6 significantly superseded rest of the treatment for the N content in the root and grain of rice crop, *i.e.*, 13.77 kg ha^{-1} and 60.13 kg ha^{-1}, and pooled data closely followed by T_8 and T_9 (root) and again T_8 (grain) based on pooled data. The lower N content in the rice root, shoot and grain were recorded with T_1, *i.e.*, control plot. An analysis of the observed data using statistics on the P content in the shoot of rice crop revealed a significant variation after using both organic and inorganic treatments. Pooled data revealed 52.022% increase with T_6 (26.68 kg ha^{-1}) over T_1, *i.e.*, control plot (17.55 kg ha^{-1}). The result (Table 4) of the study infers that the difference in P content in the root extracts rice crop was non-significant in nature. Rice grain P content was found to be significantly highest in T_8 (27.26 kg ha^{-1}) followed by T_6 (27.24 kg ha^{-1}) and lowest in T_1 (17.58 kg ha^{-1}). Data presented in table 2, revealed different nitrogen management influenced significantly on the K content in rice shoot. Pooled data recorded that T_6 and T_9 showed highest K content (68.80 kg ha^{-1}), while lowest in T_1, *i.e.*, control treatment (48.99 kg ha^{-1}). The highest K content in the root of rice also found significantly in similar trends with rice shoot. Highest were recorded in T_6 (12.51 kg ha^{-1}) followed by T_8 (12.36 kg ha^{-1}) and T_9 (12.44 kg ha^{-1}). Similarly lowest was found in T_1 plot. K content in rice grain of also showed similar trends to that of rice shoot and root. Maximum rice grain K content was found with T_6 (51.53 kg ha^{-1}) proved significant dominance compared to other treatment which was followed by T_8 (51.42 kg ha^{-1}). Pooled data showed 51.9% enhanced with T_6 over T_1, *i.e.*, control plot.

Table 1 shows that the interaction effect between Gobindobhog varieties with T_6 and T_9 had significant highest N content of rice shoot which was found to have statistically at par with each other. Minimum were found in no treatment interacting with Kalonunia variety for the years (2016-2017 and 2018-2019) as well as pooled data. For rice root N content, the interaction was also found to be significant. Results revealed that N content in the grain of rice did not influence significantly by the interaction of varieties and nitrogen management. Non significant variations were observed due to the interrelationship between varieties and management of nitrogen on the P content of rice shoot and root (Table 2). A non-significant variation was noticed due to the interaction effect of various treatments and varieties on the P content of rice shoot, root and grain.

Higher content of nitrogen, phosphorus and potassium in grain and straw, was observed in the variety Gobindobhog as compared to the variety Kalonunia. Between various management methods of nitrogen, results suggested that the highest content of N, P and K in grain as well as

Table 2: Effects of integrated nutrient management on the N, P, K content of aromatic rice

Treatments	Pooled (2016-17 and 2018-2019)								
	Nitrogen Content			Phosphorus Content			Potassium Content		
	Rice shoot (kg ha^{-1})	Rice root (kg ha^{-1})	Rice grain (kg ha^{-1})	Rice shoot (kg ha^{-1})	Rice root (kg ha^{-1})	Rice grain (kg ha^{-1})	Rice shoot (kg ha^{-1})	Rice root (kg ha^{-1})	Rice grain (kg ha^{-1})
Main plot treatments									
Kalonunia	69.72	13.29	52.14	22.31	16.44	23.14	60.16	11.48	43.86
Gobindobhog	77.15	13.83	56.32	23.91	16.68	24.93	64.18	12.00	47.55
SEm ±	0.234	0.064	0.376	0.290	0.064	0.289	0.755	0.133	0.118
CD (*P*=0.05)	1.424	0.389	2.291	1.767	NS	1.757	4.596	0.811	0.719
Sub-plot treatments									
T_1	65.21	13.03	42.17	17.55	15.40	17.58	48.99	10.14	33.92
T_2	73.16	13.55	52.04	21.72	16.44	23.48	59.86	11.64	43.96
T_3	74.35	13.62	54.81	23.75	16.75	25.18	63.89	12.15	47.36
T_4	70.30	13.45	47.50	18.67	16.20	19.78	52.85	10.55	38.61
T_5	74.32	13.62	56.95	24.39	16.77	25.01	65.05	12.17	47.23
T_6	77.37	13.77	60.13	26.68	17.08	27.24	68.80	12.51	51.53
T_7	74.89	13.65	56.53	24.15	16.75	25.23	64.60	11.85	48.09
T_8	76.61	13.74	58.65	26.61	17.08	27.26	67.58	12.36	51.42
T_9	77.45	13.73	59.03	26.06	16.99	26.88	68.80	12.44	50.94
T_{10}	72.19	13.52	54.97	22.68	16.56	23.40	61.57	11.56	44.07
T_{11}	75.20	13.66	57.45	24.96	16.88	25.71	66.12	12.29	49.29
T_{12}	70.20	13.43	50.55	20.14	15.80	21.70	57.91	11.29	41.98
SEm ±	0.308	0.062	1.061	0.655	1.038	0.846	1.832	0.319	0.882
CD (*P*=0.05)	0.879	0.177	3.024	1.866	NS	2.410	5.220	0.908	2.514
Interaction effect (A×B)									
SEm ±	0.436	0.088	1.501	0.926	1.467	1.196	2.590	0.451	1.248
CD (*P*=0.05)	1.243	0.251	NS	NS	NS	NS	NS	NS	NS

straw were under T_6 (50% N using fertilizer + 50% N using vermicompost), which was closely superseded by T_9, *i.e.*, 75% N using fertilizer + 25% N using vermicompost. An increment in the uptake of N, P and K after utilizing organic manures was drawn in various results (Virdia and Mehta, 2009; Sathish *et al*., 2011).

Effects of Integrated based Nutrient Management on the N, P and K Uptake by Straw, Grain and Total Uptake after Rice Harvest

Nitrogen Uptake

The experimental findings (Table 3) showed that the nitrogen uptake by aromatic rice (straw and grain) was recorded to be highest with Gobindobhog, *i.e.*, straw (74.41 kg ha^{-1}) and grain (53.49 kg ha^{-1}) and minimum with Kalonunia, *i.e.*, straw (65.37 kg ha^{-1}) and grain (48.62 kg ha^{-1}). The pooled mean of total N uptake also shows a similar trend.

Table 3 revealed that rice straw and grain nitrogen uptake was influenced significantly by the different nitrogen management. The treatment T_6 recorded highest uptake of nitrogen by rice straw (77.11 kg ha^{-1}) and grain (55.60 kg ha^{-1}) which was at par with T_9 (straw, 77.03 kg ha^{-1}; grain, 54.82 kg ha^{-1}). The lowest rice straw and grain nitrogen uptake pooled mean was observed in control plot (T_1). For Total N uptake, maximum uptake was observed in T_6 treatment (93.09 kg ha^{-1}) followed by T_9 (92.10 kg ha^{-1}) and lowest under control treatment T_1 (67.16 kg ha^{-1}).

Interaction effects between varieties and nitrogen management on rice straw N uptake and total N uptake was found to be significantly varied (Table 5). Pooled results of interaction connecting Gobindobhog variety and T_9, *i.e.*, V_2T_9 (82.96 kg ha^{-1}) was recorded highest rice straw nitrogen uptake. The lowest was found in the interaction between Kalonunia variety (V_1) and Control treatment (T_1), *i.e.*, V_1T_1 (49.93 kg ha^{-1}). Again, pooled results due to interaction between Gobindobhog variety (V_2) and 50% N using fertilizer + 50% N using vermicompost (T_6), *i.e.*, V_2T_6 (99.26 kg ha^{-1}) found highest in total N uptake of rice plant and the interaction between Kalonunia variety (V_1) and Control treatment (T_1), *i.e.*, V_1T_1 (65.45 kg ha^{-1}) recorded lowest.

Table 3: Effects of integrated nutrient management on the N, P, K uptake by straw, grain and total uptake after rice harvest

Treatments	Pooled (2016-17 and 2018-2019)								
	Nitrogen Content			Phosphorus Content			Potassium Content		
	Straw N uptake (kg ha^{-1})	Grain N uptake (kg ha^{-1})	Total N uptake (kg ha^{-1})	Straw P uptake (kg ha^{-1})	Grain P uptake (kg ha^{-1})	Total P uptake (kg ha^{-1})	Straw K uptake (kg ha^{-1})	Grain K uptake (kg ha^{-1})	Total K uptake (kg ha^{-1})
Main plot treatments									
Kalonunia	65.37	48.62	79.79	21.01	21.56	29.80	56.61	40.88	68.24
Gobindobhog	74.41	53.49	89.53	23.18	23.66	32.79	62.06	45.14	75.04
SEm±	0.33	0.34	0.14	0.35	0.29	0.42	0.72	0.11	0.49
CD(*P*=0.05)	1.98	2.07	0.84	2.13	1.77	2.56	4.40	0.66	3.01
Sub-plot treatments									
T_1	51.68	44.26	67.16	13.90	18.48	22.67	38.82	35.65	52.13
T_2	69.48	49.19	81.81	20.39	21.91	29.89	56.12	41.29	67.73
T_3	71.55	51.08	86.63	22.81	23.31	32.52	61.37	43.86	73.34
T_4	64.00	46.26	76.59	16.98	19.26	25.37	48.05	37.64	59.98
T_5	71.45	52.61	86.71	23.55	23.22	32.50	62.80	43.87	74.98
T_6	77.11	55.60	93.09	26.60	25.30	36.33	68.56	47.86	81.92
T_7	73.41	52.08	87.84	23.67	23.25	32.84	63.34	44.32	75.36
T_8	76.10	54.28	91.26	26.46	25.11	36.10	67.13	47.38	79.76
T_9	77.03	54.82	92.10	25.88	24.92	35.56	68.36	47.27	80.91
T_{10}	67.69	50.99	83.68	21.56	21.98	30.20	58.49	41.19	70.24
T_{11}	73.95	53.26	89.05	24.56	23.84	33.88	65.06	45.70	77.53
T_{12}	65.21	48.24	80.00	18.80	20.71	27.66	53.94	40.07	65.81
SEm ±	0.76	1.14	0.90	0.67	0.81	0.68	1.84	0.96	1.36
CD (*P*=0.05)	2.17	3.26	2.56	1.92	2.32	1.94	5.24	2.72	3.86
Interaction effect (A×B)									
SEm ±	1.08	1.62	1.27	0.95	1.15	0.96	2.60	1.35	1.92
CD (*P*=0.05)	3.06	NS	3.62	NS	NS	NS	NS	NS	NS

Vermicompost along with inorganic fertilizer (Urea) showed significantly positive interaction with the varieties. Nutrient uptake is mainly influenced by content of various nutrients as well as accumulation of dry matter and both were largely influenced by combined use of 50% N using fertilizer + 50% N using organic manures (VC/FYM/VC + FYM). It is mainly owed to slow release of nutrient on the residual effect of organic manures and partial supply of nutrients through available form of inorganic fertilizer that led to maximum rice crop N, P and K uptake. The result (Table 3) revealed that rice grain nitrogen uptake was not significantly varied by the interaction between varieties and nitrogen management.

Phosphorus Uptake

The pooled data of the P uptake (Table 3) by aromatic rice straw and grain was found to be highest with Gobindobhog variety (straw, 23.18 kg ha^{-1}; grain, 23.66 kg ha^{-1}) and lowest with Kalonunia variety (straw, 21.01 kg ha^{-1}; grain, 21.56 kg ha^{-1}). Analogous leaning was also observed in the pooled data of the total P uptake, *i.e.*, highest by Gobindobog variety than Kalonunia variety.

It is clearly show a significant variation in rice phosphorus uptake in both grain and straw due to different nitrogen management (Table 3). Pooled data of straw phosphorus uptake, grain phosphorus uptake and total uptake was recorded to be highest with T_6 (straw, 26.60 kg ha^{-1}; grain, 25.30 kg ha^{-1}; total uptake, 36.33 kg ha^{-1}) followed by T_8 (straw, 26.46 kg ha^{-1}; grain, 25.11 kg ha^{-1}; total uptake, 36.10 kg ha^{-1}) and lowest with T_1, *i.e.*, straw (13.90 kg ha^{-1}), grain (18.48 kg ha^{-1}) and total uptake (22.67 kg ha^{-1}). It was concluded that the effect of interacting between varieties and nutrient management was not influenced significantly due that phosphorus uptake by rice straw, rice grain and total phosphorus uptake by aromatic rice (Table 3).

Potassium Uptake

The rice straw and grain K uptake and total uptake by plant was found to have significant effects by the different varieties of aromatic rice. It showed similar trends to that of phosphorus uptake of rice straw (Table 3).

Sources of different nitrogen produced significant variations on rice grain K uptake, straw and total uptake. Pooled mean of potassium uptake by rice straw, grain and total uptake shows maximum under T_6 treatment, *i.e.*, straw (68.56 kg ha^{-1}), grain (47.86 kg ha^{-1}) and total uptake (81.92 kg ha^{-1}) and lowest in T_1 treatment, *i.e.*, straw (38.82 kg ha^{-1}), grain (35.65 kg ha^{-1}) and total uptake (52.13 kg ha^{-1}). Data in table 3 concluded that potassium uptake by aromatic rice straw, grain and the total uptake by plant did not influence significantly by the interaction of varieties and nitrogen management.

The results are also in conformity to the results of Bejbaruah *et al.* (2013) and Yadav and Meena (2014) where NPK uptake increases with application of chemical fertilizer and vermicompost. Increase nutrient uptake with combined use of vermicompost/ FYM and inorganic fertilizer may be accredited to consistent amount of nutrients to aromatic rice crop and reduce the loss rate while releasing nutrients on the vermicompost/ FYM decomposition process. Change of nitrogen bound in the organic form to inorganic form due to mineralization may have resulted in elevated availability of N in soil (Singh *et al.*, 2018).

Effects of Integrated based Nutrient Management on the Available Nutrients (N, P, K, Organic Carbon and pH) after Rice Harvest

Table 4 shows that the plot of Kalonunia variety recorded highest available soil N (197.1 kg ha^{-1}), P (27.88 kg ha^{-1}), K (121.5 kg ha^{-1}), organic carbon (14.93 kg ha^{-1}) and soil pH (5.47) as compared to the plot of Gobindobhog, *i.e.*, available soil N (189.5 kg ha^{-1}), P (26.09 kg ha^{-1}), K (114.8 kg ha^{-1}), OC (13.70 kg ha^{-1}) and soil pH (5.46), significantly.

The investigations revealed a significant variation among different treatments of nutrient management for various available soils N, P, K, organic carbon and pH. Results reveal that for available N, maximum was found with T_2 (217.1 kg ha^{-1}) followed by T_{12} (216.6 kg ha^{-1}) and lowest with T_1 (157.2 kg ha^{-1}). The statistical analysis of the data on available P and K revealed a significantly highest value in the plot treated with T_7 (36.31 kg ha^{-1} available phosphorus and 140.6 kg ha^{-1} available potassium) which was at par with T_2 (36.12 kg ha^{-1} available phosphorus and 137.3 kg ha^{-1} available potassium) and lowest under T_1 treatment (14.94 kg ha^{-1} available P and 85.0 kg ha^{-1} available K). Pooled data of available P in soil was reflected 43.03% increase with T_7, *i.e.*, 50% N using

Table 4: Effects of integrated nutrient management on the available nutrients (N, P, K, organic carbon and pH) after rice harvest

Treatments	Pooled (2016-17 and 2018-2019)				
	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	SOC (mg kg^{-1})	Soil pH
Main plot treatments					
Kalonunia	197.1	27.88	121.5	14.93	5.47
Gobindobhog	189.5	26.09	114.8	13.70	5.46
SEm ±	1.141	0.528	0.587	0.045	0.002
CD (*P*=0.05)	6.944	3.216	3.571	0.275	0.015
Sub-plot treatments					
T_1	157.2	14.94	85.0	7.14	5.45
T_2	217.1	36.12	137.3	8.03	5.44
T_3	192.3	25.27	122.2	13.80	5.44
T_4	207.4	29.71	131.8	12.39	5.47
T_5	172.9	21.47	96.1	10.63	5.49
T_6	198.6	26.94	125.5	18.07	5.47
T_7	213.3	36.31	140.6	16.76	5.47
T_8	179.8	22.96	107.9	18.42	5.48
T_9	184.4	23.78	114.1	17.84	5.47
T_{10}	212.6	33.48	132.3	14.75	5.47
T_{11}	167.1	18.46	93.0	14.73	5.48
T_{12}	216.6	34.34	131.8	19.22	5.47
SEm ±	2.268	0.966	4.078	0.088	0.013
CD (*P*=0.05)	6.463	2.753	11.622	0.250	NS
Initial	125.61	12.21	109.3	7.30	5.39
Interaction effect (A×B)					
SEm ±	3.207	1.366	5.766	0.124	0.019
CD (*P*=0.05)	NS	NS	NS	0.354	NS

Table 5: Interaction effect between varieties and nitrogen management

Treatments	Pooled (2016-17 and 2018-2019)						
	Nitrogen Shoot (kg ha^{-1})	Nitrogen root (kg ha^{-1})	Straw N uptake (kg ha^{-1})	Total N uptake (kg ha^{-1})	Rice SOC (mg kg^{-1})	Lentil SOC (mg kg^{-1})	Lentil pH
V_1T_1	63.10	12.99	49.93	65.45	7.01	7.73	5.53
V_1T_2	69.48	13.27	65.48	78.81	7.56	10.50	5.54
V_1T_3	70.46	13.31	67.27	81.69	13.96	15.52	5.55
V_1T_4	67.70	13.22	59.23	73.00	12.37	18.02	5.59
V_1T_5	70.19	13.30	66.81	81.35	9.03	14.28	5.58
V_1T_6	72.65	13.45	71.41	86.92	17.47	19.53	5.62
V_1T_7	71.64	13.37	68.96	82.82	16.53	16.67	5.62
V_1T_8	72.21	13.43	70.54	85.25	17.11	21.92	5.67
V_1T_9	73.14	13.41	71.10	86.01	18.47	12.55	5.56
V_1T_{10}	68.87	13.26	63.52	77.86	15.03	18.00	5.59
V_1T_{11}	70.90	13.34	69.30	83.80	10.90	19.56	5.65
V_1T_{12}	66.25	13.18	60.87	74.54	18.95	21.44	5.61
V_2T_1	67.31	13.06	53.44	68.87	7.27	8.13	5.56
V_2T_2	76.84	13.83	73.48	87.32	8.45	10.24	5.59
V_2T_3	78.22	13.94	75.84	91.56	14.34	16.72	5.58
V_2T_4	72.80	13.64	68.77	82.30	12.05	19.70	5.60
V_2T_5	78.89	13.96	76.09	92.06	10.87	15.71	5.64
V_2T_6	82.14	14.08	82.81	99.26	18.86	21.35	5.66
V_2T_7	77.60	13.89	77.87	92.87	17.28	18.14	5.64
V_2T_8	81.00	14.03	81.66	97.27	19.03	22.29	5.62
V_2T_9	81.70	14.05	82.96	98.20	18.06	13.56	5.61
V_2T_{10}	75.50	13.78	71.86	87.01	14.89	18.63	5.60
V_2T_{11}	79.60	13.99	78.60	94.30	18.55	20.83	5.65
V_2T_{12}	74.22	13.71	69.54	83.33	19.49	22.03	5.57
SEm ±	0.436	0.088	1.08	1.27	0.124	0.226	0.021
CD (*P*=0.05)	1.243	0.251	3.06	3.62	0.354	0.644	0.059

fertilizer + 50% N using FYM (36.31 kg ha^{-1}) over T_1, *i.e.*, control plot (14.94 kg ha^{-1}), respectively. The graded level of nutrient content of SOC was analyzed after harvest of rice and availability was affected significantly by the varieties of nutrient sources. Table 4 data shows that the position of organic carbon over initial stage was higher significantly due to the residual effect with T_{12} (19.22 mg kg^{-1}) which was followed by T_8 (18.42 mg kg^{-1}) while it decreases in T_1, *i.e.*, control plot (7.14 mg kg^{-1}). It was concluded (Table 4) that pooled data of soil pH after crop harvest were recorded to be highest in a plot previously fertilized T_6 (5.49), T_8 (5.48) and T_{11} (5.48) while lowest in T_2 (5.44) and T_3 (5.44).

The data recorded from the table 4 indicate the soil available N, P, K and soil pH in rice after harvest did not influence significantly on the interaction effect of varieties and nitrogen management. It has been concluded that the SOC was significantly affected by the interaction of various varieties and nitrogen management practices. The pooled data showed that the interaction between Gobindobhog variety and the plot fertilized with T_{12} (19.49 mg kg^{-1}) over the interaction between Kaloninia variety (V_1) with control plot T_1 (7.01 mg kg^{-1}).

The soil available nutrient was also significantly varied due to various intensity of vermicompost applied (Mohammadi *et al.*, 2017). The available soil phosphorus content with application of vermicompost increased which may be attributed to better soil phosphorus mobilization and increased availability through organic acids excretion. Simultaneous application of CF and organic manures produced superior K availability in soils due to decrease in fixation of K thereby releasing more K that led to higher DMP and consequently higher uptake by rice. The same results were also informed by Banger *et al.* (2009), Kumar (2016) and Aparna (2018).

Residual Effects of Nutrient Content on the Succeeding Lentil Crop by Integrated Nutrient Management

Nitrogen Content of Succeeding Lentil Crop

There is a significant impact on the lentil stover and Lentil seed N content. Highest pooled data were recorded from the plot previously planted with Kalonunia (90.65 kg ha^{-1} N in lentil stover and 96.73 kg ha^{-1} N in Lentil seed) than that of Gobindobhog (88.52 kg ha^{-1} N in lentil stover and 94.96 kg ha^{-1} N in Lentil seed). Results (Table 6) showed that N content in the lentil stover and lentil seed varied significantly as a result of lingering effect of different nitrogen management technique in experimental year 2016-17 and 2018-19. Pooled data shows that maximum N content data were seen in residual effect of T_8, *i.e.*, 94.81 kg ha^{-1} N in lentil stover and 102.46 kg ha^{-1} N in Lentil seed and lowest in control T_1. The difference of interaction between variety and treatment was found to be non-significant.

Phosphorus Content of Succeeding Lentil Crop

Table 6 shows significant effect on the residual nutrient management of succeeding lentil crops on phosphorus content. The results reveal that maximum phosphorus content in succeeding lentil stover and lentil seed was found in the plot transplanted with Kalonunia variety (46.08 kg ha^{-1} phosphorus in lentil stover and 44.47 kg ha^{-1} phosphorus in Lentil seed) compared to plot transplanted with Gobindobog variety (52.49 kg ha^{-1} phosphorus in lentil stover and 51.32 kg ha^{-1} phosphorus in Lentil seed). The P content in lentil stover and lentil seed was found to be significantly highest in the plot treated with T_6 for lentil stover (49.46 kg ha^{-1}) and T_8 for lentil seed (57.17 kg ha^{-1}) and lowest under control plot (34.95 kg ha^{-1} for lentil stover and 43.17 kg ha^{-1} for lentil seed). For P content of lentil stover, pooled data showed 41.51% increase with T_6 over T_1, *i.e.*, control treatment (Table 6). Varieties and nitrogen management practices interacted non-significantly and resulted in non-significant P content of the residual effect of the succeeding lentil stover and seed.

Potassium Content of Succeeding Lentil Crop

Results (Table 6) reveals that K content of lentil stover

Table 6: Residual effects of nutrient content on the succeeding lentil crop by integrated nutrient management

Treatments	Pooled (2016-17 and 2018-19) Nitrogen content		Pooled (2016-17 and 2018-19) Phosphorus content		Pooled (2016-17 and 2018-19) Potassium content	
	Lentil plant (kg ha^{-1})	Lentil Seed (kg ha^{-1})	Lentil plant (kg ha^{-1})	Lentil Seed (kg ha^{-1})	Lentil plant (kg ha^{-1})	Lentil Seed (kg ha^{-1})
Main plot treatments						
Kalonunia	90.65	96.73	46.08	52.49	82.94	91.01
Gobindobhog	88.52	94.96	44.47	51.32	81.39	88.98
SEm ±	0.709	0.227	0.100	0.145	0.509	0.278
CD (*P*=0.05)	4.31	1.384	0.611	0.882	NS	1.693
Sub-plot treatments						
T_1	80.70	84.81	34.95	43.17	69.18	77.42
T_2	87.99	94.66	44.63	50.94	80.65	89.27
T_3	89.08	96.42	46.26	52.77	84.05	90.88
T_4	85.93	97.50	44.78	47.56	75.64	83.50
T_5	88.81	91.08	47.02	52.80	84.02	93.76
T_6	90.99	100.89	49.46	55.46	87.36	94.93
T_7	94.41	100.24	46.64	53.00	85.20	91.49
T_8	94.81	102.46	49.44	57.17	87.94	97.82
T_9	89.14	99.66	49.07	55.56	85.45	93.67
T_{10}	93.13	94.74	39.79	51.35	80.28	88.81
T_{11}	92.93	97.67	48.21	53.62	87.73	91.66
T_{12}	87.18	93.56	43.04	49.45	78.53	86.77
SEm ±	1.693	0.606	0.585	0.606	1.816	0.745
CD (*P*=0.05)	4.825	1.728	1.667	1.726	5.176	2.122
Interaction effect (A×B)						
SEm ±	2.394	0.857	0.827	0.856	2.568	1.053
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS

and seed was recorded significantly highest from the plot previously transplanted with Kalonunia (82.94 kg ha^{-1} for lentil stover and 91.01 kg ha^{-1} for lentil seed) and that of the plot previously transplanted with Gobindobhog (81.39 kg ha^{-1} for lentil stover and 88.98 kg ha^{-1} for lentil seed, respectively). It is clearly shows that there was a significant variation in K content of lentil stover and seed owing to residual effect of varied nitrogen management. Pooled data of both years recorded for lentil stover and seed was found to be highest where the previous crop was fertilized with T_8 (87.94 kg ha^{-1} for lentil stover and 97.82 kg ha^{-1} for lentil seed) and lowest with T_1, *i.e.*, control plot (69.18 kg ha^{-1} for lentil stover and 77.42 kg ha^{-1} for lentil seed). A non-significant variation was observed due to the interaction effect of various treatments and varieties on the K content of lentil stover and seed.

Residual Effects of Available N, P, K, Soil Organic Carbon and Soil pH after Lentil Harvest

Integrated Nutrient Management

A scrutiny of the data given in table 7 showed that available nitrogen, phosphorus, potassium along with soil organic carbon after lentil harvest recorded significantly highest with Kalonunia variety previously transplanted plot (211.6 kg N ha^{-1}; 32.98 kg P ha^{-1}; 128.5 kg K ha^{-1}; 17.28 mg SOC kg^{-1}) and lower with Gobindobhog variety previously transplanted plot (204.0 kg N ha^{-1}; 29.84 kg P ha^{-1}; 125.8 kg K ha^{-1}; 16.31 mg SOC kg^{-1}). The soil pH of both the varieties scored the same value 5.60, respectively.

The table 1 revealed that available soil nitrogen, phosphorus, potassium status over initial stage was higher significantly due to the residual effect with T_7 (239.3 kg N ha^{-1}; 41.02 kg P ha^{-1}; 150.5 kg K ha^{-1}) followed by T_{12} (238.4 kg N ha^{-1}; 39.81 kg P ha^{-1}; 146.6 kg K ha^{-1}). For SOC, the highest was recorded in the plot previously fertilized with T_8 (22.11 mg SOC kg^{-1}) which was at par with T_{12} (21.74 mg SOC kg^{-1}). Pooled data of soil pH after lentil harvest were recorded to be highest in a plot previously fertilized T_6, T_8 and T_{11} (5.64) and lowest with T_3 (5.56).

It was noted that after the harvesting of lentil, soil available nitrogen, phosphorus, potassium was not found to be significantly different due to the effect of interaction between the varieties and methods of nitrogen management. SOC and soil pH were affected significantly by the interaction outcome of the different varieties and various nitrogen management methods. The pooled data of SOC showed 88.36% increase with the interaction between previously Gobindobhog variety transplanted plot (V_2) and the plot previously fertilized with T_8 (22.29 mg kg^{-1}) over

Table 7: Residual effects of available N, P, K, soil organic carbon and soil pH after lentil harvest

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	SOC (mg kg^{-1})	Soil pH
Main plot treatments					
Kalonunia	204.0	29.84	125.8	16.31	5.60
Gobindobhog	211.6	32.98	128.5	17.28	5.60
SEm ±	1.131	0.410	0.656	0.063	0.002
CD (*P*=0.05)	6.883	2.498	3.989	0.384	0.010
Sub-plot treatments					
T_1	176.1	18.50	95.7	7.93	5.58
T_2	235.8	38.48	137.0	10.37	5.57
T_3	214.3	30.29	132.5	16.12	5.56
T_4	227.3	37.81	143.1	18.54	5.59
T_5	195.7	25.05	104.6	15.00	5.60
T_6	221.3	31.58	135.6	20.46	5.64
T_7	239.3	41.02	150.5	17.41	5.63
T_8	203.8	26.55	114.3	22.11	5.64
T_9	205.9	28.76	123.9	13.06	5.60
T_{10}	232.9	36.60	140.2	18.86	5.60
T_{11}	189.3	22.48	101.7	20.18	5.64
T_{12}	238.4	39.81	146.6	21.74	5.59
SEm ±	2.349	1.110	1.647	0.160	0.015
CD (*P*=0.05)	6.694	3.164	4.693	0.455	0.042
Interaction effect (A×B)					
SEm ±	3.321	1.570	2.329	0.226	0.021
CD (*P*=0.05)	NS	NS	NS	0.644	0.059

the interaction between Kalonunia variety (V_1) and control treatment (T_1), respectively (7.73 mg kg^{-1}). In case of soil pH, after evaluation of pooled results of 2 years, due to the interaction of previously transplanted Kalonunia varieties plot (V_1) and the plot previously fertilized with T_8 treatment, *i.e.*, V_1T_8 (5.67) produced recorded highest soil pH of lentil succeeding crop followed by the plot previously transplanted with Gobindobhog variety (V_2) and the plot previously fertilized with T_6 treatment, *i.e.*, V_2T_6 (5.66) while lowest was observed in control treatment (T_1) interacting with Kalonunia variety (V_1), *i.e.*, V_1T_1 (5.53), respectively.

Utilizing combination of organic matter and inorganic fertilizer had produced higher nutrient availability contents because organic matter broke down and released significant N, organic P and K which in turn helped increase NPK availability. The Rhizobium bacteria on the root nodules of plants fix nitrogen biologically, accounting for the majority of the total nitrogen (N). The remaining N and other nutrients are recycled within the soil plant system (Rahman *et al*., 2013). This consistent supply and accessibility of nutrients eventually led to superior nutrient uptake after lentil harvest.

Conclusion

A higher content of nitrogen, phosphorus, potassium in straw and grain in Gobindobhog variety in comparison to Kalonunia was perceived through the experiment. The variety 'Gobindabhog' also recorded higher aromatic rice SPAD value. Amongst various methods of nitrogen management, it was found that content of nitrogen, phosphorus, potassium in straw and grain were highest under T_6 (50% N using fertilizer + 50% N using vermicompost), followed by T_9, *i.e.*, 75% N using fertilizer + 25% N using vermicompost. The nutrient uptake studies revealed that 'Gobindabhog' variety recorded the highest uptake of nitrogen, phosphorus, potassium as compared to 'Kalonunia'. Additionally, highest amount of nutrient uptake was obtained with 50% N using fertilizer + 50% N using VC, 50% N using fertilizer + 25% N using VC + 25% N using FYM and 75% N using fertilizer + 25% N using VC.

Therefore, a integrated based balanced nutrition is recommended through combined use of 50% N using fertilizer and 50% N using organic manure which may be VC or FYM or combination of the two in order to recuperating rice productivity. On the other hand, remaining after conjunctive use of organic effects along with inorganic form of nutrients had a positive effect toward increasing the yield of any successive crop.

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