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Nutrient omission plot technique for yield response, indigenous nutrient supply and nutrient use efficiency estimation of rice (*Oryza sativa* L.) crop in Andaman & Nicobar Islands

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ABSTRACT

A nutrient omission plot technique (NOPT) study in RCBD with 8 treatments (omission (-) of N, P, K, NP, NK, PK and no nutrient omission)and 3 replicates per treatment was made on rice at Port Blair, Andaman and Nicobar Islands during kharif 2015 to ascertain yield response and find out the most crucial nutrient for fertilization.The results revealed that yield response to fertilizers (NPK) was 2.63 t / ha (60.74%). The yield response of P (23.3 %) got multiplied by 2.16 and 2.60 times when combined with N and K applications as compared to their individual effects. Indigenous N, P and K supply capacity of the soil was estimated as 70.6, 10.0 and 80.0 kg/ha. Agronomic efficiency (kg grain / kg nutrient applied) was severely limited by P omission (10.13). The economics(Rs/ha) of rice cultivation indicates that omission of NPK & NP fertilizers results in losses. The highest profits realized with no omission (+NPK) were reduced by 52.3% with P omission. Omission of K followed by N and NK has less impact on profits. Rice crop duration got prolonged and shortened under P and N omission while K omission has no such effect.

Key words: *Agronomic efficiency, partial factor productivity, hybrid rice, indigenous nutrient supply, nutrient omission, net income*

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food crops of Andaman & Nicobar Islands (ANI) cultivated in low lands as a transplanted rain fed crop during *kharif* season and contributes 98.96 % (16,845 tonnes; from 5,340 ha acreage) of total food grain production *i.e.*, 17, 022 tonnes (DOES, 2017-18). A huge yield gap has been observed between mean rice productivity of the Islands (3.15 t / ha during 2017-18) and that of agronomic research trails *i.e.*, 5.67 t / ha during 2016 (Gangaiah et al., 2017a) that was ascribed poor crop management especially with respect to use of fertilizers. The low fertilizer consumption of Islands *i.e.*, 34.9 kg / ha of gross cultivated area during 2017-18 (1581 t for 43500 ha) as compared to the estimated demand of 9871 t (Gangaiah et al., 2017b) depicts the situation. The soils of Islands from 0.823 m ha geographical area falls in the soil orders of Inceptisols (43.9%), Entisols (37.8%), Alfisols (5.95%), Mollosols (4.86%) and others (Bhattacharyya et al., 2013) with predominantly acidic reaction (slight to severely acidic) even in coastal regions (acid sulphate / acid - saline soils) experiences several nutrient deficiencies and toxicities (Subba Rao et al., 2011) and the widespreadnutrient deficiencies were documented from the soil health card works (Gangaiah et al., 2016) that necessitates fertilizer application for higher and stable crop yields. The soil test based blanket fertilizer recommendations of researchers though have scientific merit have not reached to all the farmers and many of them are not convinced with the approach. At this juncture, site specific nutrient management (SSNM) concept developed through omission plot technique (OPT) comes handy as it not only avoids the need for chemical analysis of soil in the laboratory but also uses grain yield as measurement indices (Dobermann and Fairhurst, 2000) that farmers can see physically and get convinced. Omission plot is one where adequate amounts of all nutrients are applied except for the nutrient of interest (the omitted nutrient). The yield from nutrient omission and non-omission plotsprovide information about the indigenous soil supplying capacity and crop response, respectively from which farm specific nutrient recommendations can be arrived at for a targeted yield. Balance fertilized (more often NPK fertilized) plot yield with recommended crop management practices is taken as targeted yield (www.irri.org/irrc/ssnm). This approach is ideal to islands where farms are scattered and to get soil testing data is very difficult.Keeping the above facts in view, a field experiment was conducted to study the effects of nitrogen (N), phosphorus (P) and potassium (K) i.e. primary nutrients on growth, productivity and profitability of rice using nutrient omission plot technique (NOPT) on research farm.The indigenous nutrient supplies of soil and nutrient use efficiency indices were also worked out besides coming out the omittable nutrient in rice cropping.

MATERIALS AND METHODS

Field experiment was done during *kharif* (July - November) season of 2015 at Bloomsdale Research Farm of ICAR - Central Island Agricultural Research Institute (CIARI), Port Blair, Andaman & Nicobar Islands situated at 110 38' 06" N latitude and 920 39' 15" E longitude at an altitude of 14 m above mean sea level. Experimental site has a tropical humid (monsoonal) climate (Am) with short dry season (January- March/ April). The experimental soil that was texturally a clay loam in the plough layer (top 20 cm) analysed as per Singh et al., (2005) was slightly acidic in reaction (6.36pH), non-saline (ECe: 0.67 dS/m), rated as medium for organic carbon content (0.62%) and low for available N, P and K (248, 9.9 and 117.5 kg / ha) at the start of experiment in July 2015. A medium duration (130 days) rice hybrid "DRRH3"with medium slender grains, moderately resistant to blast, RTV and tolerant to WBPH released during 2009 by Directorate of Rice Research, Hyderabad was used in the study. The experiment consisted of eight (8) nutrient omission (-) treatments *i.e.*, -NPK, -NP, -NK, -PK, -N, -P, -K and no omission (+NPK *i.e.*, optimum plane of nutrition) were laid out in Randomized Complete Block Design (RCBD) with treatments replicated thrice. A fertilizer dose of 100-60-60 kg/ha N-P_2O_5-K_2O was applied in the study and were supplied through straight fertilizers of urea (46.4 % N), single superphosphate (16 % P_2O_5) and muriate of potash (60% K_2O) so as to supply a single / combination of nutrientsas per treatment. A gross plot size of 25 m^2 was used for the study with plots separated from each other by 30 cm bund and 100 cm channel on all sides so as to contain the movement of fertilizers from one plot to other. Water was let into each plot through a central channel separating the replications. Experimental main field was thoroughly prepared by puddling thrice with power tiller followed by manual levelling and field lay out. On such land, 30 day old nursery grown 'DRRH3' rice seedlings (nursery fertilized 10-20 kg urea and SSP / ha) were transplanted at 20 cm x 15 cm spacing by placing asingle seedling/ hill on 5th August, 2015. Entire P and K fertilizers as per treatment were applied to each plot after puddling and plot layout, mixed thoroughly by trampling (man) followed by levelling. Nitrogen was top dressed in 3 equal splits at 5, 25 and 45 days after transplanting (DAT) and the later two top dressings followed by manual weeding operations. Rice was grown under rain fed conditions with supplemental irrigation to maintain a water level of 5 cm from 3rd DAT. Water in plot was let out prior to N top dressing and let in two days later to the normal 5 cm depth. Irrigation was stopped at soft dough stage of grains. A rain fall of 146.1 cm was received in 55 days during rice crop life cycle in main field (5th August- 15th November). Pre-emergence application of pendemethalin 38.7% CS @ 0.75 kg a.i/ ha immediately after transplanting followed by two hand weedingdone at 25 and 45 DAT in all treatments provided effective weed management. Need based plant protection measures (2 insectide / fungicide sprays) were given to the crop against sucking insect pests and foliar diseases. Crop was harvested from 9-15th November as per maturity of treatments.

Growth, yield attributes and yield was recorded as per standard procedures. Plant height (cm) from ground level to the tip of the plant and number of tillers were recorded from10 hills in 2nd row of a plot leaving the boarder row at maximum tillering (40 DAT), flowering (60 DAT) and harvest stage. From the opposite side of growth observation rows, 5 plants were harvested each time at 5 cm above ground level for recording dry matter production.The growth observation plants (10) from whom number of panicles were recorded (converted into panicles / m^2 by multiplying with 3.33) was harvested for recording number of grains/ panicle and test weight (g). Each plot was harvested separately and the biomass was allowed to dry for 2 days in threshing yard and weighed. Grain was separated from biomass using power operated thresher and weighed. One kg grain and straw sample from each treatment was dried to 14 % moisture content and the loss in weight due to drying was arrived at. The factor was used to adjust the grain and biological yield / plot and from which per ha yields were worked out. Harvest index (%) was worked out as ratio of grain to biological yield x 100. Indigenous nutrient supply of soil taken as nutrient uptake (NPK) in no nutrient omitted plot (NPK fertilized plot) that was calculated as product of grain yield (t / ha) and its nutrient uptake *i.e.*, 18-3-20 kg N-P-K / t (Kamrunnahar et al., 2017). Yield response (YR) was estimated as difference in grain yield (t) of no omission and omission plot. Partial Factor Productivity (PFP) was estimated as ratio of grain yield (kg) to the nutrient applied (kg) for a treatment and reported as kg grain increase / kg nutrient applied. Agronomic Efficiency (AE) was calculated as difference of grain yield in fertilized plot (kg) - unfertilized plot (control) devided by nutrient applied (kg) and reported as kg grain / kg nutrient. In the calculation of economics, 2018-19 minimum support price (Rs /t) of 17,500 for grain, assuming straw price of Rs. 1,500 / t and a fertilizer price of Rs.12.92-56.25- 11.40 kg N-P_2O_5-K_2O were used. For every additional tonne of biomass produced over no fertilized plot, for harvest and threshing purposes, 2 man days (Rs. 920) were added to cost of cultivation.All other input prices as per 2017-18 were used. Benefit : Cost (BC) Ratio was estimated as ratio of gross income (net income + cost of cultivation) to the cost of cultivation. Unfertilized crop cultivation cost came to Rs. 48500 / ha. The analysis of variance was done for all the information generated in RBD. The significance of treatment differences was compared by critical difference at 5 % level of significance (P = 0.05) and statistical interpretation of treatments was done as per Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield attributes

Plant height (cm), dry matter production / hill and number of tillers (panicles / hill at harvest) of rice crop varied markedly due to nutrient omission treatments at all the three stages of observation (Table 1 and Fig. 1). The data reveals that -NPK plot has produced shortest plants with lowest numbers of tiller and dry matter production / hill. Rice crop on an average had attained a height of 72.4, 108.3 and 113.1 cm by 40 (maximums tillering), 60 DAT (flowering stage) and harvest stage. Further, it was also observed that all N omitted plots (-NPK, -NP, -NK, -N) have statistically at par and significantly lower plants height values than N applied plots (-P, -K, -PK, +NPK). All N applied plots have at par plant heights values from maximum tillering to harvest stage. The observations of 60 DAT coincided with flowering stage in most of the treatments and thereafter only meagre increase in plant height (4.8 cm) up to harvest stage was observed. The data thus indicates that plant growth in terms of height was controlled by N fertilization due to its role in cell division. Similar reductions in plant height of rice (Kamrunnahar et al., 2017) and BT cotton due to N omission were reported by Hussain et al. (2019).

Table 1. Impact of nutrient omissions on plant height and dry matter production of rice.

Nutrient (s) omitted (-)	Plant height (cm) at			Dry matter production (g / hill) at		
	40 DAT	60DAT	Harvest	40 DAT	60DAT	Harvest
-NPK	63.3	92.3	99.3	6.18	13.00	16.90
-NP	64.9	95.2	99.5	6.35	13.60	18.85
-NK	66.8	97.7	100	6.89	15.25	21.85
-PK	77.9	117.8	121.8	8.81	20.22	26.93
-N	66.3	98.9	103.9	7.11	16.70	23.78
-P	79.1	118.6	123.6	10.22	21.54	28.07
-K	79.8	122.1	127.5	12.10	21.95	31.05
No omission	81.2	123.4	129.1	12.84	22.70	32.45
SEm±	1.40	2.32	2.53	0.141	0.264	0.350
CD (P=0.05)	4.25	7.04	7.67	0. 428	0.800	1.062

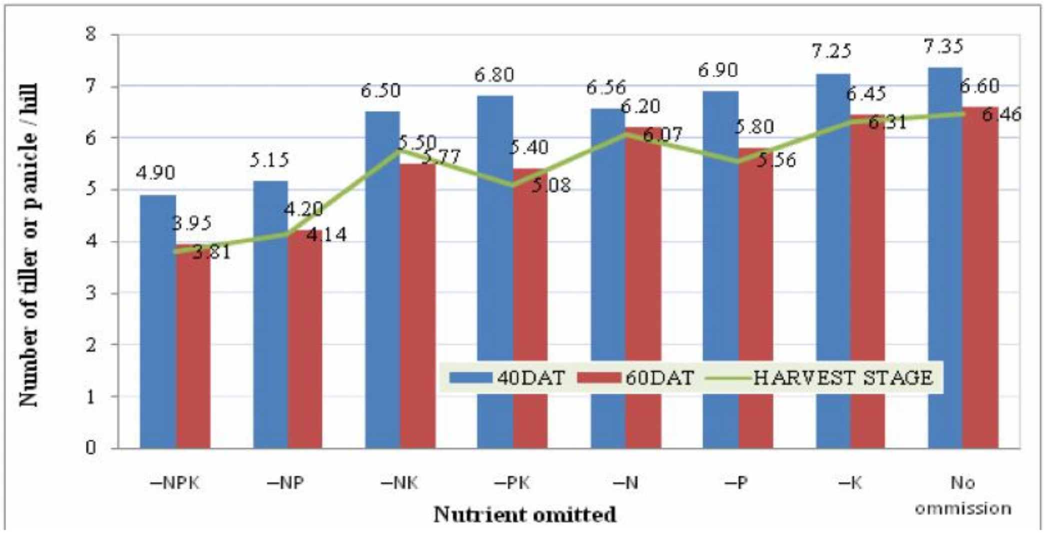

Fig. 1. Tiller production /hill and their transformation into panicles as influenced by different nutrient omission treatments.

Least tiller (panicle production at harvest) production was recorded in -NPK plot which was at par with-NP all through the rice crop life cycle. The tiller / panicle production of -NK, -P and -N plots being statistically at par were significantly higher than -NPK and -NP plot.All N applied plots (-P, -K, -PK, no omission) have statistically similar tiller production. However, on account of higher mortality / senescence of 40 DAT stage tillers,-PK plot moved out of this group and on account of better survival of 40 DAT tillers, -N plot has attained at par values as N applied treatments (-P, -K and no omission). Thus at harvest -N, -K and no omission plots have at par and higher number of panicles/hill. No nutrient omitted plot was recorded the highest no of tiller and panicle. The total tillers produced at 40 DAT (6.43/hill), 87.7 % were surviving at 60 DAT (5.57 /hill) and 97 % of tillers of 60 DAT produced panicles (5.40 / hill) at harvest stage. The tiller mortality (%) between 40 - 60 DAT was higher in -NPK (19.4 %), -NP (18.4 %) and -N (20.6%) treatments than the mean (13.3 %). Reduced photosynthetic capacity, energy production and translocation of assimilates under N, P and K stress, respectively could be the reason behind greater tiller mortality.

Dry matter production(DMP) (g / hill), a product of plant height and tiller number following the same trend of its attributes was markedly lower in -NPK and higher in no omission plots.Statistically at par dry matter producing -NPK and -NP plots at 40 and 60 DAT differed significantly by harvest timewhere -NP omission had superseded-NPK on account of 1.6 cm taller plants,2.9 more number of tillers / hill (Table 1 and Fig. 1) besides higher number of grains / panicle

Table 2. Impacts of nutrient omissions on life cycle duration and yields attributes of rice

Nutrient (s) omitted (-)	Days to		Panicles / m^2	Grain /panicle	Test weight (g)
	50 % flowering	Maturity			
-NPK	87	119	127	70.0	22.60
-NP	90	125	138	77.0	22.85
-NK	88	123	192	90.5	22.75
-PK	93	128	169	87.5	22.70
-N	85	122	202	93.0	23.11
-P	96	130	185	89.5	23.05
-K	90	126	210	93.6	22.90
No omission	90	126	215	95.2	23.20
SEm±	1.0	2.0	6.42	3.10	0.073
CD (P=0.05)	3.04	6.08	19.5	9.40	0.222

Table 3. Impact of nutrient omissions on yield, yield penalty (%) and harvest index of rice.

Nutrient (s) omitted (-)	Yield (t/ha) (t/ha)*		Yield Response	Yield penalty (%) over no nutrient omission**		Harvest index
	Biological	Grain		Biological	Grain	
-NPK	5.59	1.70	2.63	-46.89	-60.74	0.304
-NP	6.05	2.15	2.18	-42.55	-50.35	0.355
-NK	8.90	3.65	0.68	-15.48	-15.70	0.410
-PK	9.50	2.98	1.35	-9.78	-31.18	0.314
-N	9.60	3.92	0.41	-8.83	-9.47	0.392
-P	10.00	3.32	1.01	-5.03	-23.33	0.346
-K	10.02	4.00	0.33	-4.84	-7.62	0.399
No omission	10.53	4.33				0.411
SEm±	0.170	0.104				0.0154
CD (P=0.05)	0.517	0.316				0.0467

*Yield response:grain yield in no omission plot - grain yield of omission plot
** Yield penalty (%) = (yield in no omission plot - yield of omission plot)*100

(7.0) and heavier seeds (0.25 g) (Table 2). The higher DMP of no omission plot was ascribed to cumulative effect of taller plants and higher number of tillers / hill. The DMP / hill at harvest in descending order was:no omission >-K>-P >-PK > -N > -NK > -NP >-NPK and each nutrient differed significantly with the preceding one. The trend of DMP was same at 40 and 60 DAT with the exception that -NPK & -NP at both stages and -NK & -N at 40 DAT have statistically at par values.Rice plants on an average produced 9.8, 18.1 and 25.0 g / hill of dry matter by 40, 60 DAT and harvest time respectively. A significant reduction in dry matter production of cotton due to omission of N, P and K fertilizers in Bt cotton reported by Hussain et al. (2019) support the current research findings.

Days to 50 % flowering and maturity, panicles / m^2 (estimated from panicles / hill), grains/ panicle and test weight (g) data of rice was presented in Table 2. The data reveals that in-N and -P plots, the crop took 4-5 days less and 4-6 days extra for reaching 50% flowering and maturity. In -NPK plot, crop matured in shortest time (119 days). A decrease in energy rich compounds (ADP, ATP) production and their supply for plant metabolic activities (Ali et al., 2004) under P deficiency explains the delayed flowering and maturity of rice (Seneweera et al., 1994). Early flowering and maturity of N omitted plots was ascribed to hampered amino-acid and protein production leading poor growth that finally resulted in early development.Similar differences in flowering and maturity to N, P and K omission as compared to no omission (NPKS) plot were reported in Aman rice in Bangladesh (Kamrunnahar et al., 2017). Number of panicle / m^2, grains / panicle and test weight recorded were lowest in -NPK plot which was at par with -NP plot (except test weight). These two treatments had significantly lower number of panicle / m^2 and grains/panicle than all other treatments. The panicle / m^2 of -N, -K and no omission, grains/ panicle of all other treatments except -NPK, -NP and test weight of -N, -P and no omission were at par with each other. DRRH3 on an average has 179.8, 87.04 and 22.31 panicle / m^2, grains / panicle and test weight. The test weight data further revealed that K fertilization had significant impact and where ever K wasomitted, the test weight decreased perceptibly as evident from the differences between -NPK and -NP; -K and -N; -P & no omission treatments.

Yield

Biological, grain yield, harvest index, yield response and yield penalty (%) data of rice arw presented in Table 3. The data revealed that -NPK plot showed the lowest biological and grain yields. Omission of any nutrient had a significant reduction in grain yield. The trend in biological yield was same as that of grain yield with the exception that the differences between -NPK & -NP; -PK, -N & -P; -P & -K and -K & no omission were not significant. The differences in grain yield expressed as penalties (%) were of grater magnitude on grain (7.62 -60.74 %) than on biological yield (4.84 - 46.89 %). Omission of P resulted on highest grain yield declines (23.33 %) followed by N (9.47 %) and K (7.62

Table 4. Impacts of nutrient omission on economics of rice cultivation.

Nutrient (s) omitted (-)	Economics (Rs/ha)			Benefit Cost Ratio
	Cost of cultivation	Gross income	Net income	
-NPK	48500	35977	-12523	0.74
-NP	50521	43865	-6656	0.87
-NK	55378	72275	16897	1.31
-PK	54307	62582	8275	1.15
-N	57530	77688	20798	1.36
-P	55999	68788	12149	1.22
-K	58621	79632	21011	1.36
No omission	60230	85695	25465	1.42
SEm±	-	800.0	425.0	-
CD (P=0.05)	-	2432.0	1292.0	-

%). The reductions in grain yield due to omission of NP and NPK were 50.35 and 60.74% which was far greater than the sum of individual nutrient effects (N + P = 32.8 %; N + P +K = 40.42 %). The reduction of photosynthetic area by N and hampered energy relations of P and impaired translocation functions of K together have more damaging effects than the individual function impairment effects. The data also revealed that biomass production appeared to be normal in K and PK omission (4.96 % difference) but the reductions in grain yields were substantial (23.56 %). Similar differential reductions in grain and straw yield were reported between NPKS and -P plots by Kamrunnahar et al. (2017). Omission of N, K and NK has caused identical reductions in grain and biological yields. Omission of P (-P, -PK and -NPK) resulted in significant reductions in harvest index. The yield response to fertilizers was 2.63 t/ha in the current experiment (Table 3) and K and N omission recorded the lowest yield response. The yield response (decrease in yield in omission plot) of current study for N, P and K nutrients was to the tune of 0.41, 1.01 and 0.33 t / ha. Similar results were reported by Islam et al. (2013).

Economics

Economics of the rice cultivation under different nutrient omission treatments (Table 4) revealed that cost of cultivation was highest (Rs. 60,320 / ha) in no nutrient omission (+NPK) treatment and least in -NPK treatment. No nutrient omission has incurred Rs. 11,730 /ha higher cost of cultivation (Rs. 7,187 fertilizer cost + their application and Rs. 4,543 for additional biomass harvest and threshing) over their omission (Rs. 48,500). On accountof lower grain yields, unfertilized (-NPK) and K fertilized (-NP) treatments were unprofitable as evident from the losses in net income that was reflected in Benefit Cost ratio < 1.00 values (0.74 and 0.87). All other treatments recorded profits with highest being no omission plots (25, 465 / ha). Omission of K followed by N and NK are recommended for next best profits

Table 5. Fertilizer response functions and indigenous nutrient supply estimates.

Nutrient (s) omitted (-)	PFP (kg yield/ kg nutrient applied)	AE (kg grain increase/ kg nutrient applied)	Internal supply capacity (kg / ha)		
			N	P	K
-NPK	A	-	30.6	5.1	34.0
-NP	35.83	7.50	38.7	6.5	43.0
-NK	60.83	32.50	65.7	11.0	73.0
-PK	29.80	12.80	53.6	8.9	59.6
-N	32.67	18.50	70.6	11.8	78.4
-P	20.75	10.13	59.8	10.0	66.4
-K	25.00	14.38	72.0	12.0	80.0
No omission	19.68	11.95	77.9	13.0	86.6

PFP: Partial factor productivity, AE: Agronomic efficiency.

to no omission.

Nutrient use efficiency and internal nutrient supply

Partial Factor Productivity (PFP), Agronomic Efficiency (AE) and soil nutrient supply (kg / ha) data were presented in Table 5. The data revealed that both PFP and AE of rice were highest in -NK plot but were least in no omission and -NP plots respectively.

Internal nutrient supply of N, P and K estimated from their respective omitted plots were 70.6, 10.0 and 80 kg / ha respectively. The data also showed that P omission resulted in greatest reductions in NPK uptake by crop. Thus if single and double nutrients are to be applied, it should be P and NP in Islands. The K supplies through water (rain or irrigation) may meet its demand.

CONCLUSION

Current study has adopted a new approach *i.e.*, omission technique to ascertain the relative importance of each nutrient in rice production in the current soil. The impacts of P nutrient omission on grain yields were more drastic. Its impacts on biological yields are not that much perceptible indicating that though biomass production appears normal, grain yield reductions are many fold with P fertilization. Hence, there is need to identify such crucial nutrient for each farm. In the current experimental sites, K or N omission could not cause dramatic changes in rice productivity and profits, however, NP fertilization together would aid in yields near to the balanced fertilization.There is need to assess the importance of nutrients in other soil orders where rice is grown and take the same for validation and adoption in farmer's fields.

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