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Nutrient scheduling for upland rice intercropped in coconut

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ABSTRACT

Field experiment was conducted at Coconut Research Balaramapuram, during Kharif 2017 to study the effect of nutrient levels and schedule of nutrient application on the yield and economics of upland rice intercropped in coconut. The experiment was conducted in RBD with four different nutrient levels and four different schedules of nutrient application. Nutrient levels significantly influenced the grain and straw yield, net returns and B: C ratio and the highest grain yield, straw yield, net returns and B: C ratio were recorded with the application of NPK @ 90:30:45 kg ha^{-1}. Nutrient schedules also have significant effect on grain yield, net returns and B: C ratio. Among the schedule of nutrient application, N applied in three splits (15 days after sowing (DAS), active tillering and panicle initiation stage), P as basal and K in two equal splits (15 DAS and panicle initiation stage) along with foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate recorded the highest grain yield, net returns and B:C ratio. Interaction between nutrient levels and schedule of nutrient application was also found significant. NPK @ 90:30:45 kg ha^{-1}, applied as N in three equal splits (15 DAS, active tillering and panicle initiation stage), P as basal and K in two equal splits (15 DAS and panicle initiation stage) along with foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS recorded higher grain yield, net returns and B:C ratio and can be recommended for upland rice raised as intercrop in coconut.

Keywords**:** Grain yield, net returns, nutrient levels, schedule of nutrient application and upland rice

Upland rice is the most diverse among the entire rice ecosystem and nearly 100 million people depends on upland rice as their staple food. The yield of rice must be enhanced to 760 x10^{6} t by the year 2020 in order to feed the increasing global population (Mohadessi *et al.*, 2011). Upland ecosystem is prominent in most of the Indian states, covering about 13.5 per cent of the area under rice and contribute to 4 per cent of rice production. More than 90 per cent of upland rice area is in eastern India (Singh *et al.*, 2011). Recent research findings revealed that, the production potential of rice can be enhanced by enhancing the area under upland rice rather than enhancing the area under transplanted rice (Alagesan and Babu, 2011).

Upland rice comes up well under the partial shade condition in coconut garden. Nearly 60-75 per cent of the land area and 40 per cent of the solar energy in 7.5 m x 7.5 m spaced coconut are left unutilized which provides amble scope for growing compatible intercrops (Nelliat, 1979; Dhanpal, 2010). Unavailability of appropriate production technology is the main draw back for the wide acceptance of upland rice cultivation in coconut garden.

In upland rice, nutrition is one of the factor to be considered for enhancing the productivity. The yield and quality of upland rice can be enhanced by applying the nutrients at right time and dose and adopting right method of application. Application of nutrients at optimum levels to match the soil fertility, season and climate, the yield can be enhanced to 40 per cent (Murthy *et al.*, 2015). Micronutrients also plays an important role in enhancing the yield and quality of rice. Zinc plays an important role in plant metabolic activity and is a component of various enzymes like proteinases, peptidases, carbonic anhydrases and phosphohydrolases (Hossain *et al.*, 2008). It is also an essential component in protein synthesis. Foliar application of zinc enhances the yield, and uptake in rice (Rehman *et al.*, 2012). Boron nutrition increases the spikelet fertility and enhanced the grain yield in upland rice (Rehman *et al.*, 2014). With this back ground the present study entitled ''Nutrient scheduling for upland rice intercropped in coconut'' was undertaken with the objectives to study the effect of nutrient levels and schedule of application on the growth, yield and economics of upland rice raised as intercrop in coconut garden.

MATERIALS AND METHODS

A field experiment was carried out during the *Kharif* season 2017 at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala, India located at 8°222.523′ North latitude and 77°12.473′ East latitude and at an altitude of 26 m above MSL. The experiment was laid out in randomized block design with four nutrient levels *viz*., N_1 - 60:30:30 kg N:P:K ha^{-1}, N_2 - 70:30:35 kg N : P : K ha^{-1}, N_3 - 90:30:45 kg N: P : K ha^{-1} and N_4 -120:30: 60 kg N:P:K ha^{-1} and different schedules of nutrient application *viz*., S_1 – N in three equal splits (15 DAS, active tillering stage and panicle initiation stage) + K in two equal splits (15 DAS and panicle initiation stage and P as basal), S_2 - N and K in

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three equal splits (15 DAS, active tillering stage and panicle initiation stage) and P as basal, S_3 - S_1 + zinc sulphate (0.2 per cent) + sodium borate (0.04 per cent) as foliar application at 45 DAS and S_4 - S_2 + zinc sulphate (0.2 per cent) + sodium borate (0.04 per cent) as foliar application at 45 DAS. The total rainfall received during the cropping period was 884.3 mm. The mean maximum and minimum temperature recorded during the crop season was 31.84^o C and 19.57^o C. The soil of the experimental site is red sandy loam, acidic in reaction, medium in organic carbon content, N and K and high in P status. The variety used for the study was "Prathyasa" a short duration variety released from Rice Research Station, Moncompu. The seed rate adopted for the study was 80 kg ha^{-1} and seeds were dibbled at a spacing of 20 cm x 10 cm. Fertilizers were applied in the form of urea, rock phosphate and muriate of potash as per the treatment schedule. Zinc sulphate (0.2 per cent) and sodium borate (0.04 per cent) were applied at 45 DAS, in addition to N, P and K as per the treatment schedule. The crop was raised as a rainfed crop. Irrigation to field capacity was given during non-rainy periods to avoid the impact of moisture stress on crop growth.

Observations on plant height, tillers m^{-2} and DMP were recorded at harvest and LAI were recorded at 60 DAS. Yield attributes *viz*., panicles m^{-2}, weight of grains panicle^{-1}, sterility percentage and 1000 grain weight, straw and grain yield were recorded at harvest. The cost of cultivation was worked out based on the labour and input cost incurred. Economics of cultivation was worked out based on the minimum support price for paddy given by Government of Kerala during 2017. Experimental data were analyzed statistically by using Analysis of Variance technique for RBD. The significance was tested using F test and whenever, the F values were found significant, critical difference was calculated at 5 per cent probability level.

RESULTS AND DISCUSSION

Effect of nutrient levels and schedule of application on growth attributes

Nutrient levels had significant effect on growth parameters *viz*., plant height, tillers m^{-2} and DMP at harvest and LAI at 60 DAS (Table 1). It has been observed that plant height, tiller m^{-2} and LAI increased with incremental dose of N up to 90 kg ha^{-1} and K up to 45 kg ha^{-1}. This might be due to the fact that increased levels of N and K favoured greater absorption of nutrients resulting in rapid expansion of foliage which enhances the solar radiation interception and better accumulation of photosynthates eventually resulting in increased growth structures.

Increase in plant growth attributes *viz*., plant height, LAI and tiller m^{-2} due to increase in incremental dose of N was reported by Kumar *et al*. (2015) and Murthy *et al*. (2015). Enhanced rate of application of K improved the production of growth attributes might be due to its role in photosynthesis, osmoregulation, stomatal regulation, metabolism of fats, carbohydrates and nitrogenous compounds, enzyme activation, cell elongation and water use efficiency (Raza *et al*., 2014).

Dry matter production was also significantly influenced by nutrient levels (Table 1). From the results, it has been observed that, DMP was increased with the incremental dose of N and K up to 90 and 45 kg ha^{-1}, beyond that a decline in DMP was observed. Significantly higher DMP at harvest was recorded in n_3 (NPK @ 90:30:45 kg ha^{-1}). This might be due to improved vegetative and reproductive growth as indicated by taller plants, more number of panicles, large leaf area, production of more number of grains panile^{-1}, grains with higher test weight and low sterility percentage.

Schedule of nutrient application also have significant influence on the growth parameters. The treatments with foliar application of zinc sulphate and sodium borate recorded higher values for plant height, tiller m^{-2}, and DMP. The increase in growth attributes observed in these treatments might be due to the favourable influence of Zn and B which enhanced the photosynthesis and assimilation of photosynthates resulted in rapid cell division and cell elongation at the growing tips ultimately caused a better vegetative growth. Higher DMP observed in S_3 (N in three equal splits, K in two equal splits and P as basal along with foliar application of 0.2per cent zinc sulphate and 0.04per cent sodium borate at 45 DAS) and s_4 (N and K in three equal splits and P as basal along with foliar application of 0.2 per cent zinc sulphate and 0.04per cent sodium borate at 45 DAS) might be attributed to the fact that better management of nutrients resulted in increased plant height and tiller m^{-2} , which ultimately resulted in increase in DMP as these growth characters have positive correlation with dry matter production. Mohan *et al*. (2017) reported that foliar application of borax, ferrous sulphate and zinc sulphate along with recommended dose of fertilizers significantly improved the growth parameters. Patel *et al*. (2017) who observed that foliar application of B resulted in the better expression of vegetative structures.

Among the various growth parameters studied, the interaction effect was found significant for tillers m^{-2} at harvest stage. In general, application of different levels of nutrients with foliar application of sodium borate and zinc sulphate recorded higher number of tillers m^{-2}. This might be due to enhanced photosynthesis resulting from the better utilization of sunlight, availability of nutrients and uptake. Zn application increased the tillering capacity due to improved enzymatic activity (IRRI, 2000). Slaton *et al*. (2005) also reported that application of Zn significantly affected the tillers m^{-2}.

Effect of nutrient levels and schedule of application on yield attributes

Among the various yield attributes, only the fertile grains panicle^{-1}, grain weight panicle^{-1} and sterility percentage were significantly influenced by the nutrient levels (Table 2). The better expression of yield attributes in N_3 (NPK @ 90:30:45 kg ha^{-1}) might be due to higher LAI and higher number of tillers m^{-2} (Table 1) resulting from the better availability of nutrients. Optimum level of nutrients for crop uptake and translocation to sink resulting in better crop growth and development which positively reflected in the expression of various yield attributes in n_3.

Schedule of nutrient application also significantly influenced the yield attributes. Foliar application of sodium borate and zinc sulphate increased the yield attributes. The lesser sterility percentage and more number of grains panicle^{-1} were recorded in treatments with foliar application of zinc sulphate and sodium borate (S_1 and S_2) might be due to high LAI and crop growth observed in these treatments. This was also due to the better pollination, decrease in sterility, increase in seed setting and increase in grain size with the foliar application B and enhanced synthesis of carbohydrate and accumulation in seeds by the foliar application of Zn (Sudha and Stalin, 2015; Rehman *et al*., 2014) and also due to the important role of Zn in fertilization (Fageria *et al*., 2011).

Among the treatment combinations, n_3s_3 (NPK @ 90:30:45 kg ha^{-1} applied as N in three equal splits, P as basal and K in two equal splits along with foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS) and n_3s_4 (N in three equal splits, P as basal and K in three equal splits @ 90:30:45 kg ha^{-1}along with foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS) resulted in the better expression of yield attributes *viz*., fertile grains panicle^{-1} and panicles m^{-2}. This might be due to the better expression of growth attributes resulting from the adequate supply and uptake of nutrients and also due to the better translocation of assimilates from source to sink. Application of B and Zn along with recommended dose of nutrients, increased the production of fertile grains panicle^{-1} due to the role of B and Zn in grain setting (Dobermann and Fairhurst, 2000; Tahir *et al*., 2009).

Effect of nutrient levels on grain and straw yield

Results on the data on grain yield (Table 3) revealed that, grain yield increased with incremental dose of N up to 90 kg and K up to 45 kg ha^{-1}. A decrease in yield was observed at higher rate of N and K (n_4). This might be due to increase in spikelet sterility and lesser number of fertile grains panicle^{-1} (Table 2) observed, though the growth parameters *viz*., LAI and tiilers were the highest in N_4 (N: P: K @ 120:30:60 kg ha^{-1}). Nutrient level N_3 (N: P: K @ 90:30:45 kg ha^{-1}) recorded significantly higher grain yield (3001 kg ha^{-1}) compared to other nutrient levels. The treatment N_3 was followed by N_2 (N: P: K @ 70:30:35 kg ha^{-1}). The percentage increase in grain yield in N_3 compared to N_4, N_1 and N_2 were in the order 19.18 per cent, 11.53 per cent and 5.76 per cent, respectively. The increased grain yield observed in n_3 might be due to the adequate supply, translocation and utilization of N and K within the plant resulting in the better expression of growth and yield attributes. In the present study, nutrient level n_3 recorded higher number of fertile grains panicle^{-1}, test grain weight and grain weight panicle^{-1} compared to other treatments. Adequate supply and availability of N and K provided continuous and steady supply of nutrients into the soil solution to match the nutrient requirement of crop which consequently resulted in the production of longer panicles with more number of grains panicle $^{-1}$. Positive effect of number of grain panicle^{-1} on grain yield was also reported by Sowmaya, 2008; and Suryaprabha *et al*., 2011.

Schedule of nutrient application also significantly influenced the grain yield. The treatment s_3 (N in three equal splits, K in two equal splits and P as basal along with foliar application of 0.2per cent zinc sulphate and 0.04per cent sodium borate at 45 DAS) recorded the highest grain yield and it was statistically on par with S_4 (N and K in three equal splits and P as basal along with foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS). It has been observed that foliar nutrition of zinc sulphate and sodium borate had significant effect on yield. Better production of yield attributes particularly panicles m^{-2} and fertile grains panicle^{-1} resulting from the better expression of growth attributes and better availability and uptake of nutrients might be the reason for higher grain yield in S_3 and S_4. Moreover, these treatments also have foliar spray of Zn and B. Both the micronutrients may have significant effect on grain yield by its role in grain setting and accumulation of carbohydrate in grain. Saha *et al*. (2010) reported that B application in rice significantly contributed to the grain weight. Similarly, Rehman *et al*. (2014) also reported that foliar application of B significantly improved the grain yield and yield related parameters.

Interaction was also found significant. The treatment combination, N_3S_3 (N in three equal splits, P as basal and K in two qual splits @ 90:30: 45 kg ha^{-1}) recorded the highest grain yield. This might be due to the production of more number of panicle m^{-2}, fertile grains panicle^{-1}, and comparatively lesser sterility percentage (Table 2). Rehman *et al*. (2014) reported that foliar application 0.32M B along with recommended dose of

Table 1: Effect of nutrient levels and schedule of application on growth attributes

Nutrient levels (N)	Schedule of application (S)																			
	Leaf area index at 60 DAS					Plant height at harvest (cm)					Tillers (number m^{-2})					DMP at harvest (kg ha^{-1})				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
N_1	6.22	5.36			**6.31**	6.96	6.70	75.7	83.0	**79.3**	392	387	388	396	**391**	5167	5387	5060	5741	**5339**
N_2	6.55	5.87	6.48	6.33	**6.31**	86.1	83.3	86.5	88.7	**86.2**	340	355	439	435	**392**	5377	5471	5757	5927	**5633**
N_3	6.51	6.48	7.63	7.02	**6.91**	85.7	84.8	94.3	90.5	**88.8**	395	440	391	425	**413**	5978	57791	6263	6576	**6152**
N_4	6.64	6.46	6.15	6.66	**6.48**	83.3	88.8	88.4	94.8	**88.6**	408	396	448	436	**422**	5260	5258	5678	5534	**5433**
Mean	**6.48**	**6.04**	**6.80**	**6.68**		**84.5**	**83.1**	**86.2**	**89.0**		**384**	**395**	**426**	**423**		**5446**	**5477**	**5689**	**5945**	

	Leaf area index SEm (±)	Leaf area index LSD (0.05)	Plant height SEm (±)	Plant height LSD (0.05)	Tillers SEm (±)	Tillers LSD (0.05)	DMP SEm (±)	DMP LSD (0.05)
Nutrient levels	**0.14**	**0.41**	**1.64**	**4.77**	**8.36**	**24.25**	**98.3**	**285.1**
Schedule of application	**0.14**	**0.41**	**1.64**	**NS**	**8.36**	**24.25**	**98.3**	**285.1**
Nutrient levels × Schedule of application	**0.28**	**NS**	**3.29**	**NS**	**16.73**	**48.51**	**196.0**	**NS**

Note: N_1- N: P: K @ 60:30:30 kg ha^{-1}, N_2- N: P: K @ 70:30:35 kg ha^{-1}, N_3- N: P: K @ 90: 30:45 kg ha^{-1}, N_4- N: P: K @ 120: 30:60 kg ha^{-1}

S_1- N in three splits (15 DAS, active tillering stage and panicle initiation stage), P as basal and K in two splits (15 DAS and panicle initiation stage), S_2- N and K in three splits (15 DAS, active tillering stage and panicle initiation stage) and P as basal, S_3-S_1+ foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS, S_4-S_2 + foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS. NS- non-significant, DAS- days after sowing

Table 2: Effect of nutrient levels and schedule of application on yield attributes

Nutrient levels (N)	Schedule of application (S)																			
	Panicles (number m^{-2})					Fertile grains $panicle^{-1}$ (number)					Sterility percentage					1000 grain weight (g)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
N_1	316	315	325	321	**319**	67.7	54.0	69.5	65.8	**64.3**	23.9	24.3	23.8	18.8	**22.7**	25.6	25.8	26.5	26.1	**26.0**
N_2	334	317	320	379	**338**	78.5	66.1	64.6	65.8	**68.7**	20.1	23.9	16.9	19.9	**20.2**	25.7	25.0	26.0	27.6	**26.1**
N_3	319	315	352	365	**338**	70.1	63.2	83.2	80.4	**74.2**	22.0	25.4	17.8	20.8	**21.5**	26.0	25.4	26.8	26.2	**26.1**
N_4	356	335	324	324	**335**	67.4	67.8	74.7	68.8	**69.7**	17.3	24.2	21.3	25.7	**22.1**	27.2	23.8	27.3	25.4	**26.0**
Mean	**331**	**320**	**330**	**347**		**70.9**	**62.8**	**73.0**	**70.2**		**20.8**	**24.4**	**20.0**	**21.3**		**26.1**	**25.0**	**26.7**	**26.3**	

	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)
Nutrient levels	**5.27**	**NS**	**1.94**	**5.62**	**0.61**	**1.76**	**0.39**	**NS**
Schedule of application	**5.27**	**15.30**	**19.4**	**5.62**	**0.61**	**1.76**	**0.39**	**1.14**
Nutrient levels × Schedule of application	**10.55**	**30.59**	**8.88**	**11.24**	**1.22**	**3.53**	**0.78**	**NS**

Table 3: Effect of nutrient levels and schedule of application on yield and economics

Nutrient levels (N)	Schedule of application (S)																			
	Grain yield (kg ha^{-1})					Straw yield (kg ha^{-1})					Net returns (Rs. ha^{-1})					B: C ratio				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
N_1	2636	2727	2792	2466	**2466**	3532	3660	3949	3594	**3684**	20,057	22,843	23,717	14,279	**20, 224**	1.34	1.38	1.39	1.23	**1.33**
N_2	2740	2675	3027	2871	**2828**	3637	3796	3900	3886	**2805**	22,801	22,067	28,768	25,018	**24, 664**	1.38	1.37	1.47	1.41	**1.43**
N_3	2883	2727	3249	3145	**3001**	4095	4064	4327	5118	**4151**	27,982	24,153	35,637	32,140	**29, 978**	1.47	1.40	1.57	1.52	**1.49**
N_4	2596	2545	2349	2583	**2518**	3663	3713	4185	4095	**3915**	18,376	17,404	13,058	18,120	**16,740**	1.30	1.29	1.21	1.29	**1.28**
Mean	2714	2668	2854	2766		3732	3809	4090	3923		22,304	21,617	25,295	22,389		1.37	1.36	1.41	1.36	

	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)
Nutrient levels	**41.06**	**119.08**	**103.02**	**298.99**	**390.89**	**1134.43**	**0.009**	**0.027**
Schedule of application	**41.06**	**119.08**	**103.02**	**NS**	**390.89**	**1134.43**	**0.009**	**0.027**
Nutrient levels × Schedule of application	**82.12**	**238.16**	**206.05**	**NS**	**781.78**	**2268.85**	**0.029**	**0.055**

NPK and Zn enhanced the grain yield by increasing the grain size and decreasing the panicle sterility.

Straw yield was significantly influenced by nutrient levels similar to that of grain yield (Table 3). The highest straw yield was observed in N_4 (N: P: K @ 90:30:45 kg ha^{-1}) which was statistically on par with n_4 (N: P: K @ 120:30:60 kg ha^{-1}). The increased straw yield recorded in these treatments might be due to the better expression of plant height, tiller m^{-2} and DMP. The result is in conformity with the findings of Ali *et al*. (2007) who observed that application of 100 kg N ha^{-1} recorded higher straw yield compared to lower doses, N @ 60 and 80 kg ha^{-1}. Islam and Muttaleb, (2016) reported that grain and straw yield increased with increasing rate of K in boro rice. Schedule of nutrient application and interaction between nutrient levels and schedule of nutrient application did not have any significant effect on straw yield.

Effect of nutrient levels and schedule of nutrient application on economics

Results revealed that net returns were found to increase with the increasing levels of N up to 90 and K up to 45 kg ha^{-1}, respectively. The highest B:C ratio was obtained in N_3 (NPK @ 90:30:45 kg ha^{-1}), which may be attributed to significantly higher grain and straw yield (Table 3) registered in the treatment. The net returns and B:C ratio was found to be lower in highest nutrient level tested (N: P: K @ 120:30:60 kg ha^{-1}). The lowest net returns and B:C ratio recorded in n_4 might be due to the high rate of application of N and K resulting in increased cost of cultivation and also due to low grain yield (Table 3) compared to other nutrient levels.

Net returns was significantly influenced by schedule of application. The highest net returns and B:C ratio was recorded in S_3 (N in three equal splits, K in two equal splits and P as basal along foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS). This might be due to the high grain and straw yield registered in this treatment (Table 4). Firdous *et al*. (2018) reported that the highest net benefit was obtained with the soil application of 5 kg zinc sulphate ha^{-1} and foliar application of 0.5per cent zinc sulphate at tillering and before flowering.

The interaction was also found significant, among the treatment combination, N_3S_3 recorded the highest net returns and B:C ratio, might be due to higher grain and straw yield (Table 3) registered in this treatment.

Considering the growth attributes, yield attributes, yield and economics, NPK @ 90:30:45 kg ha^{-1} applied as N in three equal splits at 15 DAS, active tillering and panicle initiation stage, P as basal and K in two equal splits at 15 DAS and panicle initiation stage along with foliar application of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS (N_3S_3) can be recommended for higher grain yield in upland rice intercropped in coconut.

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