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Effect of nutrient levels and schedule of nutrient application on the grain quality of 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 application on the quality parameters of upland rice intercropped in coconut. The experiment was conducted in randomized block design (RBD) with four different nutrient levels and four different schedules of nutrient application. Quality parameters like crude protein and starch content were significantly influenced by nutrient levels. The crude protein content was found to increase with increase in N level, however starch content was found to increase up to 70 kg N and 35 kg K ha^{-1} and after that a decline in trend was observed. The highest crude protein content (8.38 per cent) was recorded with highest nutrient level, NPK @ 120:30:60 kg ha^{-1}. However, lower nutrient level, NPK @ 70:30:35 kg ha^{-1} recorded higher starch content (85.03 per cent). Among the schedule of nutrient application, N applied in three equal 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 at 45 DAS recorded the highest crude protein (7.50 per cent) and starch content (84.17 per cent). The study clearly indicated that the increased level of N and K increased the protein content due to the active role of N and K in protein synthesis. However, high rate of N application decreased the starch content. In addition to the application of NPK, foliar nutrition of zinc sulphate and sodium borate at 45 DAS considerably improved the quality of grain by increasing the starch and protein content.

Keywords: Crude protein content, Nutrient levels, Schedule of nutrient application, Starch content, Upland rice

INTRODUCTION

Rice is the oldest domesticated grain crop (10,000 years) and is the main energy source for more than 2.5 billion people. It provides 21 per cent of global human per capita energy and 15 per cent of per capita protein. Rice is cultivated in majority of the countries, with a total harvested area of about 160.75 million hectares, with an annual production of 488.23 Million metric tons (USDA, 2018). Considering its importance, the United Nations designated year, 2004 as the 'International Year of Rice'. Rice provides food for more than 65 per cent of the people living in India and is cultivated in an area of 433.88 lakh ha with an annual production of 104.32 m t and productivity of 2404 kg ha^{-1} (GOI, 2017).

Grain quality is of prime importance in rice production. Grain quality is controlled by genetic factors, environmental factors (temperature and light) and management practices (Mo, 1993; Zhou *et al*., 1997; Bao and Zia, 2000). Among the management practices, nutrient management plays an important role. The yield and quality of upland rice can be enhanced by the application of adequate amount of nutrients at optimum level and at right time. Nitrogen, the primary nutrient element plays a pivotal role in rice production. It is the integral part of chlorophyll, amino acids and genetic material *i.e.* DNA and RNA and plays a significant role in enhancing the milling quality and protein content of rice grain (Nawaz *et al.,* 2017). For balanced fertilize use potassium is used along with nitrogen and phosphorus and the optimum NPK ratio for cereals is 2:1:1. Potassium plays an indispensable role in photosynthesis, activation of more than 60 enzymes (particularly enzymes responsible for starch and protein synthesis and also the production of adenosine triphosphate), osmoregulation etc. Potassium is described as the quality element ensuring optimum quality of agricultural produce. Potassium enhance the nutritive value of grains by elevating the protein content (IPI, 2013). Zinc is vital for various biochemical process like cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production and enzyme activation and it is crucial component for protein synthesis (IRRI, 2000). Rice yield can be consistently enhanced with boron fertilization which stimulate enzymatic activity, availability of sugar and respiration which revamp the pollen growth (Mohan *et al*., 2017).

Grain protein content progressively increased with the incremental doses of N and P (Murthy *et al.,* 2015). Thao *et al*. (2015) observed that higher N level increases the grain protein content of Bp53 rice variety and recorded the highest value at 120 kg N ha^{-1}. Dwivedi *et al*. (2006) revealed that K fertilization increased the protein content of rice grain significantly. Potassium fertilization promoted the starch acquisition in rice (Ling *et al*., 2008). Same observations were also made by IPI (2013). Application of K @ 100 kg ha^{-1} increased the grain protein content but decreased the gel consistency (Thao *et al*., 2015). Li *et al*. (1999) observed that quality of rice grain was enhanced by Zn fertilization. Application of Zn along with N significantly enhanced the water absorption ratio and protein content of the grain (Khan *et al*., 2009). Application of Zn as basal and foliar application at flowering, milk and dough stages enhanced the crude protein and starch content in rice from 56.28 to 82.48 per cent and 5 to 19 per cent, respectively over control (Sudha and Stalin, 2015). The grain quality is enhanced by the application of B @ 0.75 kg ha^{-1} (Rashid *et al.,* 2009). Ahmad *et al*. (2012) reported that highest grain protein content (6.89 per cent) was recorded with the application of 1 per cent B and highest grain starch content was obtained with the application of B and Si at 1 and 1.5 per cent, respectively. Keeping this in view the present study was undertaken with the objective to study the effect of nutrient levels and schedule of nutrient application on the quality parameters of rice grain of upland rice intercropped in coconut.

MATERIALS AND METHODS

The investigation was carried out in the Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala, India during the *Kharif* season 2017. The experimental site is located at an altitude of 26 m above MSL with the geographical location at 8° 22’ 52’’ North latitude and 77° 1’ 47’’ East latitude. The total rainfall received during the cropping period was 884.3 mm. The mean maximum (31.84 ^{o}C) and minimum temperature (19.57 ^{o}C) were recorded during the crop season. The soil of the experimental site is red sandy loam, acidic in reaction (4.5), medium in organic carbon content (0.750), N (281.0 kg ha^{-1}) and K (128.5 kg ha^{-1}) and high in P (27.2 kg ha^{-1}) status. The experiment was laid out in randomized block design with two factors. One factor was nutrient levels, comprised of four 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 other factor was schedules of nutrient application, comprised of four different schedules *viz*., s_1– N in three equal splits(15 DAS, active tillering and panicle initiation stage) + K in two equal splits (15 DAS and panicle initiation stage), s_2 - N and K in three equal splits (15 DAS, active tillering 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 spray at 45 DAS and s_4 - s_2 + zinc sulphate (0.2 per cent) + sodium borate (0.04 per cent) as foliar spray at 45 DAS. The variety used for the study was “Prathyasa” a short duration variety released from Rice Research Station, Moncompu. The seeds were dibbled @ 80 kg ha^{-1} 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. In order to avoid the moisture stress on crop growth and development the crop was irrigated to field capacity during non-rainy periods.

Quality parameters like crude protein content was determined by the method suggested by Simpson *et al*. (1965) and starch content of the grain were analysed by the procedure developed by Aminoff*et al*. (1970). The data related to starch content was subjected to arc sine transformation. The 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 % probability level.

RESULTS AND DISCUSSION

Effect of nutrient levels and schedule of nutrient application on crude protein content: Nutrient levels significantly influenced the crude protein content, the most important quality determinant in rice (Table 1). With an increase in N levels, increase in crude protein content was observed. Significantly higher crude protein content (8.38 per cent) was recorded in n_4 (NPK@ 120: 30: 60 kgha^{-1}) which was followed by n_3 (NPK @ 90: 30: 45 kg ha^{-1}). This might be due to higher N uptake resulting in higher N content in the grain. As N is the principal constituent of protein, protein content

Table 1. Effect of nutrient levels and nutrient schedules on protein content of grain, per cent

Nutrient levels (N)	Schedule of nutrient application (S)				
	s_1	**s_2**	**s_3**	**s_4**	**Mean**
n_1	6.02	5.69	7.26	5.69	6.17
n_2	5.78	5.86	6.91	7.96	6.68
n_3	6.04	6.74	8.14	6.39	6.83
n_4	7.88	8.75	7.70	9.19	8.38
Mean	6.43	6.76	7.50	7.31	

	SEm (±)	CD (0.05)
Nutrient levels (n)	0.197	0.573
Schedule of nutrient application (s)	0.197	0.573
Nutrient levels x Schedule of nutrient application (N x S)	0.394	1.145

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 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 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.

Table 2. Effect of nutrient levels and nutrient schedules on starch content of grain, per cent.

Nutrient levels (N)	Schedule of nutrient application (S)				
	s_1	**s_2**	**s_3**	**s_4**	**Mean**
n_1	80.74 (63.95)	78.67 (62.47)	84.80 (67.04)	82.52 (65.27)	81.69 (64.68)
n_2	84.38 (66.70)	83.75 (66.21)	86.54 (68.46)	85.45 (67.56)	85.03 (67.23)
n_3	80.91 (64.16)	77.59 (61.72)	84.37 (66.69)	81.33 (64.38)	81.05 (64.24)
n_4	79.61 (63.14)	81.16 (64.26)	80.94 (64.09)	80.15 (66.62)	80.15 (66.62)
Mean	81.41 (64.49)	80.29 (63.67)	84.17 (66.57)	82.04 (64.96)	

Values in parentheses are original values; values are subjected to arc sine transformation

	SEm (±)	**CD (0.05)**
Nutrient levels (N)	0.301	0.874
Schedule of nutrient application (S)	0.301	0.874
Nutrient levels x Schedule of nutrient application (N x S)	0.603	1.749

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 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 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.

would always be in direct proportion with the N application rate (Javeed *et al*. 2017). It was also observed that under adequate supply of N, more efficient low affinity transport system promotes greater transport of nitrate ions into rice plants which led to the translocation of more amount of N to the rice grain from the vegetative parts leading to enhanced crude protein content (Samonte*et al*., 2006; Chandel *et al*. 2010). Cai *et al*. (2008) observed that increased N availability and uptake stimulate the enzymes, nitrate reductase and glutamine synthase, which play a crucial role in the incorporation of absorbed N into amino acid during protein synthesis. This might be the plausible reason for higher crude protein content under higher nitrogen levels in the present study also. Thao *et al*. (2015) revealed that application of N @ 120 kg ha^{-1} and K @ 80 kg ha^{-1} increased the crude protein content in rice grain.

Schedule of nutrient application also significantly influenced the crude protein content of grain. The treatments with foliar spray of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate (s_3 and s_4) recorded higher crude protein (7.50 per cent and 7.30 per cent) content compared to other two treatments without the foliar spray of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate (s_1 and s_2). The reason might be due to the enhanced uptake of N for the greater assimilation of N and protein synthesis. Application of zinc sulphate as foliar spray might have enhanced the N metabolism which increased the accumulation of amino acids. The enhanced building up of amino acids increased the protein synthesis and protein content in grain as observed by Sudha and Stalin (2015). Boron also have an important role in amino acid formation, protein synthesis and translocation of assimilates (Tisdale *et al*., 1985; Gowthami *et al*., 2018). Mohan *et al*. (2017) reported that foliar application of Zn, B and S along with recommended dose of fertilizers increased the protein content in rainfed rice.

The treatment combination n_4s_4 (NPK @ 120:30:60 kg ha^{-1} applied as N in three equal splits, P as basal and K in three equal splits along with foliar spray of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate at 45 DAS) recorded the highest crude protein content (9.19 per cent) in grains. This could be attributed to the increased uptake and higher content of N in the grain, which accelerates the protein synthesis and protein content in grain. Zinc sulphate application enhanced the Zn content and uptake in plant. Keram *et al*. (2014) observed that enhanced Zn concentration in plants trigger off the activity of RNA and ribosome which accelerated the protein synthesis.

Effect of nutrient levels and schedule of nutrient application on starch content: From the results it has been observed that, starch content was increased up to 70 kg N ha^{-1} and 35 K ha^{-1}, further increase in N and K level decreased the starch content (Table 2). The result is in agreement with the findings of Javeed *et al*. (2017), who observed that amylose content of the rice grain was the highest with 40 kg N ha^{-1} compared to 60 kg N ha^{-1}. Starch is a polymer consisting of linear fraction, amylose and branched chain fraction, amylopectin. Hu-Lin *et al*. (2007) observed that protein content in rice grain enhanced with increased level of N, but the amylose content decreased. Ling *et al*. (2008) also reported that both N and K fertilizer application promoted starch accumulation, but too much N fertilization had negative effect on starch accumulation. The high crude protein content in n_3 (NPK @ 90:30:45 kg ha^{-1}) and n_4 (NPK @ 120: 30: 60 kg ha^{-1}) may be the plausible reason for the lower starch content in these treatments.

Among the schedule of nutrient application, the higher starch content was observed in treatments with foliar spray of zinc sulphate and sodium borate (s_3 and s_4). The high starch content observed in these treatments might be due to the favourable influence of Zn and B on starch formation. The mineral element Zn has a very important regulatory role in carbohydrate metabolism (Broadley *et al*., 2007). The formation of energy rich compounds, NADPH or NADH is depend on the Zn concentration, which might have involved in tapping solar energy for photosynthesis and increased formation of starch and sugars (Sudha and Stalin, 2015). Ghasal *et al*. (2017) reported that soil application of 1.25 kg Zn–EDTA + 0.5 per cent foliar spray at maximum tillering and booting stages resulted in higher grain yield and starch content in wheat. Though B is needed in small amounts by the plant, it plays a vital role in carbohydrate transportation, fruit and seed development, cell division etc. (Gunes*et al*., 2003). Several researchers reported that foliar nutrition of B significantly increased the carbohydrate content in rice grain (Grag*et al*., 2005; Ahmad *et al*., 2012; Narendra *et al*., 2015).

Interaction between nutrient levels and schedule of nutrient application was found significant. Application of NPK @ 70: 30: 35 kg ha^{-1}, applied as N in three equal splits, P as basal and K either in two splits or three splits along with foliar spray of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate (n_2s_3 and n_2s_4) recorded higher starch content of grain compared to other treatments. The reason might be the favourable influence of Zn and B on starch accumulation in rice grain under adequate N supply.

Conclusion

It can be concluded from the results that, nutrient levels and schedule of nutrient application had significant effect on quality parameters *viz*., crude protein and starch content of the grain. NPK applied @ 120: 30: 60 kg ha^{-1} recorded the highest crude protein content. Contrary to crude protein content, starch content increased up to 70 kg N and 35 kg K ha^{-1}, further increase in N and K showed a decline in starch content. Foliar spray of zinc sulphate and sodium borate at 45 DAS enhanced the crude protein and starch content of the grain. Among the different schedule of nutrient application, application of N in three equal splits (15 DAS, active tillering and panicle initiation stage), P as basal, K in two equal splits (15 DAS and panicle initiation) along with foliar spray of zinc sulphate and sodium borate at 45 DAS registered the highest crude protein and starch content. The study clearly indicated that the high rate of N and K application increased the protein content of the grain, however, too much N fertilization decreased the starch content due to the negative impact on starch accumulation. Also, the foliar nutrition of micronutrients *viz*., Zn in the form of zinc sulphate (0.2 per cent) and B in the sodium borate (0.04 per cent) at 45 DAS improved the grain quality of upland rice by enhancing the starch and protein content of the grain.

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