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Quality of aerobic rice as influenced by site specific nutrient management (SSNM) approach

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Abstract
A field experiment was laid out in RCBD including four aerobic rice genotypes (MAS 946-1, MAS-26, MAS-77 and Rasi) and three target yield (4.5, 5.5 and 6.5 t ha^{-1}) levels conducted at ZARS, UAS, Bengaluru. Higher protein content of 9.90 per cent was obtained in MAS 946-1 than the Rasi (8.89%), MAS 77 (8.94%) and MAS 26 (9.21%). Among the genotypes rate of chalkiness differed significantly, MAS 77 recorded significantly higher rate of chalkiness (13.92%) over MAS 946-1 (7.94%), MAS 26 (8.79%) and Rasi (9.57%). It explains the exposure of plant to environmental stress condition. The grain length (1.15 cm), L/B ratio (4.46) and SAI (372.95) were higher in MAS 77. Overall quality was good in MAS 77. The protein and amylose content have differed with the nitrogen levels for higher targeted yields. Among the fertilizer levels for targeted yield of 6.5 t ha-1 recorded higher protein content of 10.97 per cent compared to other targeted yield levels. While, significantly lower protein content of 8.03 per cent was observed with 4.5 t ha^{-1} yield level. The amylase content was higher in 6.5 t ha^{-1} targeted yield (16.13%) compared to 4.5 and 5.5 t ha^{-1} targeted yields.

Keywords: SSNM, aerobic rice, SAI, protein and chalkiness

Introduction
Rice (*Oryza sativa* L.) is a world's single most important foodstuff and one of the most important cereal crops in Asia. Worldwide, more than two billion people consume rice as a staple food. It is an important and nutritional indispensable food commodity that feeds more than half of the world population. Being it is a part of balanced diet. In India, rice is the most important and extensively grown food crop, occupying about millions of hectares of lands (Verma and Shukla, 2011) [8]. However, due to the pressure of grain supply, less attention is paid to improving rice grain quality.
Rice cultivation dates back to 10,000 years which symbolises global unity and cultural identity for many countries where its cultivation is intertwined with religious observances, festivals, customs, folklore, and other traditions. On a global scale, rice provides 21 per cent of per capita energy and 5 per cent of per capita protein for humans (Maclean *et al.*, 2002). In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products. The food security in Asia is challenged by increasing food demand and is threatened by declining the availability of water with growing populations, increased urbanisation and environmental degradation. In India, rice occupies an area of 43.79 million hectare with production of 112.91 million tonnes with an average productivity of 2578 kg per hectare (Anon, 2019) [1]. With emerging water scarcity in many part of the world, the traditional way of lowland rice cultivation can no longer be sustained. Along with high water requirement, traditional system of rice production in long run leads to destruction of soil aggregates and reduction in macropore volumes (Shashidhar, 2007) [7]. Moreover, the lack of rainfall is a major production constraint in rainfed areas. Alternatives to the conventional flooded rice cultivation were developed worldwide to reduce water consumption and produce more rice with less water. Among different water saving strategies, "aerobic rice" is considered a promising cultivation system for water scarce areas.
Aerobic rice is broadly defined as "a production system in which, direct seeding of high yielding and input responsive rice cultivars with aerobic adaptation grown in non-puddle, non-flooded and non-saturated soil during the entire growing cycle". It is a new concept of reducing water requirement for rice in which rice is grown like an upland crop with high inputs and supplementary irrigations, when rainfall is insufficient. Although India has made considerable advances in agricultural research, but still the blanket recommendation of cultivation practices for adoption over larger areas are in vogue. Many of the reviews indicated that quality is affected by the imbalanced application of nutrients to soil.

These blanket recommendations are no more useful to enhance productivity as well quality of the produce and reduce the yield gap.

Rice is a high-energy or high calories food and of high biological value of the proteins. These days, several types of rice and their product are used in different nations of the world *viz*. USA. China, Indonesia, Japan, Sri Lanka, Africa. India etc. The nutritive ease of rice includes protein, fat, crude fibre, carbohydrates, ash, minerals *viz*. Ca, P, Fe, Na, K and Vitamins *viz*. Thiamine, riboflavin, niacin, tocopherol. It plays an important role in health benefits and disease prevention such as high blood pressure, cancer prevention, Alzheimer's disease, heart disease, skin care, dysentery with together in mankind. Inspite of striking agricultural progress and adequate food grain production, protein and micronutrient malnutrition are widespread among rural and poor population. Present investigation was carried out to improve the quality of food grain (aerobic rice) by adopting the balance application of nutrients (Macro and Micro) under target yield approach for site specific situations.

Material and Methods

The experiment was carried out at ZARS, UAS, Gandhi Krishi Vigyan Kendra, Bengaluru, Karnataka under rainfed condition with protective irrigation during *Kharif* season. Experimental site was red sandy loam with neutral in nature, EC (0.24 dSm^{-1}) was medium, low in organic carbon (0.42%), low in available nitrogen, medium in available phosphorous and high in available potassium. It was laid out in a RCBD with three replications. There were 12 treatment combinations comprising of four genotypes (G_1 - MAS 946-1, G_2 - MAS 26, G_3 - MAS 77 and G_4 - Rasi) and three targeted yield (4.5, 5.5 and 6.5 t ha^{-1}) levels. Based on indigenous soil nutrient supply criteria, nutrient uptake of rice for one tonne/kg (20:11.2:30 N P_2O_5 K_2O kg t^{-1}) and genetic potential yield of aerobic rice genotypes were used for calculating the exact quantity of fertilizer to achieve the targeted yield levels. If the available nutrient status (N, P and K) of the soil is medium, then applied the exact quantity as removed, if it is low, then applied the 30 per cent more than required quantity and if it is high, applied the 30 per cent less then required quantity. By using these criteria calculated the required quantity of fertilizer for different targeted yield levels. Micronutirents (Zn and Fe) were added as per the recommeded packege for aerobic rice.

Irrigation was given to the crop in 5-6 days interval depending on weather conditions to keep the soil moist. The crop was irrigated following alternate wetting and drying cycles. However, from flowering to grain filling stage, irrigations were given once in three to four days interval in order to maintain higher moisture in soil. Three hand weeding (25, 45 and 65 DAS) and two times (15 and 35 DAS) inter cultivation was done to keep the weed free during crop growth period. Observations on growth and yield components were recorded, along with these quality parameters also recorded like Grain length (cm), Grain breadth (cm), Length/breadth ratio (L/B ratio), Surface area index (SAI) computed by using the formula (Bhattacharya *et al.*, 1982) [3]. The Protein content (%), Protein yield (kg ha^{-1}), Amylose content (%) these parameters were analysed with the NIR (Nuclear Inclusive Resonance) analyser instrument and expressed in percentage. Rate of Chalkiness (%) is determined by the endosperm opacity, amount of chalkiness on the dorsal side and centre and opacity of grain. If scale is zero means no chalkiness percentage, if one means rate chalkiness percentage is <10, if scale is five means rate of chalkiness percentage is 10-20, if scale is nine means rate of chalkiness percentage is >20.

Results and Discussion

Rice is the most important food all over world. Rice quality is an important characteristic, as grain-quality traits dictate its market value and have an important effect on consumer acceptance. In any Crops genotype/variety using consumption purpose is preferred based on the quality aspects. Among the different parameters, protein plays an important role in cereal crops compare to other parameters. These quality parameters influenced by the genotypic character and nutrition management. A small variation exists in protein content of rice genotype ranging from 8.89 to 9.90 per cent. The higher protein content of 9.90 per cent was obtained in MAS 946-1 than the Rasi (8.89%), MAS 77 (8.94%) and MAS 26 (9.21%). Protein content in the genotypes is governed by genetic character.

Rice cooking and eating quality is mostly determined by the physicochemical characteristics of the starch in its endosperm, namely amylose content, gel consistency and starch pasting viscosity. Amylase content is one of the most important quality predictors for rice-eating quality (Zhou *et al.*, 2018) [9]. There is no significant difference exist between the genotypes, moreover they having the range from 13.49 to 14.08 per cent.

The appearance quality characteristics (Grain length, Grain breadth, grain length/width ratio and chalkiness) were analysed in study. Among the genotypes, rate of chalkiness differed significantly, MAS 77 recorded significantly higher rate of chalkiness (13.92%) compared to MAS 946-1 (7.94%), MAS 26 (8.79%) and Rasi (9.57%). The genotype MAS -77 which experience the more stress like physiological, nutrient, temperature during the cropping period having higher percentage of chalkiness compared to less experienced one (Table 1). Among these genotypes, MAS-77 is having the scale five and other genotypes having one. It explains the exposure of plant to environmental stress condition or the cellular arrangement and structural compactness of cells in grain under stress during crop growth period. The chalky portions of non-waxy grains are due to loose arrangement of cell contents with air spaces. These chalky areas contribute to grain breakage during milling because they are softer than the translucent portions. The higher the chalkiness greater is the breakage of grains. Chalkiness is an unfavourable characteristic of rice appearance that directly influences consumers' acceptance and rice's market value (Zhou *et al*., 2018) [9].

Other characters like grain length (1.15 cm), L/B ratio (4.46) and SAI (372.95) were recorded significantly higher in MAS 77 compared to other genotypes (Table 1). Our results indicated that the grain length of MAS 77 was much slenderer than of other genotypes. These records are in accordance with Paroussis and Ntanos, 1995 [6]. Overall appearance quality characteristics are good in MAS 77 compared to other aerobic rice genotypes.

Nevertheless, rice-grain quality depends not only on genetic background, but also on soil and climatic conditions, and agronomic treatments, during crop growth and development. Nutrients management (N rate) and other cultivation practices has a direct effect on the production of high-quality grains (Zhou *et al*., 2018) [9]. During the present study, analysed the variability in grain protein content in aerobic rice genotypes and also seen the effect of soil and nitrogenous fertilizer dose on grain protein content.

The protein and amylose content were differed with the nitrogen levels for higher targeted yields. Increasing the N dose from 118 to 169 kg N ha^{-1} (F_3) resulted in higher protein content. Among the fertilizer levels for targeted yield of 6.5 t ha^{-1} recorded higher protein content of 10.97 per cent compared to other targeted yield levels (Table 2). There is a direct relation between the nitrogen and protein content, thereby with increase in the nitrogen levels protein content also increased at higher levels. Significant effect of nitrogenous fertilizer doses were observed on grain protein content. While, low level of nitrogen fertilizer application resulted in significantly lower protein content (8.03%) was observed with 4.5 t ha^{-1} yield level. These results are agreeing with the trends reported by Grigg *et al.* (2016) [4] and Banerjee *et al*. (2010) [2]. Nitrogen fertilizer has a favourable effect on rice-protein quality, thus obviously promoting the nutritional value of rice.

According to morphological studies, chalk is a white opaque part formed from compound starch granules that are loosely packed with numerous air spaces. Mechanism of chalkiness formation has mainly been attributed to the accelerated filling rate during the grain-filling period, which results in loosely packed starch granules. During the present study, the effect of Nutrient application (NPK) on the percentage of chalkiness may be relevant to an assimilate deficit. Increased N application may enhance plant-growth rate and inefficient tillers, which then reduces assimilate supply to spikelets, causing poor starch accumulation and loosely packed starch granules, and finally producing chalky grains (Zhou *et al*., 2018) [9]. Similarly, rate of chalkiness was recorded higher (10.31%) in 169 Kg ha^{-1} of N application for 6.5 t ha^{-1} targeted yield compared to 118 Kg ha^{-1} of N application for 4.5 t ha^{-1} (9.80%) targeted yield level and on par with 144 Kg ha^{-1} of N application for 5.5 t ha^{-1} targeted yield (Table 1). Scale of rate of chalkiness is five in 6.5 and 5.5 t ha^{-1} targeted yield and one in 4.5 t ha^{-1} targeted yield.

Although Amylase content is mainly influenced by genotypes, cultivation management practices can also play a role. Kaufman *et al.*, (2013) [5] has shown that an increase in nitrogen levels decreased amylose content. In our study observed that, the Nutrient application (NPK) had a significant effect on Amylase content. Amylase content increased (Table 2) with increases in the fertilizer levels from F_1 -118: 22: 78 NPK kg ha^{-1} (4.5 t ha^{-1}) to F_3- 169: 32:113 NPK kg ha^{-1} (6.5 t ha^{-1}). The amylase content was higher in 6.5 t ha^{-1} targeted yield (16.13%) compared to 4.5 and 5.5 t ha^{-1} targeted yield. In this study amylase content increased with increaing in fertilizer levels targeted for 6.5 t ha^{-1}.

The cultivars responded differently with Nutrient application rate in the grain length and grain breadth and Surface Area Index (SAI). By increasing N application rates, no significant change in the grain length/breadth ratio for all the target yield levels. Grain length, grain breadth, and surface area index (SAI) was higher in 6.5 t ha^{-1} yield level. The grain ratio (L/B) was lower at higher fertilizer level due to increase in the width. Although higher fertilizer level seems to have increased grain length but decreased the grain ratio (Paroussis and Ntanos, 1995) [6].

Protein and Amylase content and appearance Quality like grain length, Grain breadth, L/B ratio, SAI and rate of chalkiness was not significant in interaction effect between cultivar and Nutrient dose for different target yield levels (Table 1 & 2).

Table 1: Grain length (cm), grain breadth (cm), L/B ratio, surface area index (SAI) and rate of chalkiness (%) as influenced by genotypes and nutrient management for targeted yield in aerobic rice.

Treatments	Grain length (cm)			Grain breadth (cm)			L/B ratio			SAI			Rate of chalkiness (%)		
Genotypes (G)	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
G_1	0.92	0.89	0.91	0.32	0.32	0.32	2.90	2.82	2.86	220.50	213.05	216.77	7.47	8.41	7.94
G_2	0.80	0.80	0.80	0.33	0.32	0.33	2.43	2.56	2.50	195.11	186.02	190.56	8.52	9.06	8.79
G_3	1.18	1.21	1.15	0.27	0.27	0.27	4.57	4.35	4.46	385.77	360.13	372.95	13.79	14.04	13.92
G_4	0.74	0.71	0.73	0.37	0.34	0.35	2.04	2.14	2.09	205.92	177.35	191.64	9.44	9.71	9.57
S.Em±	0.02	0.02	0.02	0.02	0.02	0.01	0.21	0.21	0.15	12.00	11.96	8.37	0.27	0.13	0.15
C.D. at 5%	0.06	0.09	0.03	0.05	0.05	0.03	0.61	0.62	0.41	35.19	35.07	23.69	0.79	0.39	0.42
Fertilizer levels for target yield (F)															
F_1 (4.5 t ha^{-1})	0.83	0.80	0.82	0.29	0.27	0.28	3.05	3.15	3.10	219.44	195.21	207.33	9.53	10.08	9.80
F_2 (5.5 t ha^{-1})	0.91	0.88	0.90	0.33	0.32	0.32	2.98	2.95	2.97	251.12	236.10	243.61	9.74	10.36	10.05
F_3 (6.5 t ha^{-1})	0.99	0.96	0.98	0.35	0.35	0.35	2.92	2.80	2.86	284.91	271.11	278.01	10.14	10.49	10.31
S.Em±	0.02	0.02	0.01	0.01	0.01	0.01	0.18	0.18	0.13	10.39	10.36	7.25	0.23	0.12	0.13
C.D. at 5%	0.05	0.06	0.04	0.04	0.04	0.03	NS	NS	NS	30.19	30.37	20.51	NS	NS	0.37
Interaction (F x G)															
S.Em±	0.04	0.04	0.03	0.03	0.03	0.02	0.36	0.36	0.25	20.78	20.71	14.49	0.47	0.23	0.26
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Grain yield (kg ha^{-1}), protein content (%), protein yield (kg ha^{-1}) and amylose content as influenced by genotypes and nutrient management for targeted yield in aerobic rice.

Treatments	Grain yield (kg ha^{-1})			Protein (%)			Protein yield			Amylase (%)		
Genotypes (G)	**2009**	**2010**	**Pooled**	**2009**	**2010**	**Pooled**	**2009**	**2010**	**Pooled**			
G_1	5978	5828	5903	10.02	9.79	9.90	595.90	592.95	594.43	14.38	13.78	14.08
G_2	5829	5723	5776	9.36	9.05	9.21	539.09	542.38	540.74	13.70	13.63	13.67
G_3	5245	5398	5322	9.01	8.88	8.94	473.50	476.13	474.81	13.61	13.48	13.55
G_4	5721	5649	5685	9.08	8.70	8.89	506.10	520.75	513.42	13.54	13.43	13.49
S.Em±	144	44	75	0.27	0.32	0.21	25.62	15.54	14.99	0.42	0.40	0.28
C.D. at 5%	422	130	212	NS	NS	0.60	75.14	45.59	42.44	NS	NS	NS
Fertilizer levels for target yield (F)												

F_1 (4.5 t ha^{-1})	4998	4913	4955	8.35	7.71	8.03	386.52	407.99	397.26	11.71	11.78	11.74
F_2 (5.5 t ha^{-1})	5589	5554	5571	8.89	8.52	8.71	479.61	493.04	486.32	13.45	12.98	13.22
F_3 (6.5 t ha^{-1})	6494	6482	6488	10.86	11.08	10.97	719.81	698.12	708.97	16.28	15.99	16.13
S.Em±	125	38	65	0.24	0.28	0.18	22.19	13.46	12.98	0.36	0.35	0.25
C.D. at 5%	366	113	184	0.70	0.82	0.52	65.08	39.48	36.76	1.06	1.02	0.70
Interaction (F x G)												
S.Em±	249	77	130	0.48	0.56	0.37	44.38	26.92	25.97	0.73	0.69	0.49
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: G_1- MAS 946-1 F_1- 118: 22: 78 NPK kg ha^{-1} (4.5 t ha^{-1}) NS- Non-Significant
G_2- MAS 26 F_2- 144: 27: 96 NPK kg ha^{-1} (5.5 t ha^{-1})
G_3- MAS 77 F_3- 169: 32:113 NPK kg ha^{-1} (6.5 t ha^{-1})
G_4- Rasi

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