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Response of Different Rice Varieties and Fertility Levels on Relative Economics and Quality of Rice under Aerobic Conditions

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Authors' contributions

This work was carried out in collaboration between all authors. Authors Sandeep Kumar and Sarabdeep Kour designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors Sandeep Kumar and KC managed the analyses of the study. Authors SL and HS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study was undertaken at Research Farm of Division of Agronomy, SKUAST-J, Chatha. The experiment was laid out in factorial randomized complete block design with four varieties *viz.* PR-115, DRRH-3, PAC-837 and PR-121, as one factor and four fertility levels *viz.* 0:0:0, 90:45:22.5, 120:60:30 and 150:75:37.5 kg N-P_2O_5-K_2O ha^{-1}, as second factor with three relications. The results revealed that among four varieties, variety PAC-837 recorded highest grain and straw yield. The quality parameters, Length: Breadth (L:B) ratio before cooking was recorded highest in PR-115 and L:B ratio after cooking was recorded highest in DRRH-3. Protein and amylose content were found higher in variety PAC-837. Rice variety PAC-837 also recorded higher net returns (Rs. 4002.28) and B:C ratio (1.24). Amongst the fertility levels, the application F_4: $N_{150}P_{75}K_{37.5}$ kg ha^{-1} fertility level

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recorded highest grain and straw yield over other fertility levels. Quality parameters *viz.* L:B ratio before cooking and after cooking, protein and amylose content also followed the similar trend, B:C ratio (1.52) was higher in F_3: $N_{120}P_{60}K_{30}$ kg ha^{-1}. On the basis of quality and relative economics it may be recommended that rice variety PAC-837 found ruminative with application of F_3: $N_{120}P_{60}K_{30}$ kg ha^{-1} fertility level.

Keywords: Aerobic rice; fertility levels; quality parameters; relative economics.

1. INTRODUCTION

Rice is the staple food for about halves of the world's population that live in Asia. India has the largest area about 43.95 million hectares and produces around 106.54 metric tons [1]. Recently, it has been reported the increasing scarcity and share of fresh water for agriculture particularly for rice cultivation due to decline in water levels in one hand and the demand of water to industries and other sectors on the other hand threatens the sustainability of the irrigated rice ecosystem [2]. In this context the new system of rice growing, "Aerobic culture" gains emphasize on sustainable basis. Aerobic rice is novel method of growing rice by direct seeding in non puddled conditions without standing water. The new concept of aerobic rice entails the use of nutrient-responsive cultivars that are adapted to aerobic culture aiming at yields of 70-80% of high input flooded rice [2]. The target environments are irrigated lowlands, where water is insufficient to keep lowland (rainfed or irrigated) paddy fields flooded and favorable uplands with access to supplementary irrigation. Shivalik foothill regions of Jammu and Kashmir are also most prone areas for variable and insufficient amount of rainfall at the time of transplanting thus needs to emphasized on shifting rice cultivation from transplanted to aerobic rice production technologies. Thus needs to the evaluation of rice varieties that could be adopted for aerobic cultivations.

Among the various cultural practices, fertilizer management is crucial factor, which influence the growth and yield of rice. One of sound principles of aerobic rice is fertilizer management leading to good root development, better tillering potential, higher accumulation of dry matter, and efficient partitioning of dry matter to economically important plant parts [2]. As aerobic rice culture is a new system, there is urgent need to develop suitable nutrient management schedule for this system. Also the nutrient behavior in aerobic soils and in puddled soil is quite different especially in relation to major nutrients. It is therefore, necessary to apply fertilizer elements particularly N, P and K through inorganic sources in optimal quantity to improve and sustain the productivity. The nutrient availability to root zone of rice significantly influence the quality of rice besides growth and yield. A significant variation due to fertilizer levels was noticed in all quality parameters [3,4]. [5] concluded that protein content, kernel length and breadth significantly increased with increased levels of nitrogen. [6] observed that the protein content of brown rice increased, amylose content decreased and the nutritional quality improved if additional P fertilizer was applied. An increase in P application at the filling stage of rice could improve cooking quality. [7] concluded that grain quality parameters *viz.* milling percent, head rice recovery, kernel length, breadth, amylose content and protein content of rice registered significantly higher values with 150 kg N ha^{-1} which was significantly superior to 125 kg N ha^{-1}, but at par with 175 kg N ha^{-1}. Remunerative economic returns play a key role in adoption of any refined version of agro-techniques. Profitable agro-techniques have great degree of adoptability by farming community. Different varieties showed significant differences in relative economics not only due to their seed rate, price of seed and grain yielding ability but also due to seed quality and market prices. Amount of fertilizer applied to rice also affects economics per se. Moreover prevailing energy crises also necessitates for balanced and proper dose of fertilizers to be applied. The study related to varieties suited for aerobic rice and their nutrient demand is meager in Shiwalik foothills region of India. Keeping in view the apprehensions of water scarcity in coming times particularly in rice growing belt of Jammu, it seems to be pertinent that the aerobic rice production technology for rice cultivars of this belt needs to be standardized with the use of fertilizers in terms of quality and economics.

2. MATERIALS AND METHODS

The field experiment was conducted at Agronomy Research Farm of SKUAST-J, Chatha. Geographically, the experimental site was located at 32^{o}-$40^{o'}$ North latitude and 74-58$^{\circ'}$ East longitude with an altitude of 332 meters above mean sea level in the Shiwalik foothills of North-Western Himalayas. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen, but medium in available phosphorus and potassium. The experiment was laid out in factorial randomised block design during *kharif* 2014 with three replications. The treatments consisted of 4 varieties (V_1: PR-115, V_2: DRRH-3, V_3: PAC-837, V_4: PR-12) and 4 fertility levels (F_1:$N_0P_0K_0$, F_2:$N_{90}P_{45}K_{22.5}$, F_3:$N_{120}P_{60}K_{30}$, F_4:$N_{150}P_{75}K_{37.5}$). The seeds were sown in furrows by *kera* method. Moist conditions were maintained at active tillering and reproductive phase and near about saturation at vegetative and maturity stage. Pre-emergence application of Pendimethalin @ 1 l ha^{-1} was done after 24 hours of sowing of crop whereas, post-emergence application of pyrazusulfuron ethyl @ 25 gm ha^{-1} was done 7 days after sowing and bispyribac sodium @ 30 ml ha^{-1} was applied after 30 days of sowing. Full dose of P and K along with one third of N were applied as basal dose at the time of sowing through inorganic sources of nutrients *viz.* urea, DAP and MOP, respectively and remaining two third of N was applied in two equal splits at 30 DAS and 60 DAS. All the observations were recorded through standard procedures. Average length of ten dehusked grains from random samples of the produce in each replication were recorded in milimeters (mm).Length/breadth ratio was calculated by dividing the grain length by grain breadth. Paddy grains were cleaned, dried and dehusked for the estimation of amylose content. The iodine is absorbed within the helical coils of amylose to produce a blue coloured complex which is measured colorimetrically by spectrophotometer at 590 nm [8]. Protein content rice grain was determined by multiplying respective nitrogen content in rice grain with a factor 6.25 [9]. The cost of different operations was calculated for different treatments on the basis of existing market prices of inputs and operations and the total cost was calculated by adding the expenditure involved in all kinds of operations as per treatment on per hectare basis in Rs ha^{-1}. The gross returns were calculated by multiplying the total grain and straw yield with prevalent market prices of the items and then were presented on per hectare basis as per treatments. The net returns were computed by deducting the total cost of cultivation from the gross returns as per treatments. Benefit: Cost ratio was calculated by dividing net returns with the cost of cultivation for each treatment. The data obtained on various parameters was tabulated and subject to statistical analysis (except relative economics). The Analysis of Variance techniques of factorial randomized block design to identify the treatment is depicted in Table 1. The interpretation of the treatment effects were made on the basis of critical difference.

Table 1. Analysis of variance of factorial randomized block design

Source of variation	Degree of freedom
Replication	r-1
Varieties	a-1
Fertility levels	b-1
Interaction (a x b)	(a-1) x (b-1)
Error	(ab-1) x (r-1)
Total	rab-1

3. RESULTS AND DISCUSSION

3.1 Influence of Varieties

Influence of varieties on grain yield presented in Table 2. Data indicated that grain yield of different varieties showed significant differences under aerobic conditions. Among the various cultivars PAC-837 recorded significantly higher grain yield (45.65 quintals ha^{-1}) with a magnitude of superiority of 5.2, 11.2 and 38.4 per cent over DRRH-3, PR-115 and PR-121, respectively. This might be due to greater vegetative growth and better light interception and higher dry matter portioning towards economic part. Yield variability among rice cultivars also attributed to genetic characters and environmental effects. It has been reported that phenotypic expressions are largely dependent upon genotype's ability and environmental effect [10]. Straw yield was also recorded highest in PAC-837 which was statistically at par with DRRH-3 and PR-115. Higher straw yield could be due to ability of rice cultivars to produce higher dry matter. The differences among the varieties in relation to straw yield was also reported by many researchers [11].

The data in Table 2 revealed that different varieties had significant influence on quality parameters. Kernel length before cooking and after cooking was recorded highest in PR-121(7.06 and 9.63 mm) than other varieties PAC-837 (6.09 and 8.07 mm), DRRH-3 (5.92 and 8.90 mm) and PR-115 (7.00 and 8.99 mm), respectively. Kernel breadth (KB) before and after cooking was significantly influenced by rice cultivars. Among different varieties, PAC-837 recorded highest KB before (2.59 mm) and after cooking (3.53 mm). Lowest KB before cooking

(2.01 mm) and after cooking (3.02 mm) was observed in variety DRRH-3. The length: breadth (L:B) ratio before cooking and after cooking was greatly influenced by rice cultivars. The highest L:B ratio before cooking was recorded in variety PR-115 whereas, L:B ratio after cooking was found to be highest with variety DRRH-3 whereas the lowest L:B ratio before and after cooking was recorded in variety PAC-837. This might be due to differential ability of rice cultivars to produce various sized seeds and their differential ability to swell after cooking. [12,13] reported similar results. Protein content was significantly influenced by rice cultivars. It was observed that highest protein content was founded in variety PAC-837 (7.78 %) and it was however, statistically at par with rice variety DRRH-3 whereas, lowest protein content was recorded in variety PR-121. Amylose content in rice grain was significantly influenced by rice varieties. The highest amylose content (24.75 %) was recorded in variety PAC-837, whereas, lowest amylose content (14.89 %) was recorded with variety PR-115. The variation in protein and amylose content in different rice varieties might be due to differential ability to uptake nitrogen in grains. These results are in agreement with previous studies [6,14].

Treatment wise economic returns were worked out by calculating operating cost of individual treatment. The data so obtained has been presented in the Table 3. Among the different varieties, PAC- 837 fetched maximum net returns of Rs. 40021.28 ha^{-1} followed by variety DRRH-3 (38763.87 Rs ha^{-1}), PR-115 (35605.83 Rs ha^{-1}) and PR-121 (21824.96 Rs ha^{-1}). Rice variety PAC-837 gave highest (1.24) B:C ratio followed by DRRH-3 (1.21), PR-115 (1.11) and PR-121 (0.68). Similar results were reported elsewhere [11,15,16].

3.2 Influence of Fertility Levels

Under aerobic conditions, increasing fertility levels increased grain and straw yield significantly (Table 2). Application of 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1} recorded highest grain (52.78 q ha^{-1}) and straw yield (73.85 q ha^{-1}). The increase in yield with increasing fertility levels may be due to increased NPK utilization by crop that led to enhanced growth and yield attributes which occurred due to increased photo synthetic efficiency of crop which in turn caused greater dry matter production and translocation to sink. Positive correlation was reported among yield NPK levels [17,18].

Significant influence on different quality perimeters were also noticed due to fertility levels. The highest kernel length of rice grain before cooking (6.63 mm) and after cooking (8.95 mm) was noticed with application of 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1} which was however, statistically at par with 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. Fertility levels also have significant impact on increase in KB before and after cooking. KB increased significantly with increase in fertility levels up to 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. The highest KB before (2.34 mm) and after cooking (3.42 mm) was recorded in 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1} which however, remained statistically at par with application of 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. The L:B ratio before and after cooking decreased significantly with increase in fertility levels up to 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. The lowest L:B ratio before and after cooking were observed with application of 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1} which remained statistically at par with 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. Highest L:B ratio before cooking and after cooking was recorded with control (0:0:0 N-P_2O_5-K_2O kg ha^{-1}). Fertility levels also had significant influence on protein content. Protein content in rice grain significantly increased with increase in fertility levels up to 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. Highest protein content was noticed with 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1} which was however, statistically at par with 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. Whereas, lowest protein content was recorded with control (0:0:0 N-P_2O_5-K_2O kg ha^{-1}). Amylose content in rice grain significantly increased with increase in fertility levels up to 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. Highest amylose content was recorded with 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1}. Whereas, lowest protein content was recorded with control (0:0:0 N-P_2O_5-K_2O kg ha^{-1}). [5,7] concluded that protein content, kernel length, kernel breadth and amylose content significantly increased with increasing level of nitrogen which may be due to fact that nitrogen forms principal constituent of protein and indisputably protein content would always be in direct proportion with the increased nitrogen application. Further, [14] also reported increased protein and amylose content due to increased phosphorus levels. Amylose content increases with increased fertility levels. This might be due to decrease in activity of starch branching enzyme with increased application of fertilizers. [19] also reported increased amylose content with increasing nitrogen application.

Table 2. Response of different rice varieties and fertility levels on grain yield, straw yield and quality of rice under aerobic conditions

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Before cooking			After cooking			Protein content (%)	Amylose content (%)
			Kernel length (mm)	Kernel breadth (mm)	L:B ratio	Kernel length (mm)	Kernel breadth (mm)	L:B ratio		
Varieties										
V_1: PR-115	41.06	59.50	7.00	2.19	3.20	8.99	3.41	2.64	7.12	14.89
V_2: DRRH-3	43.37	58.65	5.92	2.01	2.96	8.90	3.02	2.95	7.72	22.94
V_3: PAC-837	45.65	59.98	6.09	2.59	2.36	8.07	3.53	2.29	7.78	24.75
V_4: PR-121	32.99	51.42	7.06	2.28	3.10	9.63	3.51	2.75	6.44	19.72
SEm±	0.68	1.04	0.02	0.01	0.01	0.01	0.01	0.003	0.03	0.21
CD (0.05)	1.96	3.01	0.04	0.03	0.03	0.03	0.02	0.01	0.10	0.60
Fertility levels (N-P_2O_5-K_2O kg ha^{-1})										
F_1: $N_0P_0K_0$	20.86	31.33	6.29	2.14	2.98	8.80	3.27	2.71	7.05	19.11
F_2: $N_{90}P_{45}K_{22.5}$	39.22	54.85	6.54	2.27	2.92	8.89	3.37	2.65	7.25	20.48
F_3: $N_{120}P_{60}K_{30}$	50.21	69.53	6.62	2.32	2.87	8.95	3.41	2.63	7.38	21.35
F_4: $N_{150}P_{75}K_{37.5}$	52.78	73.85	6.63	2.34	2.86	8.95	3.42	2.63	7.39	21.36
SEm±	0.68	1.04	0.02	0.01	0.01	0.01	0.01	0.003	0.03	0.21
CD (0.05)	1.96	3.01	0.04	0.03	0.03	0.03	0.02	0.01	0.10	0.60

Table 3. Effect of different rice varieties and fertility levels on relative economics

	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Varieties				
V_1: PR-115	30802.80	66408.63	35605.83	1.11
V_2: DRRH-3	30752.80	69516.67	38763.87	1.21
V_3: PAC-837	31052.80	71074.08	40021.28	1.24
V_4: PR-121	30752.80	52577.76	21824.96	0.68
Fertility levels (N-P_2O_5-K_2O kg ha^{-1})				
F_1: $N_0P_0K_0$	26677.50	33481.72	6804.217	0.25
F_2: $N_{90}P_{45}K_{22.5}$	30352.32	62372.99	32020.67	1.05
F_3: $N_{120}P_{60}K_{30}$	31603.58	79760.07	48156.49	1.52
F_4: $N_{150}P_{75}K_{37.5}$	34727.80	83962.35	49234.55	1.42

A variation on gross returns and net returns has been observed by application of different doses of fertilizers. Application of 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1} fetched more (49234.55 Rs ha^{-1}) net returns followed by 120:60:30 N-P_2O_5-K_2O kg ha^{-1} (48156.49 Rs ha^{-1}), 90:45:22.5 N-P_2O5-K_2O kg ha^{-1} (32020.67 Rs ha^{-1}) and control (6804.21 Rs ha^{-1}). However, among different fertility levels, application of 120:60:30 N-P_2O_5-K_2O kg ha^{-1} registered its, supremacy in obtaining highest B:C ratio (1.52), followed by 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1} (1.42), 90:45:22.5 N-P_2O_5-K_2O kg ha^{-1} (1.05) and control (0.25). [19,20,21] also obtained similar results.

4. CONCLUSION

Rice variety PAC-837 recorded higher grain yield, straw yield, protein content and amylose content. Whereas, L:B ratio before cooking was highest in PR-115 and L:B ratio after cooking was recorded highest in DRRH-3. Gross returns, net returns and B:C ratio recorded highest by PAC-837 followed by DRRH-3, PR-115 and PR-121. Among different varieties, PAC-837 recorded highest nutrient response followed by DRRH-3, PR-115 and PR-121. Fertility levels had significant influence on grain yield and straw yield and increased up to 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1}. Quality parameters *viz*. kernel length before cooking and after cooking, kernel breadth before cooking and after cooking, protein content and amylose content increased with increasing fertility levels only up to 120:60:30 N-P_2O_5-K_2O kg ha^{-1}. Whereas, L:B ratio before and after cooking decreased significantly up to 120:60:30 N-P_2O_5-K_2O kg ha^{-1} which remained at par with 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1}. In term of B:C ratio 120:60:30 N-P_2O_5-K_2O kg ha^{-1} proved more remunerative followed by 150:75:37.5 N-P_2O_5-K_2O kg ha^{-1}, 90:45:22.5 N-P_2O_5-K_2O kg ha^{-1} and control.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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