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On-farm Assessment of Medium Duration Rice (*Oryza sativa* L.) Cultivars for Growth, Yield, Economics and Stress Tolerance

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Abstract

A field trial was conducted during *kharif* season(June to November) of 2017 at farmers' field by Krishi Vigyan Kendra, Angul of Odisha state, India with an objective to evaluate growth, yield, economics and stress tolerance in 3 medium duration rice cultivars through on farm testing using randomized block design with ten replications. The higher yield of rice cultivar Hiranmayee (48.6 q ha^{-1}), contrasted with lower yielding Surendra (45.2 q ha^{-1}) and MTU 1001 (43.5 q ha^{-1}), resulted from higher tillering ability (16.2 $hill^{-1}$), effectivity of tillers (88.74%), panicle length (26.7 cm), grains $panicle^{-1}$ (151.64), spikelet fertility (94.1%),1000 grain weight (22.74 g), straw yield (57.88 q ha^{-1}), harvest index (45.69%) and longer maturation period (134.8 day) which also recorded higher plant height (108.39 cm), dry matter accumulation (916.22 g m^{-2}) and dry matter efficiency (0.394% day^{-1}). Hiranmayee performed better in spite of occurrence of frequent dry spells during different crop growth stages for its genetic potentiality and had higher growing degree days (2412.15), photo-thermal units (32322.81), heat use efficiency (0.38), net return (₹ 30575.07 ha^{-1}), benefit- cost ratio (1.60) and profitability (₹ 83.76 ha^{-1} day^{-1}) than Surendra and MTU 1001. The highest positive correlation were observed between days to maturity with GDD (1.0) and PTU (1.0). Based on the study, it may be concluded that medium duration rice cultivar Hiranmayee was superior to Surendra and MTU 1001 due to higher tillering ability, drought tolerant capacity, growing degree days, heat use efficiency, grain yield and additional net return. Thus, it can replace the old cultivars in the existing farming situation for higher productivity and income.

Keywords: Heat use efficiency, profitability, rice, stress, yield

1. Introduction

Rice (*Oryza sativa* L.) is the most important staple food grain crop providing 43% of calorie requirements for more than 70% of India's population. In India, rice is grown over 44.5 mha area with the production of 172.5 mt and a productivity of 3.88 t ha^{-1} which is low as compared to the world average, 4.0 t ha^{-1} (Anonymous, 2020). It is also predominant crop of Odisha with a total coverage of 4.0 mha which is about 65% of the total cultivable area of the state. Area under rice crop in Angul district of the state is 0.084 mha with a production of 0.17 mt which is 48% less than that of state (Anonymous, 2014). Self-sufficiency in rice production should be achieved for providing food security and employment generation in low income people (Ghosh et al., 2009). Rice production depends on

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yield, growth and adaptation of high yielding varieties. The use of high yielding variety of rice has a major role in green revolution. The new improved technologies are helping the farmers to adopt new variety (Sharma et al., 2011).

During last four decades major advances of rice productivity was due to adoption of green revolution technology including high yielding and insect pest resistant varieties (Grover, 2012). The main reasons of low productivity and profitability in rice are vagaries of nature and poor crop management practices. Development of biotic and abiotic stress resistant cultivars by using conventional and modern biotechnology can enhance rice yields . The cultivars have different physiological and morphological characteristics and also proper crop management depends on the growth characteristics of various cultivars to get maximum benefit (Hussain et al., 2014). Lack of high yielding cultivars is the one of the factors contributing to low yield of rice and with the introduction of rice varieties, rice production is also increasing (Karki et al., 2018). Due to continuous cultivation of one variety repeatedly it has become susceptible to pest and diseases in general, which are resulting in low yields and low net returns to the farmers (Ganesh Kumar at al., 2019). In rice, grain size as well as the number of grains is the major determinant of yield potential. Since single grain size is genetically constant, with respect to yield improvement, an increase in the number of grains has been given more attention (Makino et al., 2020).

The yield loss in rice depends on the growth stage and duration, the severity of drought stress. Severe drought stress at the vegetative stage and mild drought stress applied at the flowering stage in rice result in 20% and 28% yield loss, respectively (Yang et al., 2019). Plant growth ceases when temperature exceeds a certain value or drops below a critical minimum regardless of favourable moisture and light. Higher grain yield and straw yield along with the heat units viz. accumulated growing degree days, photo-thermal unit, helio-thermal unit, radiation use efficiency and heat use efficiency were recorded maximum in early sowing than delayed sowing (Khavse et al., 2015). The rise in temperature causes early maturity in crop. Currently rice is grown in the regions where temperatures are already close to optimum and thus, further increases in mean temperatures during sensitive stages, may be supra-optimal and will reduce grain yield (Nagai and Makino, 2009). Rice growth is also affected by air temperature due to its different sensitivity to temperature and is location-specific. Inhibition of panicle exsertion in rice cultivars occurs due to high temperature and decreasing in yield from 68 to 90 % at average temperature of 32.1 °C and leaf temperature increased 3.0 °C to 6.0 °C at average temperature exposes 32.0 and 33.1 °C (Jumiatun et al., 2016).

The agro-meteorological indices provide the relation and cause or effect of temperature on phonological behavior in plant whereas; it showed significant differences in heading duration stage among wheat genotypes (Dangi and Shrestha, 2018). Growing degree days (GDD) and photo-thermal units(PTU) are good estimators of crop growth stages. Heat units determines effect of temperature and radiation or photoperiod on phenological behaviour of a standing crop and provide information of the amount, pattern and efficiency of heat energy consumption at different dates of planting and phenological stages of the crops (Jasti et al., 2017). Keeping those points in view, the field trial was taken up with an objective to evaluate growth, yield, economics and stress tolerance of medium duration rice cultivars at Angul under mid central table land zone of Odisha state in India in the existing farming situation for higher productivity and income.

2. Materials and Methods

The field experiment was conducted through on farm testing on farmers field during *kharif* season (June to November) of 2017 at Banuasahi village in Angul district under mid-central table land zone of Odisha, India with an objective to evaluate growth, yield, economics and stress tolerance of medium duration rice cultivars. The experimental site lies in 84° 56′9.3′′ E longitude and 20° 50′37.2′′ N latitude and average elevation of 195 m above sea level. Climate of the region is fairly hot and humid monsoon and the total rainfall received during the study period from June to November was 626.6 mm against a normal rainfall of 1084 mm. The mean maximum and mean minimum temperature registered in the year was 34.2 °C and 20.8 °C respectively. The soil of the experimental site was slightly acidic in reaction (pH-5.2 to 5.6), sandy loam texture with medium organic carbon content (0.53 to 0.57 %), medium in nitrogen (279 to 292 kg ha^{-1}), low in phosphorus (8.4 to 10.4 kg ha^{-1}) and medium in potassium (172 to 183 kg ha^{-1}) content.The tested high yielding variety "Hiranmayee" released from OUAT in 2012 and adopted in rainfed and irrigated medium land ecosystem, 135 days duration, non-lodging, early threshability was selected for experiment. The trial was conducted with taking treatments of 3 medium taking treatments of 3 medium duration rice cultivars MTU 1001 (T_1), Surendra (T_2) and Hiranmayee (T_3) and replicated ten times in a randomized block design. The crops were sown during 3rd week of June and harvested during 1st week of November. Ten different farmers each having 0.08 hectare of land cultivated the varieties with recommended package of practices. Observations on different growth and yield parameters were taken and economic analysis was done by calculating cost of cultivation, gross return, net return, B:C ratio and profitability. Available soil nutrients content was determined following the standard procedures (Jackson, 1973).

Final crop yield (grain & straw) were recorded and harvest index was calculated by using the formula given by Gardner et al. (1985).

The Arial biomass of crops were taken by reaping the plants at ground level and the plant samples were separated and dried in a hot air oven at 70 °C for 48 hours and weight of dried samples were taken. The soil fertility status was analyzed by standard methods.

The dry-matter efficiency is the percent of total dry matter production (seed yield and stover yield) accumulated in seed per day (Singh and Chaudhary, 2016).

$$\text{Dry matter efficiency} = \frac{\text{Seed yield}}{\text{Total dry matter production}} \times \frac{100}{\text{Duration of crop}} \quad ..(1)$$

Growing degree days (GDD) was calculated by using the equation given by Peterson (1965)

$$\text{Growing degree days} = \frac{(T_{max}+T_{min})^2}{2} - T_{base} \quad ....(2)$$

Where, T_{max} and T_{min} are the daily maximum and minimum temperature (°C), and T_{base} is the base temperature (10 °C).

Heat thermal unit (HTU) was calculated by using the equation given by Wilsie (1962).

Photo-thermal unit=Σ(GDD×N)

Where, GDD=Growing degree days, N = Maximum possible sunshine hours or day length (hrs)

The heat use efficiency at harvest was derived by

$$\text{Heat use efficiency (HUE)} = \frac{\text{Total dry matter}}{\text{Cumulative growing degree days}} \quad ....(3)$$

Correlation studies were taken up for determination of the relationship between grain yield and its growth parameters, yield attributes, agro-meteorological indices. The Pearson linear correlation analysis was applied to measure the degree of linear association between two variables. The Pearson correlation coefficient (r) was computed using the observed values of two variables as:

$$\text{Pearson correlation coefficient(r)} = \frac{n(\sum xy)-(\sum x)(\sum y)}{\sqrt{([n\sum x^2 -(\sum x)^2][n\sum y^2-(\sum y)^2]}} \quad ....(4)$$

Where, x and y are the observed variables, x^2 and y^2 are the mean of the observed variables '*x*' and '*y*' respectively, and *n* is the number of observations.

The data were statistically analyzed applying the techniques of analysis of variance and the significance of different sources of variations were tested by error mean square of Fisher Snedecor's 'F' test at probability level 0.05 (Cochran and Cox, 1977).

3. Results and Discussion

3.1. Growth parameters and days to maturity

Results (Table 1) indicated that the growth parameters of rice significantly increased by different treatments. Higher plant height (108.39 cm), tillers plant^{-1} (16.2) and effective tillers plant^{-1} (14.2) were recorded in rice cultivar Hiranmayee followed by Surendra where as lower effectivity of tillers (83.89%) was observed in MTU 1001 attributing to their genetic variability and environmental adaptability and also differential response of tillering due to its genetic potentiality. These results are in agreement with Samant (2014). Data on dry matter accumulation at maturity clearly witnessed that among the different rice cultivars, Hiranmayee achieved the maximum biomass (916.22 g m^{-2}) followed by Surendra (873.31 g m^{-2}) and MTU 1001 was the least efficient in biomass production (817.73 g m^{-2}) due to higher metabolically active tissue (Kumari et al., 2014). The study revealed that the medium duration rice Hiranmayee was late matured (134.8 days) in comparison to Surendra and MTU 1001 (Sarker et al., 2013).

3.2. Yield attributes and yield

The yield attributing characters (Table 1) varied significantly with cultivars. The longer panicle (26.7 cm) and higher 1000 grain weight (22.74 g) were produced in Hiranmayee. The same treatments also recorded higher no of total grains panicle^{-1} (151.64) and spikelet fertility (94.1%) owing to reduced no of unfilled spikelet than rest cultivars. Analysis of data revealed that significantly the maximum grain yield was recorded with Hiranmayee (48.6 q ha^{-1}) which had 11.7 and 7.52% yield advantage over Surendra (45.2 q ha^{-1}) and MTU 1001(43.5 q ha^{-1}) respectively. Among the cultivars, Hiranmayee produced higher straw yield (57.88 q ha^{-1}) with harvest index (45.69%) attributing to high vegetative biomass production, large panicles and high tillering ability (Tripathi et al., 2013).

3.3. Economics

An analysis on economics (Table 1) revealed that Hiranmayee recorded higher gross return of ₹ 81115.07 ha^{-1} with a benefit-cost ratio of 1.60 and additional net return of ₹ 21527.52 ha^{-1} as compared MTU 1001 which gave the net return(₹ 23819.29 ha^{-1}) and benefit-cost ratio(1.49).The same cultivar also recorded the maximum profitability (₹ 83.77 ha^{-1} day^{-1}) followed by Surendra. Mitra et al. (2014) also reported the advantages of growing newly introduced variety over the traditional with higher return, the variation in net return and benefit-cost ratio may be attributed to the variation in the price of agri-inputs and produce.

3.4. Tolerance to drought

Data (Table 2) indicated that during the *kharif* 2017, the crop received a total rainfall of 626.6 mm during its growth period. A total of 13 dry spells were occurred during different crop growth stages. There were long dry spells during seedling, flowering and milking stages for a period of 7, 9 and 11 days respectively. Short dry spells also found during tillering, panicle initiation and maturity stages. In spite of occurrence of frequent dry spells during different crop growth stages, the growth and yield performance were satisfactory might be due to its genetic potentiality. Still the Hiranmayee performs better than Surendra and MTU 1001 due to its drought tolerant capacity. The results of this study were in good agreement with the earlier findings in different rice genotypes by Kumar (2013) and Samant (2017).

3.4. Growing degree days (GDD), photo-thermal unit (PTU) and heat use efficiency (HUE)

Cultivars play a major role in the accumulation of GDD and

Table 1: Growth parameters, yield attributes, yield and economics of different treatment

Treatment	Plant height (cm)	Tillers hill^{-1}	Effective tillers hill^{-1}	Effectivity of tillers (%)	Dry matter accumulation (g m^{-2}) at maturity	Dry-matter efficiency (% day^{-1})	Days to maturity	Panicle length (cm)	Total grains panicle^{-1}	Spikelet fertility (%)
MTU 1001	95.87	12.5	10.4	83.89	817.73	0.404	131.8	24.5	139.83	91.2
Surendra	102.66	14.4	12.49	87.47	873.31	0.392	132.4	24.8	146.98	92.4
Hiranmayee	108.39	16.2	14.2	88.74	916.22	0.394	134.8	26.7	151.64	94.1
SEm±	0.76	0.24	0.21	1.62	6.35	0.01	0.29	0.1	0.63	0.29
CD (p=0.05)	2.25	0.7	0.62	4.82	18.87	0.02	0.87	0.29	1.88	0.85

Table 1: Continue...

Treatment	1000 grain weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Benefit cost ratio	Profitability (₹ ha^{-1} day^{-1})
MTU 1001	20.65	43.5	51.44	45.85	72569.29	23819.29	1.49	65.26
Surendra	21.58	45.2	56.23	44.59	75682.87	25642.86	1.51	70.25
Hiranmayee	22.74	48.6	57.88	45.69	81115.07	30575.07	1.6	83.77
SEm±	0.06	0.78	0.95	0.74	1163.66	1158..68	0.02	3.17
CD (p=0.05)	0.19	2.33	2.84	2.21	3457.02	3442.22	0.06	9.43

*Sale price of paddy seed:23.78 US$ q^{-1}; paddy straw: 1.53 US$ q^{-1}; 1 US$=65.16 INR for the year 2017

Table 2: Response of variety (Hiranmayee) on drought tolerance under dry spells during *kharif* 2017

Period of dry spell	No of days	Stages of crop	Total rainfall received (mm)
24-29 June	6	Seedling	626.6
1-4 July	4	Seedling	
12-15 July	4	Seedling	
17-23 July	7	Seedling	
29-30 July	2	Seedling	
6-9 August	4	Tillering	
18-19 August	2	Tillering	
21-24 August	4	Panicle initiation	
1-3 September	3	Booting	
7-12 September	6	Heading	
21-30 September	9	Flowering	
1-11 October	11	Milking	
2-6 November	4	Maturity	

*Source: District Agriculture Office, Angul, Odisha

PTU from sowing to maturity of rice crop. Growing degree days (GDD) of rice cultivars in different phonological stages (Table 3) indicated that lowest GDD was accumulated in seedling establishment stage and increase in successive phonological stages like maximum tillering, panicle initiation, heading, flowering and maturity. Hiranmayee accumulated highest GDD followed by Surendra, whereas MTU 1001 required lowest GDD at all the phonological stages. The GDD accumulation for maturity was maximum in Hiranmayee (2412.15), followed by Surendra (2372.55) and MTU 1001 (2362.65) which might have enabled the variety to escape the possible high temperature stress at later growth stages. Similar trends had observed in photo-thermal unit (PTU) during the phonological stages for the cultivars indicating maximum PTU (32322.81) in Hiranmayee followed by Surendra (31792.17) and MTU 1001(31659.51). Jagtap et al. (2018) also found the similar results in different cultivars of rice.

Results (Figure 1) showed the efficient use of heat energy by the treatments. Hiranmayee recorded significantly higher heat

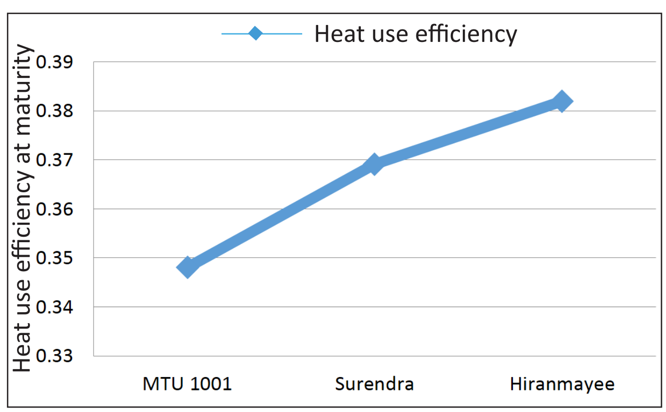

Figure 1: Variation of heat use efficiency (HUE) at maturity over treatment

Table 3: Variation of cumulative growing degree days (GDD) and photo-thermal unit (PTU) at different phonological stages over treatment

Treatment	Seedling establishment	Maximum tillering	Panicle initiation	Heading	Flowering	Maturity
MTU 1001	764.45 (10243.63)	1203.25 (16123.55)	1252.67 (16785.78)	1482.01 (19858.93)	1744.46 (23375.76)	2362.65 (31659.51)
Surendra	804.36 (10778.42)	1247.38 (16714.83)	1282.68 (17187.85)	1494.68 (20028.71)	1784.28 (23825.07)	2372.55 (31792.17)
Hiranmayee	837.90 (11227.79)	1279.15 (17140.54)	1300.33 (17424.36)	1521.83 (20392.52)	1647.17 (24394.43)	2412.15 (32322.81)
SEm±	2.58	3.24	2.86	4.69	99.67	4.86
CD (p=0.05)	7.68 (102.89)	9.63 (128.99)	8.50 (113.94)	13.92 (186.56)	296.11 (230.53)	14.43 (193.37)

*Data in parentheses indicates photo-thermal unit (PTU)

use efficiency (0.38) at maturity followed by Surendra (0.37) and MTU 1001 (0.35) indicating maximum conversion of solar energy into dry matter production in Hiranmayee as compared to MTU 1001 and Surendra. These were in agreement with findings in different rice cultivars by Islam and Sikder (2011).

3.5. Correlation studies

Correlations were worked out for determination of the relationship between grain yield and its growth parameters, yield attributes, agro-meteorological indices and also correlation coefficients (r) were given in table 4. Correlation coefficients between grain yield and various growth parameters, yield attributes, agro-meteorological indices were positively different from zero at 5% level of significance. The results also showed that significantly negative correlations were among grain yield different parameters at 5% level of significance. The highest positive correlation were observed between days to maturity with GDD and PTU (1.0). Similar values were also obtained between GDD with PTU (1.0) whereas, lowest positive correlations were observed between plant height and grains panicle^{-1} (0.997) and between grains panicle^{-1} and HUE (0.998). The results of this study were are in agreement with the earlier findings in different wheat genotypes (Dangi and Shrestha, 2018).

Table 4: Pearson correlation coefficient for grain yield and its growth parameters, yield attributes and agro-meteorological indices at maturity

	Grain yield	Plant height	Tillers hill^{-1}	DMA	Days to maturity	Grains panicle^{-1}	GDD	PTU	HUE
Grain yield	1.000	0.972	0.979	0.965	0.990	0.952	0.990	0.990	0.929
Plant height		1.000	0.999**	1.000**	0.928	0.997**	0.928	0.928	0.990
Tillers hill^{-1}			1.000	0.998**	0.940	0.994	0.940	0.940	0.985
DMA				1.000	0.918	0.999**	0.918	0.918	0.993
Days to maturity					1.000	0.998**	1.000**	1.000**	0.866
Grains panicle^{-1}						1.000	0.898	0.898	0.998**
GDD							1.000	1.000**	0.866
PTU								1.000	0.866
HTU									1.000

**Pearson correlation coefficients is significant at 5% level of significance

4. Conclusion

Medium duration rice cultivar Hiranmayee was superior to Surendra and MTU 1001 due to higher tillering ability (16.2 hill^{-1}), drought tolerant capacity, growing degree days (2412.15), heat use efficiency (0.38), grain yield (48.6 q ha^{-1}) and net return (₹ 30575.07 ha^{-1}). Thus, it can replace the old cultivars in the existing farming situation for higher productivity and income.

5. Acknowledgement

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