Effect of High Temperature at Different Growth Stages on Rice Yield and Grain Quality Traits

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Abstract

High temperature stress is one of the most important environmental factors influencing crop growth, development, and yield processes. The objective of this research is to provide an overview of the influences of high temperature stress. The experiments were conducted at IGKV, Raipur during summer season, where temperature during April and May reaches above 40^{O}C. With different dates of sowing (D1, D2 and D3 with a gap of 15 days) the plant material were subjected to different temperatures at reproductive stage. In summer season, 2010, the mean seed yield was lowest under D3 which was expected as the plant experienced high temperature stress.The results of mean sum of squares due to the genotypes were significant for plant height, panicle length, biological yield, harvest index, grain yield hulling%, milling%, water uptake, amylose and head rice recovery in high temperature stress in all set of conditions. Samleshwari (check) performed well under D1; in D2, highest yield was recorded by R-RF 76 and in D3 highest yield was recorded for Mahamaya (check) at high temperature stress. R-1837-RF-40 showed highest head rice recovery percent under D1. Under D2, R-RF-79 while, under D3, R-RF-79 showed highest values for head rice recovery per cent during high temperature stress. Overall, paddy length was the only trait which exhibited high broad sense heritability under all the dates of sowing during summer 2010. For quality traits, highest heritability was observed for length of brown rice, length of milled rice, amylose content, head rice recovery and protein content in D1, D2 and in D3 dates of sowing. R-RF-69 and R-RF-74 in D2 exhibited intermediate amylose content. The data was also recorded for grain size and shape along with alkali spreading and gel consistency. The results revealed a wide range of variation. Based on overall results of HRR and grain yield R RF-79 and Samleshwari was identified to be the best genotype under high temperature conditions.

Keywords: High temperature, rice yield, grain quality.

In Chhattisgarh, about 82% population depends on agriculture for their livelihood. The area sown under rice crop is 3.8 million hectare. The average productivity of rice in Chhattisgarh is only 2.1 tons per hectare. The prime cause of low productivity of rice in the state is that, only 21.7% area is under irrigated and rest is rainfed (Sharma, 2006). High temperature (heat) stress is considered to be one of the major environmental factors limiting crop growth and yield. This stress induces many biochemical, molecular, and physiological changes and responses that influence various cellular and whole plant processes that affect crop yield and quality. The impacts of environmental stress, particularly those of drought and heat, have been studied, independently. However, under field conditions, both of these stresses often occur in combination (Mittler, 2006). Heat stress (increase in above-optimum air temperature) often occurs, but they can have very different effects on various physiological growths, development, and yield processes. The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the rice crop by affecting its phenology, physiology, and yield components (Singh 2001, Sheehy *et al.* 2005, Peng *et al.* 2004). The sensitivity of rice to high temperature varies with growth phase, an increase in day/night temperature and genotype (Yoshida 1981, Singh 2001, Peng *et al.* 2004). The growth of a rice plant can be broadly divided into three phases: vegetative, reproductive and ripening or grain filling (Maclean *et al.* 2002 and Yoshida, 1981). The vegetative phase culminates with panicle initiation

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(PI), the reproductive phase with anthesis (flowering) and grain-filling at grain maturity. The genotype of the rice plant largely defines the characteristics of each phase, although the growth environment of the plant also contributes to the overall source-sink dynamics of the plant (Dingkuhn and Kropff, 1996). The impact of increased temperature has an accumulative effect on the later phases of plant development; changes in the vegetative and ripening phase will alter the grain-filling phase and thus, the grain quality of the rice. The present study was undertaken with the following major objectives: (i) To understand the effect of temperaturestress on yield and quality parameter of rice and, (ii) To understand the correlation between different yield and quality traits at high temperature, normal irrigated and water stressed conditions.

Materials and Methods

The present study was conducted at the Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) The climate conditions of Raipur is subtropical where temperature during April and May reaches above 40^{O}C. The temperature during *Summer* season (2010) is presented in fig 1…. . In our experiments we tried to expose our genotypes to high temperature at reproductive stage, which is a serious problem of this region. To coincide with the high temperature during reproductive stage of crop three different dates of sowing was done. The experimental details are presented in table 1. All the normal agronomic practices were followed to raise a good crop. One experiment was also conduced during *Kharif* 2011 under normal irrigated condition and served as controlled condition for purpose of comparision.

Three competitive plants were selected from each entry, each replication and from each environment for the recording of the observations on yield and yield attributing parameters along with quality traits on eight yield and sixteen quality traits. The parameters were days to 50% flowering; plant height (cm); number of tillers; panicle length (cm); number of filled grains; number of unfilled grains; hundred seed weight (g); biological yield (kg/m^2); harvest index (%); length of paddy (mm); length: breadth (l / b) ratio of paddy and grain yield (g/m^2) and quality traits were hulling (%); length of brown rice (mm); length: breadth (l / b) ratio of brown rice; milling (%); length of milled rice (mm); length: breadth (l / b) ratio of milled grains; kernel length after cooking (KLAC) (Pellaijar and Mohandoss, 1998); length: breadth (l / b) ratio of cooked rice; gelatinization temperature (GT) or alkali test (Little *et al.*1958); water uptake (ml); elongation ratio; elongation index; gel consistency test; amylose content (%); head rice recovery (%) and protein content (%) (AOAC, 1970).

The data was subjected to RBD design with two replication for various statistical analysis *viz.*, analysis of variance (Fisher, 1935); heritability (Allard, 1960); genetic advance as percentage of mean and correlation coefficients (Searle, 1961).

Results and Discussion

The material in the present study comprises of 22 genotypes in summer 2010, which included advanced breeding materials. All the plant materials were grown under three different dates of sowing i.e. 12-01-10 (D1), 2-02-10 (D2) and 22-02-10 (D3).. Variability in the breeding material is essential component for the genetic improvements of a crop as selection cannot be done among similar genotype. Equally important is the application of adequate statistical tools for the correct estimation of the magnitude of various genetic parameters, so that superior genotypes can be selected and advanced for further screening and improvement. The results of mean sum of squares due to the genotypes and were significant for plant height panicle length, biological yield, harvest index and grain yield under all the three different datesof sowing *i.e.* D1, D2, and D3. This means overall varied performance of the genotypes for maximum traits. For quality characters the mean sum of square due to the genotypes were significant for hulling %, milling%, water uptake, amylose, head rice recovery under all the three dates of sowing, while protein content was the only trait which exhibited significance only in D1 condition.

The trait, plant height, also exhibited differential performance under different conditions. The mean value for plant height was found to be least under D1 was (86.08 cm), 89.07 cm under D2 and 86.95 cm under D3 . Under D1, highest value for plant height was recorded for Mahamaya (check) while, R-RF-79 showed least value, Under D2, Mahamaya (check) showed highest value while, R-RF-84 showed least

value for plant height. The highest value for plant height under D3 was recorded for R-1837-RF-40 while, R-RF-74 showed least value for plant height under D1, D2 and D3. IR-70215-70-CPA-3-4-1-3 (33.60) showed higher percent change while, R-RF-86 (14.0) in D1, R-RF-74 (6.40) in D2 and R-RF-74 (6.3) in D3 showed lower percent change are over control (irrigated) for plant height (Table 3).

Mean value of 21.76 cm under D1, 21.91 cm under D2 and 23.14 cm under D3 was recorded for panicle length. Under D1, D2 and D3, IR64 (Check), Danteshwari (check) and Mahamaya (check) showed highest value for panicle length while, N-22 and R-RF-76 showed least value for panicle length. Under D1, R-RF-85, in D2 Samleshwari (Check) and in D3 R-RF-77 showed highest percent change while in D1, R-RF 86 (-3.0), in D2 R-RF 86 (-2.0) and in D3 R-1839-RF-42 (-12.3) showed least percent change over control (irrigated) for panicle length.

Mean value of 2.27g under D1, 2.28g under D2 and 2.11g D3 was recorded for hundred seed weight. Under D1, R-RF-85 showed highest value for hundred seed weight, Under D2, R-1837-RF-42 showed highest value while, R-RF-79 showed least value for hundred seed weight. R-RF-85 showed highest value while, R-RF-78 showed least value for hundred seed weight under D3. Under D1 R-RF-85 (28.3), D2 R-RF-69 (30.2) and D3 IR64 (Check) (39.80) showed highest percent change while, R-RF-74 (-9.70) in D1, R-RF 86 (-12.10) in D2 and R-RF-74 (-15.8) showed lower percent change over control (irrigated).

The mean value of biological yield was 127.7g in D1, 123.65g in D2 and 122.56g in D3 was recorded. Under D1, R-RF-85 showed highest value for biological yield while, R-RF-79 showed least value. Under D2, R-R-84 showed highest value while, N-22 showed lower value for biological yield. Under D3, R-RF-84 showed highest value while, Mahamaya (Check) showed lower value for biological yield. Under D1, D2 and D3 Mahamaya (Check) (87.70), Samleshwari (Check) (88.40), and Mahamaya (Check) (92.70) showed higher percent change while R-RF 78 (67.7) in D1, Poornima (Check) (61.0) in D2 and R-RF-74 (57.4) showed lower percent change over control (irrigated) for biological yield.

The mean value 42.32 % in D1, 39.89 % in D2 and 15.93 % in D3 was recorded for harvest index. Under D1, R-RF-76 showed higher value for harvest index while, R-RF-77 showed least value. Under D2, R-RF-76 showed higher value while, MTU 1010 (Check) showed least value for harvest index. Under D3, Mahamaya (Check) showed higher value while, IR64 (Check) showed least value for harvest index. Under D1, D2 and D3, R-RF-84 (58.83), MTU 1010 (check) (62.8) and R-RF-85 (84.46) showed higher percent change while R-RF-79 (-28.03) in D1, R-RF-86 (0.49) in D2 and Mahamaya (check) (13.76) in D3 showed lower percent change over control (irrigated) for harvest index.

The average length of paddy under D1 was 8.9 mm while, for D2 and D3 it was 8.8mm and 8.8mm, respectively. The highest value for length of paddy under D1, D2 was reported by R-RF-85 and under D3, R-RF-85 was recorded while, R-RF-79 in D1, R-RF-79 in D2 and R-RF-79 showed least value for length of paddy. Under D1, MTU1010 (Check) (21.28), in D2 MTU1010 (Check) (21.81) and under D3-R-RF 85 (17.24) showed higher percent change while, R-RF-86 (-41.04) in D1, R-RF-86 (-40.3) in D2 and R-RF 86 (-37.31) in D3 showed lower percent change over control (irrigated) for length of paddy.

The mean value for L/B ratio of paddy was recorded as 3.67 for D1 and 3.59 for D2 and in D3 it was 3.59. MTU1010 (Check) showed least value for L/B ratio of paddy in D1 followed by MTU1010 (check) in D2 and Annada (check) in D3. The highest value for L/B ratio of paddy was recorded for R-RF-69 under D1, for IR64 (Check) under D2, and for R-RF-85 under D3. Under D1 and D2 MTU 1010 (check) showed higher percent change 32.92 and 33.47 while for R-RF-85 (26.85) in D3. Under D1, D2 and D3 R-RF-85 showed lower percent change over irrigated as control for L/B ratio of paddy.

During summer season 2010, the mean yield was lowest under D3, which was expected as the plant experienced high temperature stress. However, the reduction in yield was different for different genotype. The mean yield was recorded as 50.52g in D1, 43.25g in D2 and 20.15g in D3. The yield performance of best three genotypes under each condition is presented in table 4. Samleshwari (check) performed well under D1

followed by R-RF-84 and R-RF-76. Under D2, highest yield was recorded for R-RF-76 followed by R-RF-77 and R-RF-86 and in D3 highest yield was recorded for Mahamaya (check) followed by R-RF-76 and Annada (Check). Under D1, Samleshwari (check) (-151.60) showed higher percent change while R-RF-79 (-3.5) showed lower percent change over control (irrigated) for grain yield. Under D2, R-RF-78 (21.93) showed highest percent change while R-RF-86 (-237.02) showed lower percent changed over control. Under D3, R-1838-RF-41 (54.27) showed highest percent change while R-RF-76 (-14.56) showed lowest percent change for grain yield.

The quality characteristics of rice such as milling turnout, cooking characteristics, taste and nutritional traits determine the acceptability at consumer end and this to a great extent affect the acceptability of a variety by the farmers. These quality traits are controlled by many physico-chemical properties (Juliano, 1985). Physical quality is determined by grain dimension, hulling, milling and head rice recovery. High hulling, milling and head rice recovery is desirable. Regarding kernel length after cooking, lengthwise expansion without increase in girth is considered as highly desirable trait in high quality rice. Gelatinization temperature is an index of chemical quality of rice. It ranges from 56°C to 79°C. The higher the gelatinization temperature of rice, the more water and time are needed to cook it.

The mean value of hulling percent was comparatively higher under D2 and D1 than the D3. A mean value of 74.64%, 75.01% and 73.64% under D1, D2 and D3, respectively was recorded. Under D1, highest value for hulling percent was recorded for R-1837-RF-40 while, R-RF-75 showed least value. Under D2, R-RF-77 showed highest value while, R-RF-84 showed least value for hulling percent. The highest value for hulling percent under D3 was recorded for Annada while, R-RF-78 showed least value for hulling percent under D3. Under D1 R-RF-76 (13.35) showed higher percent change while, R-1839-RF-42 (-3.75) showed lower percent change over control (irrigated) for hulling percent. Under D2 R-RF-76 (11.90) showed higher percent change while, R-RF-79 (-6.9) showed lower percent change for hulling percent. Under D3 R-RF-76 (11.9) showed higher percent change while, Annada (check) (-5.0) showed lower percent change for hulling percent.

The average length of brown rice in D1 was 6.50 mm, for D2 and D3 it was 6.70 and 6.50 mm. The highest value for length of brown rice under D1, D2 and D3 was recorded by R-RF-75 while, R-RF-79 showed least value for D1, R-RF-79 under D2 and R-RF-79 under D3. In D1, R-RF-75 (19.41) showed higher percent change while, R-RF-86 (-6.82) showed lower percent change over control (irrigated) for length of brown rice. Under D2, R-RF-85 (20.20) showed higher while, R-RF-86 (-6.8) showed lower percent change. Under D3, IR64 (check) (22.6) showed higher % change while, R-RF-86 (0.8) showed lower percent change for length of brown rice.

The mean value for L/ B ratio of brown rice was recorded as 3.05 for D1 and 3.14 for D2 and 3.21 under D3. The highest value for L/B ratio was recorded for R-RF-75 under D1, R-RF-75 under D2 and R-RF-78 under D3. Annada (check) (2.12) showed least value for L/B ratio of brown rice under all the three dates of sowing i.e. D1, D2 and D3. Under D1, R-1837-RF-40 (24.40) showed highest percent change while, R-RF-86 (-28.20) showed least percent change over control (irrigated) for L/B ratio of brown rice. Under D2, R-RF-77 (-25.70) showed highest percent change while, Samleshwari (check) (-28.2) showed least percent change over control. Under D3, Annada (check) (26.50) showed highest percent change while, R-RF-86 (-16.6) showed least percent change over control for L/B ratio brown rice.

Milling percent also showed similar patterns to that of hulling percent and a mean value of 61.57% were recorded for the genotypes under D1, 64.12% under D2 and 63.11% under D3. Under D1, R-1838-RF-41 showed the highest value and R-RF-75 showed least value of milling percent. Under D2, R-RF-79 showed the highest value while least value was recorded by R-RF-75. However, R-RF-79 showed highest and R-RF-75 showed least value for milling percent under D3. Under D1, R-RF-76 showed highest percent change while, R-1839-RF-42 (-5.24) showed least percent change over control (irrigated) for milling percent. Under D2, R-RF-76 (-25.17) showed highest percent change while, R-RF-77 (-13.5) showed least percent change over control. Under D3, R-RF-76 (23.0)

showed highest percent change while, R-RF-77(-21.0) showed least percent change over control for milling percent.

The average length of milled rice under D1 was 5.90 mm while, for D2 and D3 it was 6.10 mm and 5.90 mm, respectively. The highest value for length of milled rice was recorded for R-RF-85 under D1, D2 and D3. While, R-RF-79 showed least value under D1, Nagina-22 under D2 and Nagina-22 showed least value under D3. Under D1, R-RF-85 (23.81) showed highest percent change while, R-RF-86 (-25.25) showed least percent change over control (irrigated) for length of milled rice. Under D2, R-RF-85 (19.8) showed highest percent change while, R-RF-86 (-33.3) showed least percent change over control. Under D3, R-RF-85 (19.8) showed highest percent change while, R-RF-86 (-23.2) showed least percent change over irrigated as control for length of milled rice.

The mean value for L/B ratio of milled rice was recorded as 2.81 for D1, 2.86 for D2 and 2.69 for D3. The highest value for L/B ratio of milled rice was recorded for R-RF-85 under D1, D2 and D3. Annada (check) showed least value for L/B ratio of milled rice under D1 and R-RF-79 under D2 while Annada (check) showed least value for L/B ratio of milled rice D3. Under D1, R-RF-85 showed highest percent change while, R-RF-86 showed least percent change over control (irrigated) for L/B ratio of milled rice. Under D2, R-RF-85 (22.5) showed highest percent change while, R-RF-86 (-37.4) showed least percent change over control. Under D3, R-RF-77 (26.4) showed highest percent change while, R-RF-85 (-26.9) showed least percent change over control for L/B ratio of milled rice.

Mean value of kernel length after cooking (KLAC) was 9.7 mm for D1 and 10.0 and 9.5 for both D2 and D3. The highest KLAC was recorded for R-RF-78 under D1, for R-RF-76 under D2 and R-RF-85 (10.07m) under D3. Samleshwari (check) showed least value under D1, Nagina-22 showed under D2 and D3. Under D1, R-1838-RF-41 (14.35) showed highest percent change while, R-RF-78 (-13.83) showed least percent change over control (irrigated) for KLAC. Under D2, MTU1010 (check) (11.5) showed highest percent change while, Samleshwari (check) (-22.2) showed least percent change over control. Under D3, R-1837-RF-40 (20.9) showed highest percent change while, R-RF-78 (-13.8) showed least percent change over control for KLAC.

The mean value for L/B ratio of cooked rice was recorded as 3.47 for D1 and 3.35 for D2 and 3.07 under D3. The highest value for L/B ratio of cooked rice was recorded for R-RF-85 under D1, for R-RF-85 under D2 and for R-RF-85 under D3. Annada (check) showed least value for L/B ratio of cooked rice under D1, Nagina-22 for D2 and D3. Under D1, R-RF-85 (24.42) showed highest percent change while, R-RF-78 (-54.15) showed least percent change over control (irrigated) for L/B ratio of cooked rice. Under D2, R-RF-85 (35.7) showed highest percent change while, R-RF-78 (-52.7) showed least percent change over irrigated as control. Under D3, R-RF-85 (35.7) showed highest percent change while, R-RF-78 (-36.6) showed least percent change over control for L/B ratio of cooked rice.

The mean value for water uptake was higher under D3 (187.84) as compared to the D2 (174.09) and D1 (157.9). Poornima (check) showed highest while, R-1839-RF-42 showed least value for water uptake under D1. Under D2, R-1837-RF-40 showed highest while, R-RF-75 showed least value for water uptake. Under D3, IR-70215-70-CPA-3-4-1 and R-RF-75 showed highest and lowest values for water uptake, respectively. Under D1, R-RF-86 (56.84) showed highest percent change while, R-RF-74 (-11.11) showed least percent change over control (irrigated) for water uptake. Under D2, R-RF-79 (60.4) showed highest percent change while, Annada (check) (-3.1) showed least percent change over control. Under D3, IR64 (check) (47.1) showed highest percent change while, Danteshwari (check) (-23.9) showed least percent change over control for water uptake.

Mean value of elongation ratio was 1.65 for D1, 1.69 for D2 and 1.67 for D3. The highest elongation ratio was recorded for R-RF-79 under D1, D2 and D3. Danteshwari (check) showed least value for elongation ratio in D1, Nagina-22 for D2 and Danteshwari (check) showed least value for elongation ratio in D3. Under D1, R-RF-86 (9.4) showed highest percent change while, R-RF-85 (-26.24) showed least percent change over control (irrigated) for elongation ratio. Under D2, R-RF-86 (12.9) showed highest percent change while, R-RF-85 (-42.9) showed least

percent change over control. Under D3, R-1837-RF-40 (11.9) showed highest percent change while, R-RF-85 (-36.6) showed least percent change over control for elongation ratio.

A mean value of elongation index 1.31 under D1, 1.13 under D2 and 1.18 under D3 recorded for elongation index. R-1838-RF-41 showed highest values for elongation index under D1. Under D2, MTU1010 (check) showed the highest value of 1.41 for elongation index while, under D3 highest value of elongation index was recorded for R-RF-85 (2.33). Least value for elongation index was shown by R-RF-75 for D1, R-RF-74 for D2 and Nagina-22 showed least value for D3. Under D1, R-RF-76 (4.09) showed highest percent change while, R-1838-RF-41 (-44.22) showed least percent change over control (irrigated) for elongation index. Under D2, R-RF-85 (26.5) showed highest percent change while, MTU1010 (check) (-57.3) showed least percent change over control. Under D3, R-RF-86 (17.9) showed highest percent change while, R-RF-78 (-28.0) showed least percent change over control for elongation index

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The mean value for amylose content was higher under D3 (12.33 %) as compared to the D2 (11.58 %) and D1 (11.03). R-RF-74 showed highest while R-RF-85 showed least value for amylose under D1. Under D2, R-RF-74 showed highest while, R-RF-85 showed least value for amylose. Under D3, Samleshwari (check) and R-RF-85 showed highest and lowest values for amylose, respectively. Under D1, R-RF-78 (60.54) showed highest percent change while, Annada (check) (6.61) showed least percent change over control (irrigated) for amylase content. Under D2, R-RF-78 (68.4) showed highest percent change while, Annada (check) (-12.) showed least percent change over control. Under D3, R-RF-78 (62.7) showed highest percent change while, R-1837-RF-40 (-13.7) showed least percent change over control for amylose content.

The mean values observed for head rice recovery percent was 32.15% under D1, 33.31% under D2 and 35.39% under D3. R-1837-RF-40 (44.5%) showed highest while, R-RF-78 showed least value for head rice recovery percent under D1. Under D2, R-RF-79 showed highest while, Mahamaya (check) showed least value for head rice recovery percent. Under D3 R-RF-79 and IR-64 (check) showed highest and lowest values for head rice recovery percent, respectively. Under D1, R-RF-84 (64.75) showed highest percent change while, R-1838-RF-41 (-25.53) showed least percent change over control (irrigated) for head rice recovery percent. Under D2, R-RF-76 (62.4) showed highest percent change while, Annada (check) (-18) showed least percent change over control. Under D3, IR64 (check) (72.9) showed highest percent change while, MTU1010 (check) (-17.7) showed least percent change over control for head rice recovery percent.

The mean values observed for protein content was 9.47 % under D1, 8.93 % under D2 and 8.75 % under D3. Nagina-22 showed highest while, R-1838-RF-41 showed least value for protein content under D1. Under D2, Danteshwari (check) showed highest while, R-RF-69 showed least value for protein content. Under D3, R-1838-RF-41 and R-RF-86 showed highest and lowest values for protein content, respectively. Under D1, R-1838-RF-41 (23.4) showed highest percent change while, R-RF-86 (-61.34) showed least percent change over control (irrigated) for protein content. Under D2, R-RF-69 (15.6) showed highest percent change while, R-RF-85 (-30.0) showed least percent change over control. Under D3, Annada (check) (15) showed highest percent change while, R-RF-85 (-31.8) showed least percent change over control for protein content.

Heritability and genetic advance

Heritability in broad sense and genetic advance was recorded for all the characters under each set of condition. The estimates of heritability and genetic advance for quantitative characters are presented in table 5. The highest heritability estimates (>70%) was observed for hundred seed weight, biological yield and paddy length under D1, for plant height, paddy length paddy L/B ratio and grain yield under D2, and for panicle length, biological yield, paddy length and paddy L/B ratio in D3. Overall, paddy length was the only trait which exhibited high broad sense heritability under all the dates of sowing (D1, D2 and D3) during summer 2010 and biological yield also showed high heritability in D1 and D3 conditions. Highest genetic advance as percentage of mean was observed for biological yield in D1 and D3, for harvest index in D1 and in D3 and for grain yield in D1, D2 and in D3.

The highest heritability (>70%) was observed for length of brown rice, L/B ratio of brown rice, length

of milled rice, water uptake, amylose content, head rice recovery percent and protein content under D1, D2 and D3 dates of sowing for high temperature during summer 2010.

Grain size and shape in summer under high temperature stress

Apart from the grain yield, quality is also considered the second most important character. Grain quality in rice is a combination of so many physio-chemical traits determining its nutritive value. Physical quality is determined by the grain size, its hardness, and appearance of milled kernel, hulling, milling and head rice recovery. Grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for releasing in commercial production. If the variety does not confirm to recognize standards for grain size, shape and weight. The grain type categories are based upon length, shape and weight (Adair *et al.* 1973).

Kernel elongation is probably independent of physio-chemical properties, shape, size and weight of rice grain (Hussain *et al.* 1987). The appearance of milled rice is important to the consumer. Thus, grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties for commercial production (Adair *et al.* 1966). The length: breadth ratio (L/B) falling between 2.5 and 3.0 has been considered widely acceptable as long as the length is more than 6 mm (Kaul, 1970). The observation of grain size and shape were recorded in 22 entries under three different dates of sowing i.e., D1, D2, and D3 in summer 2010 as per Standard Evaluation System. Under D1, 11 entries possessed long bold grains followed by 11 entries in D2 and 12 entries under D3. In short bold class 2 entries in D1, 4 entries under D2 and 2 entries under D3. Apart from this, in D1, 4 entries possessed long slender grains followed by 3 entries under D2 and 7 entries under D3. In D1 5 entries possessed medium slender grains followed by 4 entries under D2 and 1 entry under D3 and only one entry possessed short slender grain under D3.

Performance of gelatinization temperature under summer 2010

The score for alkali spreading value or gelatinization temperature were observed under all the three different dates of sowing i.e., D1, D2, and D3 during summer season (Table 4.26). The categorization was done on the basis of gelatinization temperature *viz.*, high, intermediate and low. Under D1, 3 entries showed intermediate, 1 entry showed low and 12 entries showed high gelatinization temperature, under D2 it was 4 for intermediate, 3 for low and 10 for high gelatinization temperature. While, in D3 condition 5 entries showed intermediate and 9 entries showed high and 1 entry only showed low gelatinization temperature during high temperature stress.

Grain Chalkiness

Area of chalkiness was observed under different dates of sowing during summer for high temperature stress and under different water level condition during *Kharif* 2010. The categorization was done on the basis of A (Absent), VOC (Very Occasionally present), OC (Occasionally present), and P (Present). Under D1 (R-RF-85) and D3 (Poornima) VOC chalkiness was observed. In case of OC, 9 entries were found in D1, 6 entries under D2 and five entries in D3 were observed. Apart from this, in case of P (present) chalkiness, 11 entries were found in D1, 13 in D2 and 16 in D3.

Gel consistency

Gel consistency was observed under different dates of sowing during summer for high temperature stress and under different water level condition during *Kharif* 2010 (Table 4.28 and Fig. 4.3). The categorization was done as hard gel consistency, medium gel consistency and soft gel consistency. Under D1, three entries exhibited hard gel consistency followed by, five entries under D2, three entries under D3, sixteen entries under irrigated, fifteen entries under rainfed, and fifteen entries under TSD. In medium gel consistency, under D1 ten entries were found followed by nine entries under D2, four entries under D3, four entries under irrigated, two entries under rainfed, and three entries under TSD were observed. Again in soft gel consistency under D1, nine entries followed by, eight entries under D2, fifteen entries under D3, one entry only under irrigated, four entries under rainfed, and three entries under TSD were found.

High Temperature Stress during summer 2010

The results of mean sum of squares due to the genotypes were significant for plant height, panicle length, biological yield, harvest index and grain yield under all the three different dater of sowing *i.e*. D1, D2, and D3. The mean sum of square due to the genotypes

for quality traits were significant for hulling %, milling%, water uptake, amylose, head rice recovery under all the three dates of sowing. This means overall varied performance of the genotypes for maximum traits. Samleshwari (check) performed well under D1 followed by R-RF-84 and R-RF-76. Under D2, highest yield was recorded for R-RF76 followed by R-RF-77 and R-RF-86 and in D3 highest yield was recorded for Mahamaya (check) followed by R-RF-76 and Annada (Check).Under D1, R-RF-85 (92.8) showed higher percent change while R-RF-74 (65.10) showed lower percent change over control (irrigated) for grain yield. Under D2, Samleshwari (check) (93.3) showed highest percent change while R-RF-86 (66.3) showed lower percent changed over control. Under D3, R-RF-75 (96.10) showed highest percent change while Poornima (check) (87.00) showed lowest percent change for grain yield. R-1837-RF-40 (44.5%) showed highest while, R-RF-78 showed least value for head rice recovery percent under D1. Under D2, R-RF-79 showed highest while, Mahamaya (check) showed least value for head rice recovery percent. Under D3 R-RF-79 and IR-64 (check) showed highest and lowest values for head rice recovery percent, respectively.

Overall, paddy length was the only trait which exhibited high broad sense heritability under all the dates of sowing (D1, D2 and D3) during summer 2010 and biological yield also showed high heritability in D1 and D3 conditions. Highest genetic advance as percentage of mean was observed for biological yield in D1 and D3, for harvest index in D1 and in D3 and for grain yield in D1, D2 and in D3. For quality traits, highest heritability was observed for length of brown rice, length of milled rice, amylose content, head rice recovery and protein content in D1, D2 and in D3 dates of sowing. Grain yield exhibited significant positive association with panicle length and hundred seed weight whereas, head rice recovery exhibited significant negative association with paddy L: B ratio and length of brown rice in D1 for high temperature stress. In D2 date of sowing, grain yield observed significant positive association with panicle length; biological yield and harvest index whereas head rice recovery exhibited positive association with hulling and milling percent and negative association with panicle length and length of brown rice. In D3 condition, grain yield showed positive association with harvest index and negative association with paddy L: B ratio and head rice recovery exhibited positive association with hulling and milling percent.

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Table 1: Experimental details comprising 22 entries in summer season

Condition	No. of entries	Date of sowing	Date of transplanting	Row length	Design	Number of replications
			Summer 2010			
D1	22	12-1-10	Direct sowing	2.0 sq m.	R.B.D.	2
D2	22	2-2-10	Direct sowing	2.0 sq m.	R.B.D.	2
D3	22	22-2-10	Direct sowing	2.0 sq m.	R.B.D.	2

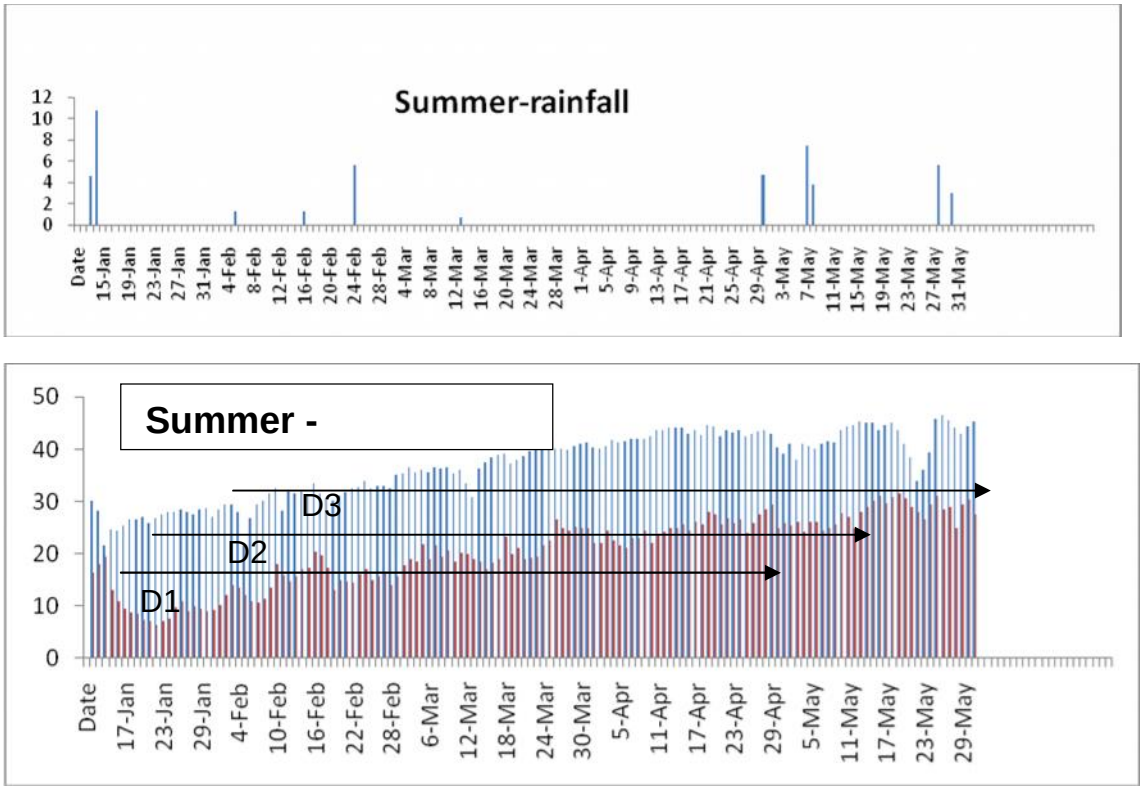

Figure 1: Rainfall and temperature pattern during *Summer* 2010

Table 2: List of plant material used for present study

S. No.	RRF No.	S. No.	RRF No.
1	R-1838-RF-41	12	Danteshwari (check)
2	R-1839-RF-42	13	R-RF-84
3	R-1837-RF-40	14	R-RF-74
4	R-RF-69	15	R-RF-75
5	IR 70215-70-CPA-3-4-1-3	16	R-RF-76
6	Annada(check)	17	R-RF-85
7	MTU1010(check)	18	R-RF-77
8	IR 64(check)	19	R-RF-78
9	Mahamaya(check)	20	R-RF-79
10	Poornima(check)	21	R-RF-86
11	Samleshwari(check)	22	Nagina-22

Table 3: Genotypes showing percent change over control (irrigated) for different quantitative and quality characters during Summer 2010

Characters	Condition	Genotypes showing highest value		Genotypes showing lowest value	
		RF No.	% change	RF No.	% change
Plant height (cm)	D1	IR 70215-70-CPA-3-4-1-3	33.60	R-RF-86	14.00
	D2	IR 70215-70-CPA-3-4-1-3	29.30	R-RF-74	6.40
	D3	IR 70215-70-CPA-3-4-1-3	29.70	R-RF-74	6.30
Panicle length (cm)	D1	R-RF-85	25.30	R-RF-86	(-)3.00
	D2	Samleshwari(check)	27.60	R-RF-86	(-)2.00
	D3	R-RF-77	26.60	R-1839-RF-42	(-)12.30
Hundred seed weight	D1	R-RF-85	28.30	R-RF-74	(-)9.70
	D2	R-RF-69	30.20	R-RF-86	(-)12.10
	D3	IR 64(check)	39.80	R-RF-74	(-)15.80
Biological yield	D1	Mahamaya(check)	87.70	R-RF-78	67.70
	D2	Samleshwari(check)	88.40	Poornima(check)	61.00
	D3	Mahamaya(check)	92.70	R-RF-74	57.40
Harvest index	D1	R-RF-84	58.83	R-RF-79	(-)28.03
	D2	MTU1010(check)	62.80	R-RF-86	0.49
	D3	R-RF-85	84.46	Mahamaya(check)	13.76
Paddy length	D1	MTU1010(check)	21.28	R-RF-86	(-)41.04
	D2	MTU1010(check)	21.81	R-RF-86	(-)40.30
	D3	R-RF-85	17.24	R-RF-86	(-)37.31
Paddy length : breadth ratio	D1	MTU1010(check)	32.92	R-RF-86	(-)62.26
	D2	MTU1010(check)	33.47	R-RF-86	(-)49.42
	D3	R-RF-85	26.85	R-RF-86	(-)49.42
Grain yield	D1	Samleshwari(check)	(-)151.6	R-RF-79	(-)3.5
	D2	R-RF-78	21.93	R-RF-86	(-)237.02
	D3	R-1838-RF-41	54.27	R-RF-76	(-)14.56
Hulling %	D1	R-RF-76	13.35	R-1839-RF-42	-3.75
	D2	R-RF-76	11.90	R-RF-79	-6.90
	D3	R-RF-76	11.90	Annada(check)	-5.00
Brown rice length (mm)	D1	R-RF-75	19.41	R-RF-86	-6.82
	D2	R-RF-85	20.20	R-RF-86	-6.80
	D3	IR 64(check)	22.60	R-RF-86	0.80
L/B ratio of brown rice	D1	R-1837-RF-40	24.40	R-RF-86	-16.46
	D2	R-RF-77	25.70	Samleshwari(check)	-28.20

	D3	Annada(check)	26.50	R-RF-86	-16.60
Milling %	D1	R-RF-76	26.42	R-1839-RF-42	-5.24
	D2	R-RF-76	25.10	R-RF-77	-13.50
	D3	R-RF-76	23.00	R-RF-77	-21.00
Length of milled rice (mm)	D1	R-RF-85	23.81	R-RF-86	-25.25
	D2	R-RF-85	19.80	R-RF-86	-33.30
	D3	R-RF-85	19.80	R-RF-86	-23.20
L/B ratio of milled rice	D1	R-RF-85	26.30	R-RF-86	-29.10
	D2	R-RF-85	22.50	R-RF-86	-37.40
	D3	R-RF-77	26.40	R-RF-85	-26.90
Kernel length after cooking	D1	R-1838-RF-41	14.35	R-RF-78	-13.83
	D2	MTU1010(check)	11.50	Samleshwari(check)	-22.20
	D3	R-1837-RF-40	20.90	R-RF-78	-13.80
L:B ratio of cooked rice	D1	R-RF-85	24.42	R-RF-78	-54.15
	D2	R-RF-85	35.70	R-RF-78	-52.70
	D3	R-RF-85	35.70	R-RF-78	-36.60
Water uptake	D1	R-RF-86	56.84	R-RF-74	-11.11
	D2	R-RF-79	60.40	Annada(check)	-3.10
	D3	IR 64(check)	47.10	Danteshwari(check)	-23.90
Elongation ratio	D1	R-RF-86	9.40	R-RF-85	-26.24
	D2	R-RF-86	12.90	R-RF-85	-42.90
	D3	R-1837-RF-40	11.90	R-RF-85	-57.40
Elongation index	D1	R-RF-76	4.09	R-1838-RF-41	-44.22
	D2	R-RF-85	26.50	MTU1010(check)	-57.30
	D3	R-RF-86	17.90	R-RF-78	-28.00
Amylose	D1	R-RF-78	60.54	Annada(check)	6.61
	D2	R-RF-78	68.40	Annada(check)	-12.00
	D3	R-RF-78	62.70	R-1837-RF-40	-13.70
Head rice recovery per cent	D1	R-RF-84	64.75	R-1838-RF-41	-25.53
	D2	R-RF-76	62.40	Annada(check)	-18.00
	D3	IR 64(check)	72.90	MTU1010(check)	-17.70
Protein content (%)	D1	R-1838-RF-41	23.40	R-RF-86	-61.34
	D2	R-RF-69	15.60	R-RF-85	-30.00
	D3	Annada(check)	15.00	R-RF-85	-31.80

Table 4: Performance of best three genotypes under three different dates of sowing for yield in summer 2010

S. No.	D1		D2		D3	
	Entries	**Plot Yield**	**Entries**	**Plot Yield**	**Entries**	**Plot Yield**
1.	Samleshwari (check)	770.0	R-RF-76	690.0	Mahamaya (check)	335.0
2	R-RF-84	710.0	R-RF-77	655.0	R-RF-76	295.0
3	R-RF-76	630.0	R-RF-86	610.0	Annada (Check)	270.0

Table 5: Summary of estimates of heritability and genetic advanced as percentage of mean for different characters at different dated of sowing

S. No.	Characters	D1		D2		D3	
	Quantitative Characters	h^2	GA	h^2	GA	h^2	GA
1	Plant height			H			
2	Panicle length						
3	Hundred seed wt.	H					
4	Biological field (g/sqm)	H	H			H	H
5	Harvest index (%)		H				H
6	Paddy length (ms)	H		H		H	
7	Paddy length Breath ratio			H		H	
8	Grain field (g/sqm)		H	H	H		H
	Qualitative Characters						
1	Hulling %	H					
2	Length of Brown rice	H		H		H	
3	L/B ratio of Brown rice	H		H			
4	Milling%						
5	Length of milled rice	H		H		H	
6	L/B ratio of milled rice	H		H		H	
7	Kernel length after cooking						
8	L/B ratio of cooked rice						
9	water uptake	H	H		H	H	H
10	Elongation ratio						
11	Elongation index	H					
12	Amylose	H		H	H	H	H
13	Head rice recovery %	H	H	H	H	H	H
14	Protein	H		H		H	

D1= 12-1-10; D2= 2-2-10; D3= 22-2-10 (Different dates of sowing in summer 2010)

Table 6: Intermediate genotype for amylose content during summer and *Kharif* 2010

Amylose content	Summer 2010		
Intermediate	**D1**	**D2**	**D3**
	-	R-RF-69, R-RF-74, R-RF-75	Samleshwari (check)

Table 7: Protein content during summer 2010

R-RF-No	D1	D2	D3	R-RF-No	D1	D2	D3
R-1838-RF-41	6.65	10.27	10.55	Danteshwari (check)	8.48	10.49	9.45
R-1839-RF-42	11.98	9.04	7.38	R-RF-84	11.56	10.29	8.85
R-1837-RF-40	8.73	8.67	8.61	R-RF-74	9.15	8.80	8.65
R-RF-69	8.41	7.19	8.69	R-RF-75	8.91	9.52	9.64
IR 70215-70-CPA-3-4-1-3	8.36	8.58	8.28	R-RF-76	8.55	8.37	8.51
Annada(check)	9.80	9.11	8.25	R-RF-85	10.89	9.28	9.41
MTU1010(check)	7.62	7.68	7.80	R-RF-77	10.88	8.45	8.82
IR 64(check)	8.07	8.13	9.72	R-RF-78	9.41	9.48	9.67
Mahamaya(check)	8.64	8.22	8.38	R-RF-79	10.23	8.38	8.45
Poornima(check)	9.21	8.76	9.28	R-RF-86	11.92	8.91	6.35
Samleshwari(check)	8.74	8.58	8.59	Nagina-22	12.40	10.40	9.39

Table 8: Intermediate genotype for alkali spreading value (Gelatinization temperature) during summer2010

Gelatinization temperature	Summer 2010		
Intermediate	**D1**	**D2**	**D3**
	R-1837-RF-40, IR 70215-70-CPA-3-4-1 R-RF-74	R-1837-RF-40, IR 70215-70-CPA-3-4-1 R-RF-74, R-RF-75	R-1837-RF-40, IR 70215-70-CPA-3-4-1, Poornima (check), R-RF-74, R-RF-84