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*Research Article*

# Drought Tolerance in Upland Rice: Genetic Variability and Correlation Analysis

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**ABSTRACT**

*The genetic material for the study comprised of three $F_2$ populations (Vaishak x Vyttila 6, Vaishak x Harsha and Thottacheera x Harsha) and their parents (Vaishak, Thottacheera, Vyttila 6 and Harsha). In the experiment the genotypes were raised in the field under rainfed upland condition exposed to natural stress. The characters studied were days to 50% flowering, nature of panicle exsertion, leaf rolling score, plant height at maturity (cm), number of productive tillers plant$^{-1}$, number of filled grains panicle$^{-1}$, spikelet sterility(%), 1000 grain weight(g), grain yield plant$^{-1}$(g), straw yield plant$^{-1}$(g) and harvest index(%). Based on the mean performance of the genotypes, the $F_2$ segregants, Vaishak x Harsha and the parents, Vaishak and Vyttila 6 performed well under upland condition. The correlation analysis revealed that among parents, there was significant positive correlation for number of filled grains panilce$^{-1}$ and 1000 grain weight with grain yield plant$^{-1}$ whereas in $F_2$ populations, grain yield plant$^{-1}$ was positively correlated with number of filled grains panicle$^{-1}$, 1000 grain weight and harvest index. In both the cases spikelet sterility(%) recorded a significant negative correlation with grain yield plant$^{-1}$.*

***Key words:*** *Genotypes, Upland, Rainfed, $F_2$ segregants, Correlation*

## INTRODUCTION

Rice (*Oryza sativa* L.) as a cereal grain, is the most widely consumed staple food feeding more than 3.5 billion people worldwide[1]. More than 90 percent of rice is produced and consumed in south and south-east Asia with China and India leading the way[2]. Rice, being semi-aquatic, is commonly grown in irrigated or lowland systems. Globally, 18.5 million hectare of rice is grown under rainfed lowlands[3]. In Asia, more than 50 percent of all water used for irrigation is expended on rice. Being an extravagant consumer of water, rice uses around 5,000 l of fresh water to produce 1 kg of grain[4]. Shrinking arable land and diminishing water resources have resulted in a switching over to upland rice cultivation. A serious problem faced by upland rice ecosystem is drought. Drought can be defined as "a period of no rainfall or irrigation that affects crop growth" [5].

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Upland rice accounts for 12 percent of global rice production area where drought at any stage of crop growth ultimately reduces the grain yield. It is generally the lowest yielding rice ecosystem. The breeding strategies adopted for drought stress depends on the moisture stress environments. Direct selection for yield may not be sufficient as yield will be affected by water holding capacity of soil, root characteristics etc. A more reasonable strategy is to select for yield under various drought prone environments. Moreover, a number of morphological, physiological and biochemical traits are utilised for the selection process. The present investigation deals with the evaluation of the pattern of variability in $F_2$ for yield and yield contributing traits under upland condition.

## MATERIAL AND METHODS

The study was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram. The genotypes selected for the study were Vaishak x Vyttila 6, Vaishak x Harsha and Thottacheera x Harsha among $F_2$ segregants and Vaishak (PTB 60), Thottacheera, Vyttila 6 and Harsha (PTB 55) among parents. The crop was raised in the field under rainfed upland condition exposed to natural stress. Observations on various morphological characters were taken at appropriate stages and recorded. In the experiment genotypes with desirable agronomic traits and superior yield attributes were selected from the segregating $F_2$ populations. Selfed seeds were collected from the selected plants for carrying forward to the next generation. The design used was Randomized Block Design with seven treatments and three replications. The spacing adopted was 30cm x 30cm. A population size of 300 plants for each parent and 600 plants for each $F_2$ population was maintained. Five plants from each replication of parents and fifteen plants from each $F_2$ were taken as observation plants to calculate the mean value for 11 characters *viz*., Days to 50% flowering, Nature of panicle exsertion (based on the standards set by DRR[6]: Table 1), Leaf rolling score (based on the scoring scale standardized for rice by IRRI[7]:Table 2), Number of productive tillers plant$^{-1}$, Plant height at maturity (cm), Number of filled grains panicle$^{-1}$, Spikelet sterility (%), 1000 grain weight (g), Grain yield plant$^{-1}$ (g), Straw yield plant$^{-1}$ (g) and Harvest index (%).Simple correlation of all the characters observed with grain yield plant$^{-1}$ were also worked out for parents and $F_2$ population.

## RESULTS AND DISCUSSION

### Genetic variability

The mean values of the seven genotypes for the characters under consideration were tabulated and are presented in Table 3.

The early flowering and maturing genotypes among parents and $F_2$ populations were Thottacheera(75.76 days) and Thottacheera x Harsha (77.43 days) respectively wherein the mean values were lower than the parental mean (89.31 days) and $F_2$ segregants mean (85.83days). The late flowering and maturing genotypes were Vyttila 6 (99.44 days) and Vaishak x Vyttila 6 (97.82 days) segregants. The mean value for parents and $F_2$ segregants were comparable for this character. A close association between time taken to flowering and drought tolerance was observed in upland rice varieties by Laffitte and Curtosis[8]. Panthuwan *et al.*[9], have reported similar results that the greater the delay in flowering the greater is the yield and harvest index reduction[9].

Under upland condition, Thottacheera and $F_2$ population of Thottacheera x Harsha recorded well exserted panicles whereas the panicles were only partially exserted in Vyttila 6. Vyttila 6 had its panicles partially exserted from the flag leaf. The nature of panicle exsertion is presented in Table 4.

Cruz and O'Toole[10] reported that panicle exsertion is sensitive to changes in leaf water potential and upto 30 percent of water stress mediated spikelet sterility was associated with poor panicle exsertion[10]. Thus, degree of panicle exsertion during flowering stage water stress could be used as an important visual

criterion in selection of genotypes with high degree of reproductive stage drought tolerance.

Leaf rolling is a reversible phenomenon which reduces the leaf area exposed to stress reducing transpiration and thus has an adaptive role in tissue water conservation. Leaf rolling is determined based on scores. Leaf rolling score was noted after seven days of dry spell and the mean values are presented in Table 5. When exposed to natural stress under upland condition the varieties Vaishak, Thottacheera and $F_2$ population of Vaishak x Vyttila 6, Vaishak x Harsha and Thottacheera x Harsha recorded a leaf rolling score of 3 which was marked by the folding of leaves with a deep "V" shape. Leaf rolling in Vyttila 6 and Harsha were not significant (score 1). Similar findings were reported by Singh and Singh[11]. that leaf rolling is an adaptive response to water deficit which helps in maintaining favourable water balance within plant tissues thus resulting in relatively better plant performance[11]. Hence, the high score for reversible leaf rolling observed in the present $F_2$ population can be considered as a positive character.

All the three $F_2$ populations recorded higher number of productive tillers compared to the better parent *i.e* Vyttila 6 (10.13) and this character had a major role in increasing grain yield and harvest index among $F_2$. The lowest value among the parents was for Thottacheera (9.00). The mean of $F_2$ segregants of Vaishak x Harsha recorded the highest number of productive tillers with the value of 14.13. The $F_2$ population of the other two *viz;* Vaishak x Vyttila 6 (12.06) and Thottacheera x Harsha (11.13) were superior to the better parent. The mean of $F_2$ segregants (12.44) for this character exceeded the parental mean (9.44) considerably. The result is in agreement with the findings of Valarmathi and Leenakumary[12]. that grain yield increased when the number of productive tillers increased[12].

For plant height at maturity, the $F_2$ segregants mean (127.49cm) was higher than the parental mean (101.03cm). Vaishak (126.40cm) was the tallest parent which effectively transferred its height to both the $F_2$ segregant populations (Vaishak x Vyttila 6 (127.40) and Vaishak x Harsha (128.13 cm)) wherein it featured as the female parent. This is in line with the report by Basu and Das (1981) pointed out that moisture stress had resulted in a reduction in plant height and upland rice varieties were less sensitive compared to lowland rice varieties[13].

The parent Vaishak marked the highest mean values for number of filled grains panicle$^{-1}$(158.22) 1000 grain weight (28.53g) and grain yield plant$^{-1}$(40.13g). Among the $F_2$ populations, Vaishak x Harsha segregants recorded the highest mean values for number of filled grains panicle$^{-1}$(137.11), 1000 grain weight (28.47g) and grain yield plant$^{-1}$(47.99g) .Vaishak which featured as the female parent was observed to be the best general combiner for number of spikelets panicle$^{-1}$ and grain yield plant$^{-1}$ under upland rainfed situation by Haunsajirao[14]. Vaishak might have successfully transferred its superior grain characters to its hybrid which has become evident in the $F_2$ segregating generation under both conditions. Guimaraes *et al.*[15], have reported similar findings that precocity, less dense panicles, low sterility and greater 100-grain weight under water stress should be prioritised while selecting genotypes for drought tolerance[15].

Spikelet sterility ranged from 7.44 percent in Vaishak to 13.56 percent in Vyttila 6 among the parents whereas in $F_2$ population, Thottacheera x Harsha (41.33%) recorded the highest mean spikelet sterility percentage. Spikelet sterility was comparatively high among the $F_2$ populations (26.59%) compared to parental varieties (10.21%) It was also observed that the segregants of Vaishak x Vyttila 6 recorded a mean spikelet sterility of 20.35 percent whereas that of Vaishak x Harsha was 18.11 percent. The reason is the high range of variability in the days to onset of different growth phases expressed in the heterozygous segregating populations as against the strict, narrow range of the homozygous parental varieties. This is supported by the finding of Liu *et al.*[16], and

Wopereis *et al.*[17]. that moisture stress at an early reproductive stage reduces the number of filled grains panicle$^{-1}$, 1000 grain weight and grain yield plant$^{-1}$ and increases spikelet sterility[16,17]. Haunsajirao[14] had in his study reported such a situation in a long duration variety Uma[14]. This finding further stresses the significance in recommending short duration types for drought situations.

The mean value for straw yield plant$^{-1}$ did not vary much for parents and $F_2$ segregants. Among the parents it varied from 30.98g in Vyttila 6 to 58.29g in Harsha. When the mean of $F_2$ population was recorded, the segregants of Vaishak x Harsha (57.14g) recorded the highest value whereas Thottacheera x Harsha (33.03g) recorded the lowest. For harvest index, the $F_2$ segregant mean was greater than the parental mean. Harvest index was the highest for Vyttila 6 (46.84%) and the lowest for Harsha (39.63%). Among $F_2$ population, the segregants of Vaishak x Vyttila 6 (47.33%) represented the highest mean value which was higher than the better parent. The $F_2$ segregants of Thottacheera x Harsha (46.68%) and Vaishak x Harsha (45.56%) also recorded high values. These obsevations are in line with the reports of Shanmugasundaram *et al.*[18]. that straw yield and harvest index forms an important selection criterion for superior genotypes under rainfed condition[18].

**Correlation Studies**

Simple correlation for all the characters with grain yield plant$^{-1}$ was worked out and is presented in Table 6. The parental genotypes marked significant correlation for characters such as number of filled grains panicle$^{-1}$ (0.773), spikelet sterility (0.628), and straw yield plant$^{-1}$ (0.885). In the $F_2$ population, significant correlation was observed for number of productive tillers plant$^{-1}$ (0.801), number of filled grains panicle$^{-1}$ (0.792), spikelet sterility (0.823) and straw yield plant$^{-1}$ (0.984). In both the cases, all other characters except spikelet sterility recorded significant positive correlation with grain yield plant$^{-1}$. Various studies have revealed similar results that days to 50% flowering, fertile spikelets panicle$^{-1}$, harvest index, productive tillers panicle$^{-1}$ and 100 grain weight are positively correlated with grain yield[19,20]. Kahani and Hittalmani[4]. reported that grain yield plant$^{-1}$ was significantly and positively correlated with number of tillers, number of panicles, grain length and straw yield whereas days to flowering, days to maturity, plant height, 100 grain weight, grain width and leaf width were negatively correlated with grain yield plant$^{-1}$ [4].

**Table 1: Nature of panicle exsertion[6]**

| Sl. No | Type of panicle exsertion | Percentage panicle exsertion from flag leaf |
|---|---|---|
| 1 | Partly exserted | Less than 80% |
| 2 | Mostly exserted | 81-99% |
| 3 | Well exserted | 100% |

**Table 2: Leaf rolling score[7]**

| Decimal score | Leaf rolling description |
|---|---|
| 0 | Leaves normal (no rolling) |
| 1 | Leaves start to fold(shallow V shape) |
| 3 | Leaves folding(deep V shape) |
| 5 | Leaves fully cupped(U shape) |
| 7 | Leaf margins touching(O shape) |
| 9 | Leaves tightly rolled |

**Table 3: Mean performance for the morphological characters of parents and $F_2$ segregants under rainfed upland condition**

| Sl.No | Parents and F2 segregants | Days to 50% flowering | No. of productive tillers plant$^{-1}$ | Plant height at maturity (cm) | No. of filled grains panicle$^{-1}$ | Spikelet sterility (%) | 1000 grain weight (g) | Grain yield plant$^{-1}$ (g) | Straw yield plant$^{-1}$ (g) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Vaishak ($T_1$) | 95.34 | 9.23 | 126.40 | 158.22 | 7.44 | 28.53 | 40.13 | 48.56 | 44.80 |
| 2 | Thottacheera | 75.76 | 9.00 | 95.60 | 135.87 | 9.51 | 23.27 | 30.98 | 41.31 | 42.73 |
| 3 | Vyttila 6 | 99.44 | 10.13 | 90.60 | 128.56 | 13.56 | 26.77 | 27.41 | 30.98 | 46.84 |
| 4 | Harsha | 86.69 | 9.40 | 88.20 | 152.99 | 10.24 | 26.77 | 38.37 | 58.29 | 39.63 |
| 5 | Vaishak x Vyttila 6 | 97.82 | 12.06 | 127.40 | 134.67 | 20.35 | 27.57 | 41.25 | 45.65 | 47.33 |
| 6 | Vaishak x Harsha | 82.25 | 14.13 | 128.13 | 137.11 | 18.11 | 28.47 | 47.99 | 57.14 | 45.56 |
| 7 | Thottacheera x Harsha | 77.43 | 11.13 | 129.27 | 122.00 | 41.33 | 26.47 | 28.95 | 33.03 | 46.68 |
| Parents mean | | 89.31 | 9.44 | 101.03 | 144.33 | 10.21 | 26.33 | 34.23 | 44.79 | 43.50 |
| $F_2$ segregants mean | | 85.83 | 12.44 | 127.49 | 131.26 | 26.59 | 27.38 | 39.39 | 45.27 | 46.52 |

**Table 4: Nature of panicle exsertion in parents and $F_2$ segregants under rainfed upland rice**

| Sl. no | Parents and $F_2$ segregants | Nature of panicle exsertion |
|---|---|---|
| 1 | Vaishak | Mostly exserted |
| 2 | Thottacheera | Well exserted |
| 3 | Vyttila 6 | Partially exserted |
| 4 | Harsha | Mostly exserted |
| 5 | Vaishak x Vyttila 6 | Mostly exserted |
| 6 | Vaishak x Harsha | Mostly exserted |
| 7 | Thottacheera x Harsha | Well exserted |

**Table 5: Leaf rolling score for parents and $F_2$ segregants under rainfed upland condition**

| Sl. no | Parents and $F_2$ segregants | Score | Description |
|---|---|---|---|
| 1 | Vaishak | 3 | Leaves folding (deep V shape) |
| 2 | Thottacheera | 3 | Leaves folding (deep V shape) |
| 3 | Vyttila 6 | 1 | Leaves start to fold (shallow V shape) |
| 4 | Harsha | 1 | Leaves start to fold (shallow V shape) |
| 5 | Vaishak x Vyttila 6 | 3 | Leaves folding (deep V shape) |
| 6 | Vaishak x Harsha | 3 | Leaves folding (deep V shape) |
| 7 | Thottacheera x Harsha | 3 | Leaves folding (deep V shape) |

**Table 6: Simple correlation of characters under study with grain yield plant$^{-1}$ in parents and $F_2$ segregants under upland condition**

| Sl.No | Characters | Parents | $F_2$ segregants |
|---|---|---|---|
| 1 | Days to 50% flowering | -0.003 | 0.159 |
| 2 | No. of productive tillers plant$^{-1}$ | 0.154 | 0.801** |
| 3 | Plant height at maturity(cm) | 0.388 | 0.076 |
| 4 | No. of filled grains panicle$^{-1}$ | 0.773** | 0.792* |
| 5 | Spikelet sterility(%) | -0.628* | -0.823** |
| 6 | 1000 grain weight(g) | 0.465 | 0.355 |
| 7 | Straw yield plant$^{-1}$ | 0.885** | 0.984** |
| 8 | Harvest index(%) | -0.250 | 0.098 |

**significant at 1% level
*significant at 5% level

## CONCLUSION

The world population is growing at an alarming rate and is expected to reach 9 billion by 2050[21]. In order to meet the food requirements of the ever increasing population, there must be a several-fold increase in food grain production compared to the present level. Rice is semi-aquatic and is cultivated either as irrigated (lowland) or rainfed (upland). Most of the researches till date are concentrating on improving lowland rice productivity. Since the availability of good quality water is diminishing, upland rice which depends entirely on rainfall needs special attention. Keeping this in view, the present investigation aimed to evaluate the pattern of variability in $F_2$ generation for yield and yield contributing traits under upland condition and to select superior segregants combining drought tolerance and high yield. On analysing the mean performance of the genotypes for all the above characters under rainfed upland condition, it was found that among the parents the variety Vaishak recorded the highest mean grain yield plant$^{-1}$. It also recorded the highest mean value for plant height at maturity, number of filled grains panicle$^{-1}$, 1000 grain weight and the lowest value for spikelet sterility. The variety Thottacheera was the earliest in flowering. Vyttila 6 was late in flowering with the lowest mean straw yield plant$^{-1}$ but the number of productive tillers plant$^{-1}$ and harvest index were found to be the highest. Harsha recorded the lowest mean value for plant height at maturity but its straw yield plant$^{-1}$ was the highest. Among the $F_2$ populations, segregants of Vaishak x Harsha recorded the highest mean value for number of productive tillers plant$^{-1}$, number of filled grains panicle$^{-1}$, 1000 grain weight and straw yield plant$^{-1}$ and the lowest mean value for spikelet sterility. The $F_2$ population of Vaishak x Vyttila 6 was late in flowering with the lowest value for plant height at maturity but recorded the highest mean values for harvest index. The $F_2$ segregants of Thottacheera x Harsha flowered early and was having the highest mean value for plant height and the lowest value for straw yield plant$^{-1}$.

There was significant positive correlation of grain yield plant$^{-1}$ with number of filled grains panicle$^{-1}$ and straw yield plant$^{-1}$ in case of parents whereas for $F_2$ segregants a significant positive correlation was noted for number of productive tillers plant$^{-1}$ and straw yield plant$^{-1}$. Spikelet sterility recorded a significant negative correlation in both the cases.

Appearance of plants in $F_2$ populations which perform better than their respective parents is an indication that desirable segregants may appear in later segregating

generations which can be isolated out to develop high yielding, drought tolerant upland rice varieties.

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