Evaluation of Recombinant Inbreed Lines (RIL) population of upland rice under stress and non stress conditions for grain yield and drought tolerance

Manish Kumar*, N.P. Mandal¹ and A. Kumar

Department of Botany,
Vinoba Bhave University, Hazaribag-825 301, Jharkhand, India.

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ABSTRACT
Drought is the major abiotic factor that limit rice productivity in rainfed and upland occurring ecosystems; worldwide, it reduces yield by 15–50 % depending on the stress impact on crop growth period. Stress period occurring more than 7-14 days drastic reduction is observed in all the parameters i.e. average plant height 12.9-29.5%, panicle number 41.6-65.4%, yield of inbred lines 17.34 -86.04% followed by an average of overall 44.86% over non stress condition. Similarly it was found that biomass, harvest index, filled grain per panicle, total grain per panicle, fertility % and so on were reduced under stress condition in comparison to congenial condition. Variation in drought susceptibility index (DSI) and drought resistant index (DRI) in the inbred lines ranges 1.081 to 2.116 and 0.04 to 2.80 respectively. Significant variations observed in the population for different agronomical traits and derived indices would facilitate selection of recombinant inbred lines (RILs) with drought tolerance and high yielding.

Key words: Drought susceptibility Index (DSI), Drought Resistant Index (DRI), Non stress, Recombinant inbred lines (RILs), Stress.

INTRODUCTION
Rice, (Oryza sativa L.) is the most important food crop for nearly half of the world’s population (Sellamuthu et al., 2011). Worldwide, rice is cultivated on an area of 154 million hectares with an annual production of 700 million tonnes (FAO, 2011). Drought is a major abiotic stress that limits rice productivity in rainfed and upland ecosystems (Bimpong et al., 2011) and worldwide, drought affects approximately 27 million ha of rice. Drought reduces yield by 15–50 per cent depending on the stress intensity and crop growth period at which the stress occurs in rice (Srividhya et al., 2011). Eastern India, comprising Jharkhand, Orissa, and Chattisgarh alone accounts loss of about 40 per cent of the total rice production due to severe drought (Pandey and Bhandari, 2009). Developing high yielding and drought resistant varieties for rainfed area is priority for improving rainfed rice production.

Plant response to drought stress is one of the most complex biological processes, and it involves numerous changes at the physiological, cellular, and molecular levels. Many genes have been identified to be involved in the response of drought stress in plants (Zhang et al., 2012). The effect of drought on rice plants considerably varies with genotypes, developmental stages, and degree and duration of drought stress (Wang et al., 2011).

The narrow genetic base of modern crop cultivars is one of the serious obstacles to sustain and improve crop productivity due to rapid vulnerability of genetically uniform cultivars by potentially new biotic and abiotic stresses (Esbroeck et al., 1999). Some rice cultivars particularly landraces contain a wealth of information that can explain the large morphological, physiological, and ecological variation. The innovative use of such diverse varieties will play a key role in reaching ambitious goal of high productivity in rice and also help to overcome future problems associated with narrowing genetic base of modern rice cultivars. It has now been demonstrated that drought-tolerant upland rice can be bred by directly selecting for yield in stress environments. The goal of research was to phenotype the Recombinant Inbred Lines (RIL) population (Heera x Brown gora) under stress and control condition for grain yield and drought resistance.

MATERIALS AND METHODS
The experimental trials were conducted during 2012-2015 in the fields of Central Rainfed Upland Rice Research Station (CRURRS), Hazaribag and Krishi Vigyan Kendra, Jainagar, Koderma, Jharkhand, India (latitude 24° 21’53”N, longitude 85° 38’58”E, altitude 321 m of Jainagar, Koderma and latitude 23° 59’N, longitude 85° 25’E, altitude 610 m Hazaribag ), located in north India.

Plant materials: In this study, a total of 114 population of rice, 109 Heera x Brown gora Recombinant Inbred Lines +2 parents, Heera and Brown gora+3checks- Vandana; CO-
39 and Kalinga III, representing different ecotypes and geographical origins were used. Seeds of the rice accessions were obtained CRURRS, Hazaribag, Jharkhand, India.

Field evaluation: The inbred populations of rice were evaluated under two different hydrological conditions viz., non stress (favorable or irrigated as per needed) and stress under rainfed condition during North-East monsoon, rainfed region in the experimental fields as above. Seeds of the rice lines were hand dibbled in dry soil before monsoon in 2.5 × 0.6 m² size plots with three replications under lattice square design and data collected were 50 per cent flowering, plant height, length of panicle, number of productive tillers/0.5m, number of grains/panicle, number of filled grains, grain yield kg per hactre, total biomass kg/ha.

Statistical analysis of the phenotypic data: Mean, range, standard deviation and correlation coefficient were worked out using Microsoft Excel statistical tools and SAS statistical package in order to check the genetic variance among the rice lines for all the traits.

RESULTS AND DISCUSSION

Results obtained from the field experiments conducted with the objectives viz., to phenotype the Recombinant Inbred Lines (RIL) population of Heera x Brown gora under stress and non stress condition for grain yield and drought tolerance.

Drought screening trial: A total of 114 population of rice, 109 Heera x Brown gora Recombinant Inbred Lines (RIL) population of Heera x Brown gora under stress and non stress condition for grain yield and drought tolerance.

Yield attributes: The means of, 50 per cent flowering (62.67 and 72.09), plant height (100.43 cm and 118.86 cm), length of panicle (21.94 cm and 24.56 cm) number of productive tillers/0.5m (34.95 and 59.82), number of grains/panicle (100.67 and 117.56), number of filled grains (91.41 and 51.94), grain yield kg/ha (1310.0 and 2376.0), total biomass kg/ha (4205 and 5247) under stress condition (Table 2) and non stress condition (Table 1) respectively.

The ranges varies of, 50 % flowering (50.0 - 79.0 days and 60.0 - 104.0 days), plant height (25.0 - 138.30 cm and 35.40 - 158.84 cm), number of productive tillers/0.5m (10.0-70.0 and 29.0-120.0), panicle length (0.0 - 28.10 cm and 18.96 - 62.10 cm), number of grains/panicle (49.0 - 218.0 and 55.0 - 166.0), number of filled grains (1.33 - 105.3 and 037.0 - 162.0), Grain yield kg/ha (73.0-4800 and 523.0-5807.0), total biomass kg/ha (1633.0 - 4038.70 and 3302 - 6087.30) stress (Table 2) and non stress (Table 1) respectively.

Under stress condition date of 50 % flowering flowered 7-14 days before than the non stress condition. Drought stress delays flowering in crops (Fukai 1999), which is due to low plant water status and longer delay in flowering is related to drought susceptibility (Kumar and Kujur, 2003). It is observed that average plant height reduced by 12.9-29.5%, panicle numbers drastically reduced to 41.6%-65.4%, yield of inbred lines decreased from 17.34 -86.04% and average of 44.86%. Similarly it is observed that biomass, harvest index, filled grains, total grains, fertility etc phenotypic characters are less under stress condition in comparison to non stress condition. Plant-type traits such as plant height and tiller number modify the expression of secondary and integrative traits by affecting transpiration

Table 1: Rice accessions showing variation in drought resistance under non stress rainfed condition

| Variable | Mean | Std Dev | Sum | Minimum | Maximum |
|----------|------|---------|-----|---------|---------|
| DTF      | 72.09| 5.67    | 16438| 60.00   | 104.00  |
| APHT     | 118.87| 21.70   | 27102| 35.40   | 158.84  |
| PNo      | 59.82| 14.84   | 13641| 29.00   | 120.00  |
| Yield    | 2376 | 961.32  | 541575| 523.00  | 5807    |
| TBM      | 5247 | 2831    | 1196269| 1633.0  | 40387   |
| HI       | 0.47 | 0.14    | 107803| 0.09    | 1.019   |
| FG       | 91.41| 29.97   | 20843| 37.00   | 162.00  |
| UFG      | 26.15| 14.88   | 5963 | 6.00    | 58.00   |
| TG       | 117.56| 32.81   | 26804| 49.00   | 218.00  |
| PF       | 0.77 | 0.11    | 176.608| 0.40    | 0.94    |
| PS       | 0.22 | 0.11    | 51.39| 0.05    | 0.59    |
| PL       | 24.56| 5.62    | 5601 | 18.96   | 62.10   |

DTF- Days to 50% flowering, APHT-Average Plant Height (cm), P No-panicle no. in 0.5m, yield in Kg/ha, TBM- Total biomass (Kg/ha), HI- Harvest Index, FG- filled grains per panicle, UFG- unfilled grains per panicle, TG-Total grains per panicle, PF.- fertility, PS.- sterility and PL- Panicle length (cm).
Leaf rolling is one of the drought avoidance mechanisms to prevent water deficit during stress (O’Toole and Chang, 1979). Rolled leaves of rice transpire 41 per cent less water than did the unrolled ones (Courtois et al., 2002). Rice crop responds to drought condition by stomatal closure, leaf rolling, enhanced root growth, enhanced ABA production etc., to minimize water deficit (Price et al. 2002b). Leaf rolling and canopy temperature are also useful (Lafitte et al., 2004; Hirayama et al., 2006) for quickly screening of lines. The rate of yield or biomass reduction by stress (e.g. yield under stress as percent of yield under non-stress) is often used as an estimate of resistance in terms of plant production, in addition to absolute yield under stress. (Fischer and Maurer, 1978, Bidinger, et al.,1982). Spikelet fertility can be visually estimated under field conditions and has been used as an indirect index for drought screening in rice (Garrity and O’Toole 1994; Fukai 1999). The low value leaf drying score (LDS) i.e.0, 1,2 etc. inbred lines are more resistant to stress environments and similar condition also observed for leaf rolling score.

### Drought resistance index (DRI)

It for inbred lines rice varies from 0.04 to 2.80 with average of 1.02. The inbred lines having higher value of DRI i.e CO-39(2.80), Br. gora(1.15),HxB-1(1.81),HxB-13,14,19,20,31, 34,80,81,107 etc.(+) are comparatively more tolerance to drought than the low value DRI inbred lines i.e. HxB-101 (0.09), HxB-18(0.05), HxB-24(0.04) etc. So that it make easier selection of desired lines.

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#### Table 2: Rice accessions showing variation in drought resistance under stress rainfed condition

| Variable | Mean | Std Dev | Sum | Minimum | Maximum |
|----------|------|---------|-----|---------|---------|
| DTF      | 62.67| 6.47    | 14290| 50.00   | 79.00   |
| APHT     | 100.43| 20.134  | 22900| 25.00   | 138.30  |
| PNo      | 34.95| 11.228  | 7969 | 10.00   | 70.00   |
| GY       | 1310 | 880.301 | 298776| 73.00   | 4800    |
| TBH      | 4205 | 50.93   | 958663| 330.20  | 60873   |
| HI       | 0.36 | 0.19    | 82.376| 0.01    | 1.17    |
| FG       | 51.94| 21.68   | 11843| 1.00    | 105.00  |
| UFG      | 48.71| 25.74   | 11106| 7.00    | 36.00   |
| TG       | 100.67| 24.91   | 22953| 55.00   | 166.00  |
| PF       | 0.52 | 0.20    | 120.24| 0.010   | 0.91    |
| PS       | 0.47 | 0.20    | 107.76| 0.090   | 0.99    |
| PL       | 21.94| 3.35    | 5004 | 0       | 28.10   |
| LRS      | 7.61 | 1.22    | 1737 | 0       | 9.70    |
| LDS      | 7.16 | 4.40    | 1634 | 0       | 12.71   |

**DTF- Days to 50% flowering., APHT-Average Plant Height (cm), P No-panicle no. in 0.5m, yield in Kg/ha, TBM- Total biomass (Kg/ha), HI- Harvest Index, FG- filled grains per panicle, UFG- unfilled grains per panicle, TG-Total grain per panicle s, PF- fertility, PS- sterility and PL- Panicle length (cm),LRS-Leaf rolling score andLDS-Leaf drying score.**
Table 3: Correlation coefficient among traits under stress conditions.

|       | DTF   | APHT  | P NO  | GY    | TBM   | HI    | FG    | UFG   | TG    | FERT  | STER  | PL    | LRS   | LDS   |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| DTF   | **1.0** |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       |       | **1.0** |       |       |       |       |       |       |       |       |       |       |       |       |
| APHT  | **0.009 NS** | **1.0** |       |       |       |       |       |       |       |       |       |       |       |       |
|       | **0.881** | **1.0** |       |       |       |       |       |       |       |       |       |       |       |       |
| P NO  | **-0.063 NS** | **-0.095 NS** | **1.0** | **1.0** |       |       |       |       |       |       |       |       |       |       |
|       | **0.346** | **1.0** |       |       |       |       |       |       |       |       |       |       |       |       |
| GY    | **0.002 NS** | **0.046 NS** | **0.039 NS** | **1.0** | **1.0** |       |       |       |       |       |       |       |       |       |
|       | **0.151** | **1.0** |       |       |       |       |       |       |       |       |       |       |       |       |
| TBM   | **0.071 NS** | **0.139** | **0.298** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |       |       |       |
|       | **0.394** | **1.0** |       |       |       |       |       |       |       |       |       |       |       |       |
| HI    | **0.015 NS** | **-0.046 NS** | **0.684** | **-0.215 NS** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.001 NS** | **0.817 NS** | **0.483** | **0.001 NS** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| FG    | **0.019 NS** | **0.098 NS** | **0.038** | **0.001 NS** | **-0.040 NS** | **1.0** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.774** | **0.139 NS** | **0.561** | **0.987 NS** | **0.542** | **0.545** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| UFG   | **0.046 NS** | **-0.043 NS** | **0.025 NS** | **0.23 NS** | **0.026 NS** | **1.0** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.487** | **0.512** | **0.497** | **0.698** | **0.71** | **0.689** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| TG    | **-0.031 NS** | **-0.013 NS** | **0.028 NS** | **0.063 NS** | **-0.009 NS** | **1.0** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.644** | **0.537 NS** | **0.845 NS** | **0.667 NS** | **0.341 NS** | **0.89** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| PF    | **0.013 NS** | **0.077 NS** | **0.067 NS** | **-0.035 NS** | **-0.002 NS** | **-0.048 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.844** | **0.243 NS** | **0.312 NS** | **0.59** | **0.976 NS** | **0.467 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| PS    | **-0.013 NS** | **-0.077 NS** | **-0.067 NS** | **0.035 NS** | **0.002 NS** | **0.048 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.844** | **0.243** | **0.312** | **0.90** | **0.976** | **0.467** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| PL    | **0.092 NS** | **-0.068 NS** | **0.059 NS** | **-0.072 NS** | **-0.012 NS** | **-0.002 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.163** | **0.306 NS** | **0.367** | **0.276 NS** | **0.859 NS** | **0.974 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| LRS   | **0.095 NS** | **-0.055 NS** | **0.066 NS** | **-0.078 NS** | **0.002 NS** | **-0.085 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.151** | **0.404 NS** | **0.319 NS** | **0.237 NS** | **0.982 NS** | **0.199 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
| LDS   | **-0.069 NS** | **-0.018 NS** | **0.004 NS** | **-0.038 NS** | **0.101 NS** | **-0.085 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |
|       | **0.30** | **0.787 NS** | **0.955 NS** | **0.566 NS** | **1.027 NS** | **0.197 NS** | **1.0** | **1.0** | **1.0** |       |       |       |       |       |

Significance at 1% level** (0.149) and at 5% level* (0.113), NS-non significant

DTF- Days to 50% flowering., APHT-Average Plant Height (cm), P No-panicle no. in 0.5m, GY Grain yield in Kg/ha, TBM-Total biomass (Kg/ha), HI- Harvest Index, FG- filled grains per panicle, UFG- unfilled grains per panicle, TG-Total grains per panicle, PF- fertility, PS.- sterility and PL- Panicle length (cm), FERT-Fertility, STER-Sterility, LRS-Leaf rolling score and LDS-Leaf drying score.
Table 4: Correlation coefficient among traits under non-stress conditions.

|         | DTF | APHT | P NO | GY   | TBM  | HI   | FG   | UFG  | TG   | FERT | STER | PL   |
|---------|-----|------|------|------|------|------|------|------|------|------|------|------|
| DTF     | 1 **| 1    | -0.133* | 0.039 NS | 1    | -0.133* | 0.033 NS | 0.094 NS | 0.097 NS | 0.044 NS | 0.076 NS | 0.152* |
| APHT    | 1   | 1    | 0.094 NS | 0.039 NS | 1    | 0.140** | 0.149** | 0.555** | 0.039 NS | 0.097 NS | 0.076 NS | 0.199** |
| P NO    | -0.133* | 0.039 NS | 1    | -0.003 NS | 1    | 0.044 NS | 0.555** | 1    | 0.039 NS | 0.097 NS | 0.076 NS | 0.199** |
| GY      | -0.049 NS | 0.033 NS | -0.003 NS | 1    | 0.459** | 0.619** | 0.964** | 1    | 0.039 NS | 0.097 NS | 0.076 NS | 0.199** |
| TBM     | 0.044 NS | 0.097 NS | 0.039 NS | 0.407* | 1    | 0.507 NS | 0.140** | 0.549** | 0.001 NS | 0.024 NS | 0.001 NS | 0.127 NS |
| HI      | -0.101 NS | -0.117* | -0.711* | 0.622* | -0.250* | 1    | 0.127 NS | 0.280** | 0.001 NS | 0.024 NS | 0.001 NS | 0.127 NS |
| FG      | -0.076 NS | 0.049 NS | -0.110 NS | 0.047 NS | 1    | 0.428** | 0.458** | 0.968 NS | 0.710 NS | 0.076 NS | 0.076 NS | 0.076 NS |
| UFG     | -0.052 NS | -0.006 NS | -0.041 NS | 0.024 NS | 1    | 0.248** | 0.458** | 0.968 NS | 0.710 NS | 0.076 NS | 0.076 NS | 0.076 NS |
| TG      | -0.094 NS | 0.042 NS | -0.085 NS | 0.021 NS | 0.890 | 0.405  | 1    | 0.127 NS | 0.280** | 0.001 NS | 0.024 NS | 0.001 NS |
| PF      | 0.020 NS | 0.034 NS | -0.078 NS | 0.067 NS | 0.591* | -0.845* | 0.091 NS | 1    | 0.024 NS | 0.042 NS | 0.042 NS | 0.042 NS |
| PS      | 0.020 NS | 0.029 NS | -0.052 NS | 0.061 NS | -0.591* | 1    | 0.127 NS | 0.280** | 0.001 NS | 0.024 NS | 0.001 NS | 0.001 NS |
| PL      | 0.152* | 0.085 NS | -0.021 NS | 0.003 NS | 0.003 NS | -0.003 NS | 0.073 NS | -0.027 NS | -0.080 NS | 0.006 NS | -0.006 NS | 1    |

Significance at 1% level** (0.149) and at 5% level* (0.113), NS-non significant

DTF- Days to 50% flowering, APHT-Average Plant Height (cm), P No-panicle no. in 0.5m, yield in Kg/ha, TBM- Total biomass (Kg/ha), HI- Harvest Index, FG- filled grains per panicle, UFG- unfilled grains per panicle, TG-Total grains per panicle, FERT- fertility, STER- sterility and PL- Panicle length (cm FERT-Fertility, STER-Sterility, PL- Panicle length (cm).
Drought susceptibility indexes (DSI): The variation of DSI for rice ranges from -1.081 to 2.116 and value of DSI made it possible to rank rice genotypes lines according to their drought tolerance in comparison to checks (Brown gora, Vandana, CO39).

The values of DSI made it possible to rank the examined rice genotypes according to their drought tolerance. So that it makes easier selection of desired lines/varieties. Leafrolling is an important agronomic trait in rice breeding (Xiang et al., 2012). It is an adaptive response to water deficit, which helps in maintaining favorable water balance within plant tissues under conditions of water scarcity and depleting soil moisture (Singh and Singh, 1999).

According to our earlier research (Grzesiak et al., 2012) drought susceptibility indexes (DSI) for maize and triticale genotypes were calculated by determining the changes in grain yield (GY) under two soil moisture levels (irrigated and drought).

Correlation coefficient analysis: Correlation coefficient between different yields attributes and drought indicators/index were significantly correlated with each other’s given in table 3 and table 4 under stress and non stress condition respectively at 1% (0.149) and 5% (0.113) such as yield was significant with DTF at 5%(0.243) and at 1% with plant height(0.484) and panicle numbers (0.552). Similarly yield under non stress condition significantly correlated with at 1% with DTF (0.459), plant height (0.619) and panicle numbers (0.964). it is observed that biomass significantly correlated with DTF (0.394) and Plant height (0.280) at 1% and panicle numbers(0.139) and yield (0.298) at 5% under stress so on for non stress(table 3 and 4).

Grain yield under drought has been reported to be a function of biomass production and harvest index at the vegetative and reproductive stage respectively (Atlin et al., 2008). Grain yield under drought stress is a complex quantitative trait whose repeatability is thought to be low relative to yield in non-stress environments, reducing selection efficiency (Fukai and Cooper, 1995; Venuprasad et al., 2007). Panicle length was positively correlated with number of grains per panicle, straw yield total biomass and root thickness under rainfed condition. Mirza et al. (1992) found panicle length was positively correlated with number of grains per panicle. Harvest index was positively correlated with grain number, percentage spikelet fertility and yield in rice. In the current study, the traits such as days to heading, number of chaffs and panicle length had negative correlations with harvest index. Li et al. (2012) also reported harvest index was negatively correlated with days to fifty percent flowering, panicle length. Spikelet fertility is the most important yield component trait under water stress condition (Cruz and O’ Toole, 1984).

CONCLUSION

Rice, (Oryza sativa L.) is one of the most important crops providing staple food for a large segment of the world population. Drought stress is a major limitation to rice yields and its stability in rainfed areas. Developing drought resistant cultivars will help to increase production of rice in rainfed area. Developing high yielding and drought resistant varieties for rainfed area is priority for improving rainfed rice production.

Plant response to drought stress is one of the most complex biological processes some rice cultivars particularly landraces contain a wealth of information that can explain the large morphological, physiological, and ecological variation. The innovative use of such diverse varieties will play a key role in reaching ambitious goal of high productivity in rice and also help to overcome future problems associated with narrowing genetic base of modern rice cultivars. It has now been demonstrated that drought – tolerant upland rice can be bred by directly selecting for yield in stress environments. By the phenotyping of recombinant Inbred Lines (RIL) population (Heera x Brown gora) under stress and non stress condition for grain yield and drought resistance we can be developed new lines which tolerant to stress as well as more yielding.

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