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**SOME CHARACTERS ASSOCIATED WITH STAGNANT FLOODING TOLERANCE IN RICE**

**ABSTRACT**

Tolerance mechanisms of stagnant flooding stress are controlled by various traits. Determination of secondary traits as selection criteria will be useful for crop improvement for water stress. The aims of the research were to study variation of agronomical traits and to determinate secondary traits related to stagnant flooding tolerance. The experiment was conducted at the Indonesian Center for Rice Research in dry season of 2015. Materials used were 10 rice genotypes, arranged in a randomized complete block design with three replicates in each normal condition and gradual flooding. The agronomic traits observed were plant height, intensity of leaf green color, productive tillers, number of filled grains per panicle, weight of 1000 grains, grain yield, stem length, stem diameter, length of leaf blade, width of leaf blade, and panicle exertion. Data were analyzed using combined analysis of variance, correlations, multiple linear regressions, and genetic variability. The results showed that effects of water regime were significant on plant height, stem length, stem diameter, length of leaf blade, grain yield, and productive tillers. Additionally, genotypic effects were significant on all traits observed, and interaction of water regime and genotype were significant on plant height, width of leaf blade, and panicle exertion. A linear model involving weight of 1000 grain, panicle length, stem diameter, intensity of leaf green colour, and stem length could explain 92.3 % of the variance of stress tolerance index (STI). Stem length, intensity of leaf green color, and panicle length had broad genetic variability and highly heritability therefore that it would be relative easily to select the traits under flooding stress. Number of productive tillers was correlated with grain yield under SF and highly heritable, so it may also suggest as one of determining characters for stagnant flooding tolerance. Based on STIStd, Ciherang, and INPARI 30 had good performance under 50 – 60 cm of water depth while IR 42 did not.

**KEYWORDS**

*secondary traits, partial submerged, genetic variability*

**INTRODUCTION**

Agricultural expansion to flood-prone area is potential for increasing the national rice production. Flood-prone area is defined as area that is always saturated or waterlogged for a long period in the year. This condition is caused by its position in between land and coastal area, therefore is saturated or having shallow ground water. Grounds are flooded to the least of 50 cm in depth or more over period of weeks to months or so. In total, Indonesian flood-prone area covers around 33.41 billion hectares, consists of swampy (13.28 billion hectares), and tidal swamp (20.13 billion hectares) (Subagyo 2006).

Stagnant flooding (SF) is flooding stress which during this time water does not recede and remains in the field at the depths of 50 to 60 cm for several months (Mallik *et al.* 1995). Stagnant flooding may also occur after a flash flooding event. Medium or semi-deep stagnant flooding occurs for a longer duration, more than 2 weeks and often several months, at depths up to 50 cm.

In the flood-prone ecosystem, common modern rice varieties are unlikely to grow normally, due to the water depth. Yield lost ranges from 10 to 100% under flooding stress, depending on flood duration, depth, and floodwater conditions (Ismail *et al.* 2012). So far, the number of high yielding genotypes that have been identified as stagnant flooding tolerant are still limited (Vergara *et al.* 2014).

International Rice Research Institute (IRRI) began to develop unfavourable area tolerant rice, such as stagnant flooding of 25 to 50 cm water depth above the ground over the whole plant duration. No varieties were officially released that tolerant to stagnant flooding until today. Furthermore, development of rice varieties which are tolerant to both of submergence and stagnant flooding is principal in IRRI. Some of IRRI lines that have submergence and stagnant flooding tolerance have been tested in Asia and Africa over 2011 to 2012 (Mackill *et al.* 2010).

Under stagnant flooding condition, most of plants produce low yield because of reduction of the sink capacity such as number of panicle, spikelet fertility, and grain size (Mallik *et al.* 2004; Singh *et al.* 2011; Kato *et al.* 2014). Effects of stagnant flooding (25-50 cm of depth) were vegetative vigour are mostly poor, increasing on plant height, delaying of day to heading, and severe logging (Amante, 1986).

Under stagnant flooding stress, yield is primary criterion based on visual selection. Tolerance mechanisms are controlled by various characters, therefore it is necessary to identify the secondary characters that have strong correlation with yield. The traits are preferably non-destructive and of the pre-flowering stage. Singh *et al.* (2011) and Kato *et al.* (2014) suggested that reduction in tiller number directly affected rice yield under stagnant flooding. Faster shoot elongation contributed to establishing a larger aerial leaf area and higher light interception, biomass production, and plant survival under stagnant flooding. Collard *et al.* (2013) suggested that number of tillers, elongation ability at vegetative stage, leaf area development, and logging resistance can be used to estimate tolerance.

Many secondary characters are easier to measure across representative stress environments. The selection of secondary characters will be effective if it is expressed constitutively, or if it can be measured on seedlings or vegetative stage. Determination of secondary characters as selection criteria will be useful for crop improvement for waterlogging stress. The study was aimed to determine secondary traits correlated with stagnant flooding tolerance in rice.

**MATERIALS AND METHODS**

**Plant materials**

Materials used are 10 rice genotypes that were identified as tolerant, susceptible, and unknown. The genotypes are INPARA 3, INPARA 7, IRRI 119, INPARA 4, INPARA 5, INPARI 30, IR 64, IR 42, Ciherang, and INPARI 29. IRRI 119 was considered to be stagnant flooding tolerant in rice breeding program at IRRI (Miro *et al.* 2013, Collard *et al.* 2013; Kato *et al.* 2014; and Vergara *et al.* 2014). IR 42 is determined as stagnant flooding susceptible by Vergara *et al.* (2014) and Yullianida *et al.* (2015). Under stagnant flooding stress, the yield reduction of IR 42 is 57%, stem elongation is 36.7 cm, stem elongation rate is 1 cm day-1 and the number of tillers are 3 (Vergara *et al.* 2014; and Yullianida, *et al.* 2015). Meanwhile Vergara *et al.* (2014) reported the IR 42 yield reduction was 85%. INPARA 3, 4, 5, 7 are swampy rice, INPARI 29 and 30 are varieties with SUB1 gene, Ciherang and IR 64 are popular irrigated varieties.

**Design of field trials**

The experiment was conducted in Experimental Station of Indonesian Center for Rice Research, Sukamandi, Subang, West Java on dry season of 2015 (April to August 2015)**.** The treatments were normal condition (control with shallow flooding of 5 cm) and gradual flooding which was starting at 30 days after transplanting (DAT) with 20 cm water depth then will be gradually increased weekly by 5 cm up to 50-60 cm. When 50-60 cm had been reached, it was maintained throughout the maturity (Vergara *et al.* 2014). Seedlings (21-day-old) were transplanted using one plant per hole with 25 × 25 cm spacing. The experiment was designed as nested design. Set of water regime treatment was designed as a randomized complete block design with three replications, in both normal (shallow-flooded) and Stagnant Flooding (SF) field plots. Seedlings were transplanted in 3 m × 4 m plots.

The agronomical/morphological traits observed were plant height, intensity of leaf green colour, number of productive tiller, number of filled grain per panicle, weight of 1000 grain, grain yield, stem length, stem diameter, length of leaf blade, width of leaf blade, and panicle exertion.

**Statistical analysis**

The ability of genotypes to perform reasonably well in stagnant flooding stress is paramount for stability of grain yield. The relative yield performance of genotypes in stagnant flooding stressed and non-stressed environment can be used as an indicator to identify stagnant flooding tolerant genotypes. Several index have been suggested on the basis of mathematical relationship between yield under stagnant flooding stressed and non-stress environments.

Rosielle and Hamblin (1981) proposed stress tolerance (TOL) as the differences of yield under stress (S) and non-stress (NS) environment. TOL = (Yi)NS – (Yi)S . Higher value of TOL indicate susceptibility of genotype. Hossain *et al.* (1990) defined mean relative performance, as and relative efficiency index, REI = . Fernandez (1992) defined a stress tolerance index as STI = ; which can be used to identified genotypes that produce high yield under both stress and non-stress environment. High value of STI indicate higher tolerance of stress. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) that assesses the reduction of yield under unfavourable compared with favourable environment. SSI = SI = . Lower SSI indicate more tolerant to stress. Singh *et al.* (2011) suggested a modified formula for Schneider’s stress severity index (SSSI). SSSI = . SSSI estimate the relative tolerance of a genotype relative to the population mean in grain yield reduction response due to stress. The six methods was analysed using correlation analysis to identify the relationship between methods.

To conclude based on the six indices, each method was standardize by standard deviation. In mathematics, the standardization formula is as follows (IndexStd)i = ((Index)i - (Overall mean)i/Std. Standardized STI is corrected (subtract) by susceptible index (standardized SSI, SSSI, and TOL), we called STI. The conclusion is based on the consistency of the corrected STI index in explaining the tolerant and susceptible genotypes.

The phenotypic variance was calculated based on mean basis from variance estimation that given from the ANOVA. The standard deviation of variance genetic and phenotypic were determined by Burton (1952) *in* Wahdah *et al.* (1996). Genetic variability and phenotypic variability were determined by the ratio variance with their standard deviation. If then genetic and phenotypic variability considered as broad. The estimation of heritability was the ratio of genetic variance with phenotypic variance (Fehr 1987).

Data were analysed using combined analysis of variance across environment, correlation analysis, multiple linear regressions, genetic variability, and heritability. Analysis of variance (ANOVA) for combined environment followed method described by Fehr (1987). All statistical procedure were analysed using Ms excel, and STAR software.

**RESULTS AND DISCUSSION**

**Genotype and water regime interaction on grain yield and yield components**

According to the combined analysis of variance, effect of water regime on grain yield and productive tillers were significantly difference. Meanwhile, the effect of genotype was also significantly different on grain yield, productive tillers, filled grains, and weight of 1000 grains. However, effect of water regime and genotype interaction was not significantly different on grain yield and yield components. It means that all the tested genotype have similar response of reduction of grain yield and yield components (Table 1).

Stagnant flooding stress increased plant height, at the average of 13 %, and the genotype range of 6–28 % (Table 2). INPARA 4 has highest percentage of increased plant height, although was not greater than of IRRI 119. In the normal and stagnant flooding stress, plant height of IRRI 119 was highest among others. INPARI 29 and INPARI 30 were shorter than IRRI 119, although those three genotypes were all submergence tolerant varieties. Nevertheless, the increased plant height among the genotypes is not much different (6-9%). When the submergence develops to stagnant flooding, the submergence tolerance varieties will respond differently. Study to short stature type variety, namely Swarna-Sub1 (INPARA 4) did not perform well under stagnant flooding after submergence treatment (Singh *et al.* 2009; Singh *et al.* 2011).

INPARI 29 and INPARI 30 were shorter than IRRI 119, although those three genotypes were all submergence tolerant varieties. Nevertheless, the increased plant height among the genotypes is not much different (6-9%). When the submergence develops to stagnant flooding, the submergence tolerance varieties will respond differently. Study to short stature type variety, namely Swarna-Sub1 (INPARA 4) did not perform well under stagnant flooding after submergence treatment (Singh *et al.* 2009; Singh *et al.* 2011).

In addition to the increasing of plant height, reduction in the number of tillers is a response to stagnant flooding stress (Collard *et al.* 2013). Stagnant flooding reduced number of productive tillers, with average of 25 % and genotype range of 3-46 % (Table 2).

The decrease of filled grains number per panicle was moderately low (Table 2). Some genotypes even have higher number of filled grains in stagnant flooding stress than normal conditions. This was probably caused by assimilate substitution from number of reduced productive tillers to the number of filled grains, as shown by INPARA 3, INPARI 30, and Ciherang. INPARA 4 and INPARA 5 were only have slightly decreased productive tillers number and also number of filled grain. Increased number of panicle accounted largely for grain yield response to increased CO2 (Ziska *et al.* 1997; Baker et al. 1990, 1992). Increased tillering is not desirable characteristic in high yielding irrigated condition as it increased susceptibility to lodging. Thus selecting cultivar which can channel increased resources into converting juvenile spikelets into grains rather than developing extra tillers must be a priority for condition of increased atmospheric CO2 (Sheehy *et al.* 2001).

The average decrease of grain yield from normal to stagnant flooding stress was 27 % (Table 2). Meanwhile yield decreasing of every genotype was ranged from 20 to 41 %. Genotypes which have greater decreasing of grain yield were INPARI 29 and INPARA 3.

**Genotype and water regime interaction on morphological characters**

Effect of water regime was significantly different on plant height, stem length, stem diameter, and length of leaf blade (Table 3). Meanwhile effect of genotype was significantly different on all observed characters. Interaction of water regime and genotype was only significantly different on plant height, width of leaf blade, and panicle exertion. It means that response of genotypes on the characters were different in both treatments of water regime (normal and SF condition).

Stem elongation ability is one of plant adaptation mechanism to escape anaerobic respiration when submergence occurs. Genotype with stem elongation ability will be able to perform photosynthesis because the leaves are still positioned above the water. In the normal and stagnant flooding condition, stem length of IRRI 119 was the greatest, but increasing percentage of stem length was quite low (7 %). This suggested that tolerance is not only influenced by stem elongation, but also depend on plant stature at normal conditions. Varieties with stagnant flooding tolerance should have a relatively higher stature than lowland varieties. Mallik *et al.* (1995) observed that genotypes with moderate elongation had good survival and higher yield. Stagnation of water needs the enhancement of shoot elongation, which allows plants to extend their leaves out of the water for restoring contact with the atmosphere (Voesenek *et al.* 2004). This makes possible reason of plant which have submergence tolerance as well as moderate stem elongation become adapted under stagnant flooding (Nugraha *et al.* 2013).

The average stem diameter was increased by 18 % from normal to stagnant flooding stress. All tested genotypes have increased thickness of stem after stress condition (Table 4). Increasing of stem thickness in tolerant genotypes are important to avoid lodging in standing water. Vergara *et al.* (2014) reported that stem become thicker under stagnant flooding condition where stem diameter increased by range of 10-45 % from normal condition. Tolerant genotypes had thicker stem. Visual comparison of stem between normal and stagnant flooding condition showed that increasing of stem thickness also increased hollowness, which might aid further in root aeration.

The average length of the leaf blade was increased by 11.9 % (Table 4). Under normal conditions, IRRI 119 has the longest leaves and no significant increase under stress condition. The genotypes that have the shortest leaves under normal conditions were growing longer by 20 to 29 % under stress condition. Width of leaf blade has got narrower in all varieties under stagnant flooding stress. The same result also reported by Anandan *et al.* (2015). This suggests that, rapid elongation clearly uses photosynthesis mechanism to increase blade length by restoring contact between the leaves and air (Mazaredo *et al.* 1982; Sakagami *et al.* 2009).

Panicle exertion under normal condition was scanty varied (Table 4). In stress condition, panicle exertion was quite varied. All genotype were elongate the length of panicle, except IR 42. Panicle exertion of IR 42 was enclosed so that the panicle neck was minus. This may be caused grain filling was not going well so many grain were unfilled, as showed by the number of filled grain per panicle of IR 42 was low.

Panicle length in normal and stress conditions were varied (Table 4). The variance of the character which observed in the two conditions provide an opportunity to obtain information panicle length characteristic of tolerant and susceptible genotypes. Panicle of IRRI 119 was higher than Ciherang and INPARI 30. However, based on the grain yield in drought stress (Table 3.4), the grain yield of three genotypes were not significantly different. Despite INPARI 29 has panicle length was not significantly different with IRRI 119, but grain yield was lowest. This suggests that in addition to panicle length, other characters such as panicle density and the number of secondary branches, must be consider for selection.

**Tolerance Index of stagnant flooding stress**

Stress Tolerance Index is a measure of tolerance degree of a genotype to stress. Genotype with a higher value is considered more tolerant. Based on the STI, the tolerant genotypes were IR 64, Ciherang, INPARI 30, and INPARA 7, respectively. The identified susceptible genotypes were INPARA 3 and IR 42. SSI is a measure of the level of susceptibility to stress. Genotypes with high SSI value means more sensitive to stress. Based on SSI, identified tolerant genotypes were IR 42 and Ciherang. While the sensitive genotypes were INPARA 3 and INPARI 29. TOL is grain yield difference under normal and stress conditions. If the difference between normal and stress is small, it means that the genotype can be identified as tolerant. The tolerant genotype identified based on TOL was IR 42, and the susceptible was INPARI 29. However, the approach of tolerant index using the formula is largely bias. REI is an index of relative efficiency. Genotype which has high REI value is identified as tolerant genotype. Based on REI, tolerant genotype identified were INPARI 30 and IR 64, while INPARA 3 and IR 42 were susceptible. SSSI measures the relative tolerance that is calculated from yield reduction of a genotype relative to the reduction of mean population as grain yield response to stress conditions. Lower value of SSSI shows the tolerant genotypes that were IR 42 and Ciherang. Meanwhile, INPARA 3 and INPARI 29 were identified as sensitive genotypes. MRP indicates performance of average relative. Genotype with high value of MRP is identified as tolerant, and low value indicates sensitive. Based on MRP, IR 64, INPARI 30 and Ciherang were indicated as tolerant genotypes. INPARA 3 and IR 42 were identified as sensitive genotype (Table 5).

According to the six tolerance index methods, generally INPARA 3 was identified as susceptible to stagnant flooding stress. Ciherang was identified as tolerant based on 5 methods. IR 42 identified as tolerant based on 3 methods, and as susceptible based on 3 methods. Therefore, the levels of tolerance of the tested genotypes still needs to be confirmed by further experiments on several seasons.

Coefficient of correlation among tolerance parameters indicated that STI correlated with REI and MRP. SSI correlated with TOL and SSSI. The significance was also showed by the consistency of tolerant genotypes that were identified using the six methods above. The genotype which was identified as tolerant by STI was also identified as tolerant based on REI and MRP. IR 42 is consistent as susceptible genotype based on STI, REI and MRP methods. Likewise for tolerant genotypes based on SSI, it also showed similar tolerance levels based on TOL and SSSI (Table 6).

STI may be useful in identifying genotype which have high yield under normal condition and can produce well under severe stress. TOL and SSI proposed for identifying genotype that perform well under stress environment. MRP and REI are respectively the sum and product of two ration, (a) genotype control mean/overall control mean and (b) genotype stress mean/overall stress mean. The index values are increase if (a) or (b) is higher. If (b) high, the genotype enters the set of top performers though the performance under normal condition is not the top-most and vice versa. So, MRP and REI are not very effective in distinctively discriminating genotypes that perform well under both normal and stress condition (Raman *et al.* 2012).

Based on correlation analysis, stress tolerant index could be grouped into two groups. First is tolerance index group involving STI, REI, and MRP. The second is sensitive index group involving SSI, TOL, and SSSI. Level of tolerance based on the six indices was determined using standardizes of index. For first group, STI was selected to be standardized with three sensitive index. Standardized STI was corrected with standardized index of sensitive group so that resulting new standardized index, namely STI (Table 7).

The STI showed STIStd-ssi was no different with STIStd-sssi (Table 7). This may be both of index had same derivate of formula. Three STIStd were consistent to identified tolerant and sensitive genotypes. High index values indicating tolerant genotype, vice versa lowest index value indicating sensitive genotype. Based on three index, Ciherang and INPARI 30 were tolerant genotypes, while INPARA 3 and IR 42 were sensitive genotypes. IR 64 was consistent in high value based on STIStd-ssi and STIStd-sssi, but was moderate based on STIStd-tol. IRRI 119 which identified tolerant based on previous study, however in our study it showed moderate sensitive.

**Modelling Stress Tolerance Index**

Regression analysis described the effect of one or more characters (designed as independent variables) on a single character (designed as dependent variable) by expressing the latter as a function of the former. In regression, the character of major importance, for example, grain yield, usually becomes the dependent variable and the factors of character that influence grain yield become independent variables (Gomez 1976).

Linear regression with tolerance index as Y and grain yield as x showed that the fitted model for determining stagnant flooding stress was = -0.371 + 0.235GY (Table 8 and 9). It could be showed that grain yield independently could be explain by 87.76 % of the tolerance variation. It means that level of tolerance greatly affect the grain yield. To determine the level precision of STI predictive value than STI actual, it was correlated between variables which was calculated from each genotypes. Correlation analysis between STI and predictive value of STI was significant with r = 0.9567 (Table 10). It was indicated that STI predictive is accurate to estimate actual value of STI.

Large proportion of variance contributed by grain yield to SF stress tolerance index indicating the grain yield independently could distinguished tolerant and sensitive genotype. The implication for screening method is further experiment just need stressed condition (SF) without normal site to select the tolerant genotypes. It will increase the efficiency and effectiveness of screening method especially in relation to the cost of research.

Linear multiple regression with tolerance index as Y and morphological traits as x showed the fitted model to explain the stagnant flooding tolerance was STI = -3.17 + 0.08W1000 – 0.14PL – 0.56SD + 0.11SPAD + 0.04 SL with R2 adjusted 0.923 (Table 11 and 12). Variance of STI could be explained by 92.3 % of weight of 1000 grain (W1000), panicle length (PL), stem diameter (SD), intensity of leaf green colour (SPAD), and stem length (SL). Weight of 1000 grain is observed at generative stage. For simplifying selection process, it is better to select traits which expressed at seedling or vegetative stage. Therefore, we tried to exclude weight of 1000 grain from the model. It resulted no significance of the model and R2 became very low (0.1045), which was largely explained by stem diameter. The implication for the breeding is selection cannot only using vegetative traits, but also need to consider generative traits.

**Correlation among Traits**

Correlation analysis was to know level of correlation between traits observed under stagnant flooding stress. Plant height was significantly correlated with morphological traits such as stem length, stem diameter, length of leaf blade, panicle length, and also weight of 1000 grain. Stress Tolerance Index (STI) was significantly correlated with grain yield. Grain yield only correlated with number of tillers (Table 13). Number of productive tiller is one of yield components. The traits may be considered as one of selection criterion for stagnant flooding tolerance (Ismail *et al.* 2012; Singh *et al.* 2011; Kato *et al.* 2014; Suwignyo 2014), although in this study showed there was no correlation between number of productive tiller and STI. Other yield components such as number of filled grain and weight of 1000 grains correlated biologically with grain yield, in this case, both of them were not correlated statistically. This may because the variance of number of filled grain and weight of 1000 grains of genotypes tested were scanty varied therefore it could not raise the correlation.

**Genetic variability and heritability**

Under stagnant flooding stress, all observed traits except panicle length showed broad of phenotypic variability, and their genetic variability were varied among the traits (Table 14). It mean that the variation greatly influenced by environment not only by genetic per se.

Most of the report identified that grain yield was quantitative trait which is controlled by minor gene and had low heritability. In this study, the heritability of grain yield under stagnant flooding was high. Nugraha *et al.* (2013) suggested that the flooding stress was obvious discriminator between tolerance and sensitive genotypes resulting a consistent grain yield in a given environment hence the heritability also was high.

Our study showed variability of grain yield was narrow although effect of genotype variance was significantly different (data not shown). Narrowness of grain yield variability may be caused by the narrowness of genetic background of genotypes used. It could be explained through some varieties come from same parent. INPARA 5 (IR 64 SUB1), INPARI 30 (Ciherang SUB1), IR 64, Ciherang have a close genetic relationship. However, the selection based on grain yield under stagnant flooding stress could be done at early generations using bulk segregation.

Plant height, intensity of leaf green color, stem length, panicle exertion and panicle length had broad genetic variability and high heritability. It mean that it would be relative easily to select the traits under flooding stress. The traits can be recommended as secondary trait for stagnant flooding tolerance. The selection can be done at early generation, using bulk segregation or pedigree method.

**CONCLUSIONS AND SUGGESTION**

A linear model involving weight of 1000 grain, panicle length, stem diameter, intensity of leaf green color, and stem length could explain 92.30 % of the variance of stress tolerance index. Intensity of leaf green color, panicle length and stem length had relatively broad genetic variability and high heritability under flooding stress, and therefore may be used for selection. Number of productive tillers was correlated with grain yield under SF and highly heritable, hence it may also suggest as one of determining characters for stagnant flooding tolerance. Based on STIStd, Ciherang, and INPARI 30 had good performance under 50 – 60 cm of water depth while IR 42 did not. The tolerance levels of the genotypes need to be confirmed by further experiments across several seasons.

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Table 1. Mean Square of combined analysis of variance of plant height, yield and yield components

| Source of variance | DF | PH | | PT | | FG | | W1000 | | GY | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Water regime (W) | 1 | 2806.067 | \*\* | 336.067 | \*\* | 303.750 | ns | 0.053 | ns | 45.501 | \*\* |
| Replication/W | 4 | 17.428 | ns | 5.333 | ns | 210.383 | ns | 0.847 | ns | 0.065 | ns |
| Genotype (G) | 9 | 462.818 | \*\* | 33.622 | \*\* | 537.076 | \* | 28.156 | \*\* | 2.047 | \*\* |
| G x W | 9 | 38.572 | \*\* | 11.104 | ns | 278.972 | ns | 5.510 | ns | 0.375 | ns |
| Error | 35 | 12.203 |  | 5.519 |  | 235.124 |  | 3.095 |  | 0.434 |  |
| CV (%) |  | 3.01 |  | 14.07 |  | 16.83 |  | 6.72 |  | 11.79 |  |

Remarks: PH, plant height; PT, productive tillers; FG, filled grain; W1000, weight of 1000 grains; GY, grain yield; DF, degree of freedom. \*, \*\* represent significance at P < 0.05 and P < 0.01, respectively

Table 2. Grain yield and yield component under normal and stagnant flooding (SF) condition

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Genotype | Plant height (cm) | | | | | Number of productive tillers | | | | | | Filled grains | | | | Weight of 1000 grains (g) | | | | | Grain yield (t/ha) | | | | |
| Normal | | SF | | SF/N (%) | Normal | | SF | | SF/N (%) | Mean | Normal | SF | SF/N (%) | Mean | Normal | | SF | SF/N (%) | Mean | Normal | SF | | SF/N (%) | Mean |
| INPARA 3 | 114 | b | 129 | b | 113 | 15 | e | 9 | c | 59 | 12 | 104 | 114 | 110 | 109 | 26.6 | cd | 25.8 | 97.0 | 26.2 | 6.23 | 3.86 | d | 61.96 | 5.05 |
| INPARA 7 | 113 | b | 125 | bc | 110 | 19 | bcd | 15 | ab | 80 | 17 | 94 | 89 | 94 | 91 | 28.6 | b | 27.5 | 96.3 | 28.1 | 6.83 | 5.02 | ab | 73.50 | 5.93 |
| IRRI 119 | 129 | a | 136 | a | 106 | 17 | cde | 13 | bc | 77 | 15 | 99 | 92 | 93 | 95 | 30.4 | a | 29.5 | 97.1 | 29.9 | 6.57 | 4.79 | abc | 72.91 | 5.68 |
| INPARA 4 | 91 | e | 117 | de | 128 | 19 | bcd | 19 | a | 97 | 19 | 76 | 100 | 131 | 88 | 21.2 | e | 25.1 | 118.8 | 23.1 | 6.38 | 4.99 | ab | 78.21 | 5.69 |
| INPARA 5 | 101 | d | 110 | f | 109 | 17 | de | 15 | ab | 88 | 16 | 100 | 101 | 101 | 101 | 27.7 | bc | 25.1 | 90.7 | 26.4 | 5.81 | 4.43 | bcd | 76.25 | 5.12 |
| INPARI 30 | 113 | b | 123 | bc | 109 | 23 | a | 12 | bc | 54 | 18 | 75 | 97 | 129 | 86 | 26.7 | cd | 26.6 | 99.7 | 26.6 | 6.89 | 5.32 | ab | 77.21 | 6.11 |
| IR 64 | 101 | d | 114 | ef | 113 | 21 | ab | 17 | ab | 79 | 19 | 91 | 78 | 86 | 84 | 26.2 | d | 26.5 | 101.2 | 26.3 | 7.42 | 5.35 | a | 72.10 | 6.39 |
| IR 42 | 106 | cd | 122 | cd | 116 | 23 | a | 16 | ab | 72 | 20 | 75 | 72 | 96 | 74 | 21.3 | e | 23.4 | 109.5 | 22.4 | 5.10 | 4.07 | cd | 79.80 | 4.59 |
| Ciherang | 111 | bc | 125 | bc | 113 | 20 | abc | 15 | ab | 72 | 18 | 81 | 103 | 127 | 92 | 26.8 | cd | 24.9 | 92.8 | 25.9 | 6.86 | 5.49 | a | 80.03 | 6.18 |
| INPARI 29 | 115 | b | 128 | bc | 112 | 17 | de | 13 | bc | 76 | 15 | 94 | 90 | 95 | 92 | 26.6 | cd | 27.0 | 101.6 | 26.8 | 6.49 | 3.84 | d | 59.17 | 5.17 |
| Mean | 109 |  | 123 |  | 113 | 19 |  | 14 |  | 75 |  | 89 | 93 | 105 |  | 26.2 |  | 26 | 99.8 |  | 6.46 | 4.72 |  | 73.03 |  |

Remarks: Different letter in the same column indicate statistical significant (P<0.05)

Table 3. Mean Square of combined analysis of variance of morphological characters

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Source of variance | DF | SL |  | SD |  | LB |  | WB |  | PE |  |
| Water regime (W) | 1 | 3039.466 | \*\* | 12.198 | \*\* | 313.344 | \* | 0.016 | ns | 12.595 | ns |
| Replication/W | 4 | 17.884 | ns | 0.261 | ns | 23.373 | ns | 0.018 | ns | 2.469 | \* |
| Genotype (G) | 8 | 170.372 | \*\* | 0.627 | \*\* | 105.714 | \*\* | 0.021 | \* | 13.762 | \*\* |
| G x W | 8 | 4.362 | ns | 0.175 | ns | 25.548 | ns | 0.003 | \*\* | 8.570 | \*\* |
| Error | 31 | 9.668 |  | 0.119 |  | 12.925 |  | 0.010 |  | 0.873 |  |
| CV (%) |  | 3.48 |  | 5.97 |  | 8.35 |  | 7.55 |  | 27.94 |  |

Remarks: SL, stem length; ST, stem diameter; LB, length of leaf blade; WB, width of leaf blade; PE, panicle exertion; DF, degree of freedom. \*, \*\* represent significance at P < 0.05 and P < 0.01, respectively

Table 4. Morphological characters under normal and stagnant flooding (SF) condition

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Genotype | Stem length (cm) | | | | | | Stem diameter (mm) | | | | | Length of leaf blade (cm) | | | | | Width of leaf blade (cm) | | | Panicle exertion (cm) | | | |
| Normal | | SF | | SF/N (%) | Mean | Normal | | SF | | SF/N (%) | Normal | | SF | SF/N (%) | Mean | Normal | SF | SF/N (%) | Normal | SF | | SF/N (%) |
| INPARA 3 | 85 | b | 101 | b | 119 | 93 | 5.2 | bc | 6.8 | a | 129.9 | 45.1 | bc | 48.5 | 107.6 | 46.8 | 1.4 | 1.4 | 100.0 | 3.3 | 3.5 | cd | 105.7 |
| INPARA 7 | 81 | bc | 95 | c | 117 | 88 | 5.1 | c | 5.8 | b | 114.3 | 41.6 | cd | 43.4 | 104.5 | 42.5 | 1.3 | 1.3 | 104.0 | 2.8 | 3.0 | d | 105.7 |
| IRRI 119 | 92 | a | 107 | a | 117 | 100 | 5.9 | a | 6.6 | a | 111.7 | 49.7 | a | 50.2 | 101.0 | 50.0 | 1.5 | 1.5 | 101.4 | 4.1 | 7.9 | a | 194.3 |
| INPARA 5 | 77 | cd | 89 | d | 116 | 83 | 5.2 | bc | 5.7 | b | 110.0 | 40.7 | de | 40.9 | 100.4 | 40.8 | 1.3 | 1.3 | 104.7 | 2.8 | 5.6 | b | 198.9 |
| INPARI 30 | 82 | bc | 98 | bc | 120 | 90 | 5.0 | c | 6.3 | ab | 125.5 | 34.6 | f | 42.1 | 121.6 | 38.3 | 1.3 | 1.4 | 104.6 | 3.0 | 3.8 | cd | 126.2 |
| IR 64 | 74 | d | 88 | d | 119 | 81 | 4.8 | c | 5.8 | b | 121.2 | 34.3 | f | 43.1 | 125.5 | 38.7 | 1.4 | 1.3 | 98.5 | 2.5 | 4.5 | bcd | 183.7 |
| IR 42 | 82 | bc | 96 | c | 117 | 89 | 5.8 | ab | 6.5 | a | 112.1 | 36.6 | ef | 47.4 | 129.6 | 42.0 | 1.3 | 1.4 | 109.6 | 2.6 | -1.9 | e | -74.2 |
| Ciherang | 81 | bc | 99 | bc | 122 | 90 | 5.4 | abc | 6.3 | ab | 117.0 | 36.1 | f | 44.9 | 124.5 | 40.5 | 1.4 | 1.4 | 100.7 | 3.0 | 5.2 | bc | 170.6 |
| INPARI 29 | 82 | bc | 98 | bc | 119 | 90 | 5.4 | abc | 6.6 | a | 122.6 | 47.2 | ab | 48.8 | 103.3 | 48.0 | 1.4 | 1.4 | 100.7 | 1.7 | 3.0 | d | 174.7 |
| Mean | 82 |  | 97 |  | 118 |  | 5.3 |  | 6.3 |  | 118.1 | 40.7 |  | 45.5 | 111.9 |  | 1.3 | 1.4 | 102.6 | 2.9 | 3.8 |  | 0.000 |

Remarks: Different letter in same column indicate statistical significant (P<0.05)

Table 5. Stagnant flooding response indices of rice genotypes

| Genotype | STI | SSI | TOL | REI | SSSI | MRP |
| --- | --- | --- | --- | --- | --- | --- |
| INPARA 3 | 0.58 | 1.40 | 2.37 | 0.79 | 0.11 | 1.78 |
| INPARA 7 | 0.82 | 0.95 | 1.81 | 1.12 | -0.01 | 2.12 |
| IRRI 119 | 0.76 | 0.96 | 1.79 | 1.04 | -0.01 | 2.03 |
| INPARA 4 | 0.77 | 0.79 | 1.39 | 1.05 | -0.06 | 2.05 |
| INPARA 5 | 0.62 | 0.84 | 1.38 | 0.85 | -0.04 | 1.84 |
| INPARI 30 | 0.88 | 0.84 | 1.56 | 1.21 | -0.04 | 2.20 |
| IR 64 | 0.95 | 1.02 | 2.08 | 1.30 | 0.01 | 2.28 |
| IR 42 | 0.50 | 0.73 | 1.03 | 0.68 | -0.07 | 1.65 |
| Ciherang | 0.90 | 0.71 | 1.37 | 1.24 | -0.08 | 2.22 |
| INPARI 29 | 0.60 | 1.49 | 2.64 | 0.82 | 0.13 | 1.82 |

Remarks: STI = Stress Tolerance Index; SSI = Stress Susceptibility Index; TOL = Stress Tolerance; REI = Relative Efficiency Index; SSSI = Stress Susceptibility Index; MRP = Mean Relative Performance

Table 6. Correlation coefficient among stress index of rice

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | SSI | TOL | REI | SSSI | MRP |
| STI | -0.3347 | -0.0433 | 0.9999\*\* | -0.3330 | 0.9990\*\* |
| SSI |  | 0.9532\*\* | -0.3377 | 0.9993\*\* | -0.3170 |
| TOL |  |  | -0.0468 | 0.9533\*\* | -0.0251 |
| REI |  |  |  | -0.3360 | 0.9989\*\* |
| SSSI |  |  |  |  | -0.3159 |

Table 7. Standardized stress tolerance index of rice

| Genotype | STIStd-ssi | STIStd-tol | STIStd-sssi |
| --- | --- | --- | --- |
| INPARA 3 | -2.61 | -2.27 | -2.61 |
| INPARA 7 | 0.61 | 0.39 | 0.61 |
| IRRI 119 | 0.19 | 0.05 | 0.19 |
| INPARA 4 | 0.87 | 0.89 | 0.87 |
| INPARA 5 | -0.25 | -0.03 | -0.25 |
| INPARI 30 | 1.42 | 1.27 | 1.42 |
| IR 64 | 1.20 | 0.70 | 1.20 |
| IR 42 | -0.63 | -0.12 | -0.63 |
| Ciherang | 2.03 | 1.81 | 2.03 |
| INPARI 29 | -2.83 | -2.69 | -2.83 |

Remarks: STIStd-ssi, STIStd-tol, STIStd-sssi = standardized STI corrected by standardized SSI, TOL, dan SSSI, respectively

Table 8. Parameter estimates of linear regression of rice

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Estimate | Std. Error | t value | Pr(>|t|) |
| Intercept | -0.371 | 0.138 | -2.690 | 0.028 |
| Grain yield | 0.235 | 0.029 | 8.090 | 0.000 |

Table 9. Analysis of variance of linear regression of rice

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Source | DF | Sum of Square | Mean Square | F Value | Pr(> F) | Adj R2 |
| Model | 1 | 0.1952 | 0.1952 | 65.5 | 0.000 | 0.8776 |
| Error | 8 | 0.0238 | 0.003 |  |  |  |
| Total | 9 | 0.219 |  |  |  |  |

Table 10. Descriptive statistic and correlation of STI

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variable | Min | Max | Mean | Stdv | r coefficient | p value |
| STI actual | 0.50 | 0.95 | 0.74 | 0.1543 | 0.9567 | 0.00000 |
| STI predictive | 0.81 | 1.25 | 1.05 | 0.1477 |  |  |

Table 11. Analysis of variance of multiple linear regression of rice

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Source | DF | Sum of Square | Mean Square | F Value | Pr(> F) | Adj R2 |
| Model | 5 | 0.212 | 0.042 | 22.64 | 0.005 | 0.923 |
| Error | 4 | 0.008 | 0.002 |  |  |  |
| Total | 9 | 0.219 |  |  |  |  |

Table 12. Parameter estimates of multiple linear regression of rice

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Estimate | Std. Error | t value | Pr(>|t|) |
| Intercept | -3.17 | 0.791 | -4.01 | 0.016 |
| 1000 grain weight | 0.08 | 0.016 | 5.08 | 0.007 |
| Panicle length | -0.14 | 0.017 | -8.06 | 0.001 |
| Stem diameter | -0.56 | 0.094 | -5.94 | 0.004 |
| Intensity of leaf green color | 0.11 | 0.017 | 6.23 | 0.003 |
| Stem length | 0.04 | 0.008 | 5.10 | 0.007 |

Table 13. Correlation among traits of rice genotypes under stagnant flooding stress (plot-basis)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Traits | PT | FG | W1000 | GY | SPAD | SL | SD | LB | WB | PE | PL | STI |
| PH | -0.347 | 0.023 | 0.356\* | -0.193 | -0.070 | 0.850\*\* | 0.584\*\* | 0.569\*\* | 0.107 | 0.196 | 0.516\*\* | -0.130 |
| PT |  | -0.330 | -0.314 | 0.368\* | 0.108 | -0.469\*\* | -0.305 | -0.304 | -0.011 | -0.262 | -0.294 | 0.178 |
| FG |  |  | -0.014 | 0.077 | -0.197 | 0.082 | 0.064 | -0.044 | 0.052 | 0.346 | -0.033 | -0.032 |
| W1000 |  |  |  | -0.026 | -0.211 | 0.416\* | 0.263 | 0.112 | 0.315 | 0.399\* | 0.569\*\* | 0.151 |
| GY |  |  |  |  | -0.102 | -0.204 | -0.394\* | -0.326 | 0.035 | 0.225 | -0.277 | 0.866\*\* |
| SPAD |  |  |  |  |  | -0.117 | -0.293 | -0.243 | -0.207 | -0.264 | 0.014 | -0.043 |
| SL |  |  |  |  |  |  | 0.578\*\* | 0.662\*\* | 0.348 | 0.322 | 0.535\*\* | -0.129 |
| SD |  |  |  |  |  |  |  | 0.467\*\* | 0.214 | -0.030 | 0.183 | -0.332 |
| LB |  |  |  |  |  |  |  |  | 0.422\* | 0.125 | 0.436\* | -0.250 |
| WB |  |  |  |  |  |  |  |  |  | 0.048 | 0.313 | 0.080 |
| PE |  |  |  |  |  |  |  |  |  |  | 0.351 | 0.291 |
| PL |  |  |  |  |  |  |  |  |  |  |  | -0.099 |

Remarks: PH, plant height; PT, number of productive tiller; FG, number of filled grain; W1000, weight of 1000 grains; GY, grain yield; SL, stem length; SD, stem diameter; LB, length of leaf blade; WB, width of leaf blade; PE, panicle exertion; PL, panicle length; STI, Stress Tolerance Index

Table 14. Genetic and phenotypic variability of rice traits under stagnant flooding stress in dry season of 2015

| Traits | Stagnant Flooding Stress | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
|  | Criteria |  | Criteria | H | Criteria |
| Plant height | 55.16 ± 25.43 | B | 59.54 ± 1.39 | B | 0.93 | H |
| Intensity of leaf green color | 2.28 ± 0.99 | B | 2.32 ± 0.01 | B | 0.98 | H |
| Number of Productive tillers | 4.99 ± 3.31 | N | 7.27 ± 0.80 | B | 0.66 | H |
| Number of filled grain | 64.14 ± 69.30 | N | 171.60 ± 0.80 | B | 0.43 | M |
| Weight of 1000 grain | 0.97 ± 1.36 | N | 3.53 ± 0.60 | B | 0.34 | M |
| Grain yield | 0.30 ± 0.17 | N | 0.36 ± 0.60 | B | 0.77 | H |
| Stem length | 33.93 ± 15.92 | B | 32.08 ± 1.05 | B | 0.91 | H |
| Stem diameter | 0.09 ± 0.06 | N | 0.12 ± 1.05 | B | 0.68 | H |
| Length of leaf blade | 7.26 ± 6.05 | N | 14.14 ± 1.95 | B | 0.54 | M |
| Width of leaf blade | 0.00 ± 0.00 | N | 0.01 ± 1.95 | B | -0.86 | N |
| Panicle exertion | 7.31 ± 3.28 | B | 6.59 ± 0.12 | B | 0.95 | H |
| Panicle length | 2.27 ± 1.05 | B | 2.46 ± 0.06 | B | 0.93 | H |

Remarks: is genotypic variance and its standard deviation; is phenotypic variance and its standard deviation; h2 is heritability; B = broad; N = narrow; H = high; M = medium; L=low