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# Evaluation of Agronomic and Resistance Characters to the Main Diseases of Rice Nuclear Collection of Highlands in Tocantins State

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**Abstract:** Rice has low productivity in Tocantins due to the low genetic potential of the varieties and high susceptibility to diseases. Therefore, the objective of this study was to evaluate a rice nuclear collection of highlands in relation to its agronomic and resistance characters to the main diseases in the south of Tocantins State. It was used the randomized blocks design with ninety treatments (genotypes) and three repetitions under highlands conditions in southern Tocantins. The following agronomic characters were evaluated: average flowering, height and productivity of the plants. The evaluated diseases were: leaf and panicle blast, brown spot, leaf scald and grain spots. The Scott-Knott test showed high variability in productivity and in resistance to the diseases. The Tocher Method grouped the 90 genotypes, according to the diseases and productivity, in 10 different groups. These results indicate the existence of significant genetic variability for these characters in the genotypes.

**Keywords**: Oryza sativa, Magnaporthe grisea, Cochliobolus miyabeanus, Monographella albescens

**RESUMO: CARACTERES AGRONÔMICOS E RESISTÊNCIA ÀS DOENÇAS DE GENÓTIPOS DE ARROZ DE TERRAS ALTAS NO ESTADO DO TOCANTINS**

O arroz cultivado em terras altas no Tocantins apresenta baixa produtividade, devido ao baixo potencial genético das variedades e alta suscetibilidade às doenças. O objetivo deste trabalho foi avaliar genótipos de arroz de terras altas quanto aos caracteres agronômicos e de resistência às principais doenças no Sul do estado do Tocantins. O delineamento utilizado foi o de blocos casualizados, com noventa tratamentos (genótipos) e três repetições em condições de terras altas. Avaliaram-se os seguintes caracteres agronômicos: floração média, altura das plantas e produtividade. As doenças avaliadas foram: brusone das folhas e panículas, mancha-parda, escaldadura das folhas e mancha dos grãos. O teste de Scott-Knott mostrou alta variabilidade na produtividade e na resistência às doenças. O Método de Tocher agrupou os 90 genótipos, de acordo com as doenças e produtividade, em 10 grupos distintos. Estes resultados indicam a existência de variabilidade genética significativa para estes caracteres nos genótipos.

**Palavras-chave:** Oryza sativa, Magnaporthe grisea, Cochliobolus miyabeanus, Monographella albescens

## 1. INTRODUCTION

Planted and consumed in all continents, rice (*Oryza sativa* L.) stands out for its production and growing area, playing a strategic role in both economic and social aspects. In the State of Tocantins, during the agricultural harvest of 2007/2008, around 53 thousand irrigated hectares of rice were planted with an average yield of 4.481 kg/ha, while the rice planted in highlands system had 107 thousand ha of planted area and the productivity reached only 1.828 kg/ha (CONAB, 2009).

That low productivity of highlands rice is mainly associated to the planting of cultivars with a narrow genetic base and the planting of extensive areas. The increase of the genetic base of the rice cultivars of Brazil has been proposed as a strategy to break through, in a medium and long term, the present productivity baseline. One of the alternatives for this is to use the diversity to the germplasm collection, especially, among the traditional varieties, which have been little used in genetic improvement (ABADIE et al., 2005).According to Rangel et al. (1994), under the conditions of Tocantins, with high humidity and temperature,

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the rice crops are subjected to a greater pressure from diseases and pests. Nowadays, in the highlands system, the varieties Maravilha, Primavera and Curinga are among the most planted ones, although their main limitation is their susceptibility to diseases. The scarcity of cultivars is a limiting factor for the cultivation of rice in the State of Tocantins (SANTOS et al., 2002).The blast, whose causal agent is *Magnaporthe grisea* (T.T. Hebert) M.E. Barr (=*Pyricularia grisea* (Cooke) Sacc.), is the most significant rice disease in Brazil and in the world, causing large losses in the yield of the susceptible varieties. Although this disease occurs in the whole Brazilian territory, the losses are variable, being greater with highlands rice in the Central-West Region and in the State of Tocantins (PRABHU et al., 2002).

The high incidence of the blast and the frequent summery periods during some seasons of the year contribute to the low productivity of the highlands rice (PRABHU et al., 2002). In rainy years, the stain of the grains, caused by a complex of fungi, principally formed by *Drechslera, Rhynchosporium, Alternaria, Nigrospora, Pyricularia* and *Phoma*, has caused great concern due to of the losses inflicted on the rice crops of several Brazilian States, such as Goias (COSTA, 1991), Mato Grosso (SOUZA, 1993) and Tocantins (SANTOS et al., 1994). The brown spot and the leaf scald caused by the fungi *Cochliobolus miyabeanus* (S. Ito & Kurib.) Drechsler ex Dastur and *Monographella albescens* (Thüm.) V.O. Parkinson, Sivan. & C. Booth, respectively, are secondary importance diseases in Tocantins state and only in favorable climatic conditions to their dissemination (excessive rainfall and high temperature) they can cause significant damages (SANTOS et al., 2005). Given these facts, the present work was done with the objective of evaluating a germplasm collection of highlands rice in relation to its agronomic and resistance characters to the major diseases in the south of Tocantins State.

## 2. MATERIAL AND METHODS

The experiment was conducted in the agricultural year of 2007/2008, in an experimental area of the Support Base to Agricultural Research and Development, located in the southern region of Tocantins state, in the municipality of Formoso do Araguaia. The evaluated genotypes consisted from strains and cultivars constituents of a nuclear collection, transferred by Embrapa Arroz e Feijão. The soil of the experimental area was classified as Dystrophic Yellow Red Typic ( DYRT), according to Embrapa (2006).

The results of the soil analysis of samples collected at the depth of 0-20 cm revealed the following values: 4.9 pH ($CaCl_2$); 0.20 $cmol_c.dm^{-3}$ of Al; 5.92 $cmol_c.dm^{-3}$ of H+Al; 2.05 $cmol_c.dm^{-3}$ of Ca+Mg; 0.26 $cmol_c.dm^{-3}$ K; 15.8 $mg.dm^{-3}$ of P; 2.51 $cmol_c.dm^{-3}$ of CTC; 2.3 $g.dm^{-3}$ of M.O. and 28.10 of saturation by bases, according to the method used by Embrapa (1997). During the experimental period, the following climatic variables were daily monitored: Rainfall in mm (PPT), Highest temperature in °C (Tmax), Lowest temperature in °C (Tmin) and Relative Humidity (UR%).

The experimental design used was the one with randomized blocks with ninety treatments (Table 1) and three repetitions. Each experimental plot was represented by four rows of 5 meters in length and with spacing of 0.3 m between the rows. The density of the sowing was 80 seeds $m^{-1.}$ The crop fertilization was done in the furrow with 12, 90, 48 and 20 $kg.ha^{-1}$ of N, $P_2O_5$, $K_2O$ and zinc sulfate respectively. After 45 days of cropping (DAC), a coverage with 40 $kg.ha^{-1}$ of N was made. The Weed control was made with oxadiazon at a dosage of 1000g $i.a.ha^{-1}$, in pre-emergence, and after 40, DAC, a manual weeding was done.

The agronomic evaluations were done according to the recommendations of the International Center of Tropical Agriculture (IRRI, 1996). The number of days from the sowing to the flowering was taken into account, with 50% of the panicles opened, to determine the flowering period. The height of the plants was obtained in the soft dough stage, measuring the length of the flag leaf. The productivity of each treatment was determined by the collect and the weighing of the grains of the two central rows of each plot (2.0 m²) and the results were transformed into kilograms per hectare ($Kg.ha^{-1}$).

In relation to the diseases, an evaluation of the severity of the leaf blast was made initially at 50 DAC. The evaluations of the severity of the leaf scald, brown spot and grain spot as well as the incidence of the panicle blast were made 10 days before the harvest to avoid the contamination by saprophytic organisms. For the severity of the leaf scald and brown spot, the following grading scale was used (IRRI, 1996): 0 = without symptoms of the disease; 1 = < 1% of sick tissue; 3 = 1 to 5% of sick tissue; 5 = 6 to 25% of sick tissue; 7 = 26 to 50% of sick tissue; 9 = more than 50% of sick tissue. For the grain spot, in the laboratory, around 500 seeds per plot, after having been threshed from the panicles, were used in the quantification of the severity, according to the following grading scale (SANTOS et al., 2000): 0 = healthy grain; 1 = points of the size of a pin head; 2 = well defined spots with 25 to 50% of the grain surface stained; 3 = 51 to 75% of the surface stained; and 4 = 76 to 100% of the surface sick. A total of 100 tillers per plot were sampled for the incidence evaluation of panicle blast. The result was obtained by calculating the ratio of the damaged panicles over the total of evaluated panicles.

The obtained data, except flowering and height of the plants, were submitted to a variance analysis. The Scott-Knott test of grouping the averages for all characteristics was made (SCOTT and KNOTT, 1974). Afterwards a multivariate analysis was performed for the separation of the genotypes by the Tocher Method (RAO, 1952), based on the generalized distance D2 of Mahalanobis. The relative contribution of each variable in the determination of the genetic dissimilarity was detected through the methodology proposed by Singh (1981). All the statistical analysis were made with the use of the computer program Genes (CRUZ, 2006).

## 3. RESULTS AND DISCUSSION

The results obtained by the test of grouping of averages of Scott-Knott, for the six studied characteristics, showed that there is high variability in the resistance to leaf blast, leaf scald, brown spot, grain spot and panicle blast. None of the genotypes showed immunity to those diseases (Table 2).

The height of the plants varied from 0.78 m to 1.48 m and the period of flowering from 68 to 145 days. From these data it can be deduced that, probably, under planting normal conditions in commercial areas, there would be difficulties to perform the cultivating methods for those genotypes with stature above 1.0 m; apart from that, these areas where the leading of the crop is less controlled, the plants can be more subjected to higher nitrogen dosages and dense spacing . These conditions result in higher growth and lesser stem diameter of the plants, which, associated to strong winds provokes the flattening of the crop. This way the flattened plants complicate the mechanized harvesting, since the platform of the combine does not reach the panicles of flattened stems. Presently, the improvement programs have preference for plants with height of around 0.9 m in order to avoid such situations, which result in losses to the rice growers. In relation to the cycle, plants with flowering over 100 days should be avoided in our conditions, because they get more exposed to the frequent summery periods.

In the evaluation of the diseases, in relation to the severity of the leaf blast, five groups were formed by the grouping test of the averages of Scott-Knott, represented by the letters “a” to “e” in the columns. It was also observed that 80% of the genotypes obtained severity grades above 3.0, being considered susceptible (Table 2).However, in the culture of irrigated rice and studying other genotypes, different results were obtained by Santos et al. (2000, 2002, 2005), where they verified resistance in more than 80% of the genotypes evaluated in experimental conditions. It is known that the climatic conditions influence directly the level of severity of the leaf blast and other diseases. The climatic variables showed that the rainfall average was 7.4 mm, the temperature ranged from 20°C to 35°C and 90% of relative humidity, which were very favorable to the occurrence of all evaluated diseases. Besides, in the region of Formoso do Araguaia, TO, may have occurred an increase in the prevalence of varieties of blast. In this study, a large number of genotypes were planted, the majority susceptible to diseases and descending from similar parents. In agreement with Montalban et al. (1998), in Brazil the genetic base of highland rice is narrow, where 81% of the gene pool of the cultivars liberated during the period of 1971-1993 were descendants of only eleven ancestors. According to Santos et al. (2005), even with the resistance being conditioned by one or two dominant genes, the obtaining of resistant cultivars is hampered for a long time due to the *M. grisea* fungus be highly variable and the existence of numerous physiological varieties of the pathogen. The prevalent breeds in a given region are in function, principally, of the cultivar planted and the handling of the culture allied to the climatic conditions favorable to the pathogen (Ou, 1985). In this case, the high level of susceptibility between the genotypes can be influenced by the existence of specific breeds in the infection of the plants. It also must be considered that the availability of inoculum of the neighboring crops may have favored in a significant way the development of these diseases.In relation to the leaf scald most of the genotypes presented severity grades higher than 3.0, being considered as susceptible. The high humidity and the rainfall during the flowering period of most of the genotypes certainly favored the incidence of the disease. According to comments made by Ou (1985) and Groth (1992), those observed climatic conditions are favorable to the development of the leaves scald. Using the grouping of the averages by the Scott and Knott (1974) test, two distinct groups were formed, considering the severity of the disease (Table 2). A similar result was obtained by Araujo et al. (2001), studying the resistance of somaclones of the rice IAC 47 cultivar the *M. albescens*.

The difference between the genotypes in relation to the brown spot severity of the leaves was significant (Table 2). Most of those genotypes (72.3%) were susceptible to that disease, agreeing with the results, which were obtained by Santos et al. (2002, 2005). The emphasized severity is justified by the climatic conditions, which occurred during the period of this study. Humidity over 93%, and wetting of the leaves by the rain or by prolonged periods of dew, are very favorable conditions for its occurrence. Besides, the combination of the climatic factor with the availability of inoculum of the neighboring crops favored in a significant way the development of the brown spot.We could observe that occurred a high severity level of the grain stain in the evaluated genotypes. By the grouping test of averages of Scott-Knott, the formation of five groups appeared, where group A was formed only by the Pindare and Samambaia rice genotypes (70 and 33), which had grain damage over than 76% of the affected tissue. Generally, the more productive genotypes showed moderate resistance to the grain stain, while the most susceptible ones to that disease (70 and 33), had low productivity. Such results evidence that the grain stain can affect the productivity of rice. Similar results were obtained by Santos et al. (2005), when low productivity and high incidence of grain stain in the lineage of irrigated rice CNAi 9097 was also observed. These authors also commented that the disease affected the quality of the grains.

Regarding the incidence of blast on the panicles, the formation of eight groups of genotypes was verified (Table 2).Where group A was represented only by the Arroz Ligeiro genotype (53) with average incidence on 30% of the panicles and productivity around 400 $kg.ha^{-1}$. This high incidence of blast on the panicles affected directly the productivity of the majority of the studied genotypes. When it occurs in the period of filling of the grains this disease provokes the obstruction of the local vessels, impeding the translocation of carbohydrates, provoking the symptom of “soft grain” (SANTOS et al., 2005). The lowest incidences were on the Cacho Duplo, Brejeiro, Iguape Sem Arista and Pindare Rice genotypes (21, 25, 30, 70), respectively. The Brejeiro, Iguape Sem Arista and Pindare Rice genotypes (25, 30, and 70), also had low productivity, besides the susceptibility to leaf scald, those genotypes showed low resistance to leaf blast. This disease attacks the rice culture from the phase of the seedling to the harvest, causing direct and indirect damages. According to Prabhu et al. (1986), the leaf blast during the vegetative phase causes a reduction in the number of grains per panicle and grain weight. In this phase it can also cause indirect effects such as: reduction of the rate of photosynthesis and respiration (Sun et al., 1986; Bastiaans et al., 1994).

In relation to productivity, there was the formation of nine statistical groups among the genotypes. The highest productivity rates were found in the Pico Negro, BRA032033, Amarelo Ligeiro and BRS Primavera genotypes (63, 90, 10 and 82, respectively) with the majority of these genotypes showing the lowest levels of this disease in relation to the others. The Rice Agulinha and Agulinha Ipameri genotypes (65 and 74, respectively) had the lowest productivity, reaching a reduction of approximately 95% in relation to the most productive. One factor, which must have been limiting for the genotype to reach lower productivity, was that the flowering period of both passed 138 days and, according to picture number 1, the absence of rainfall during this period was noted. The lack of water during the filling period of the grains decreased substantially the translocation of photoassimilates in the plant, which can provoke a strong reduction of productivity. According to Venuprasad et al. (2007), under the hydrous stress condition there is a significant reduction in the productivity of rice. The low productivity is verified in the most of the genotypes with flowering periods over 120 days, showing that the water shortage is determinant for a lower productivity when associated to a high pressure of diseases.

The use of the optimization method of Tocher, based on the dissimilarity, expressed by the distances of Mahalalobis permitted the distribution of the 90 genotypes in 10 distinct groups (Table 3). In the present study, the characters that contributed most to the genetic diversity (Table 4) were the productivity (51.96%), the incidence of blast on the panicles (25.46%), the severity of blast on the leaves (9.33%) and the grain stain (7.09%). These results indicate the existence of significant genetic variability for these characters in the evaluated genotypes. Although the genotypes did not present resistance to diseases, additional studies indicated that breeding programs of rice have resulted in broad-based rice genotypes (BRONDANI et al., 2006; MELO et al., 2005). The variables that least contributed to the genetic divergence detected in these genotypes were the severity of leaf scald (2.17%) and the brown spot (3.97%).

The relative importance of the characters was also evaluated attempting to identify possible dispensable features. According to Cruz (2006) the great interest in the evaluation of the relative importance of the characters resides in the possibility of discarding features, which contribute little for the discrimination of the evaluated material, reducing, this way, labor, time and expensive costs in the experimentation. According to Cruz et al. (2004), the dispensable characters in the study of genetic divergence include the ones that are relatively non-variants between the studied individuals, besides presenting instability with the change of the environmental conditions. The obtained results may infer that of all evaluated genotypes there was no genetic variability so that no source of resistance to scald and brown spot was verified.

Under normal conditions they are diseases of secondary importance in Brazil and only in favorable conditions (excessive rain and high temperatures) they can cause damages (SANTOS et al., 2005). The relative contribution to the genetic divergence of the scald and of the brown spot was low when compared to the other studied characteristics. However, it must be considered that in the region of Formoso do Araguaia, factors, which favor the development of these diseases are constant in the harvest period, which can cause great losses to the producers. Characters of severity of leaf scald and brown spot are important in studies of genetic divergence of rice in the State of Tocantins.

The low productivity found in all genotypes evaluated in the present study can be attributed to two main factors, which can be limiting: hydrous stress and the high incidence and severity of diseases. The most productive genotypes were those, which had flowering period between 80 and 90 DAP and the least productive around 120 DAP. From the 112 DAP on there was scarcity of water in the soil which inhibited the translocation of water and nutrients for the filling of the grains. The more precocious genotypes were less injured. Associated to strong pressure of diseases at the location, most of the genotypes produced far below the average of the region. Thus, it is important that the genetic improvement programs prioritize the search for new sources of resistance to the hydrous stress as well as to those diseases, concluding from the present study, that these were the most limiting factors for the development of the studied genotypes in the highland cultivation system.

## 4. CONCLUSIONS

1. Using the optimization method of Tocher, based on dissimilarity, expressed by the Mahalanobis distances enabled the distribuition of 90 genotypes into 10 distinct groups.
2. The characters that contributed most to the genetic diversity in descending order were productivity, incidence of panicle blast, leaf blast severity and stains of the grains.

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Table 1. Identification of highland rice genotypes, components of the Germplasm Bank (B.G. Code) of the nuclear collection of Embrapa Rice and Beans

| TN* | Common Name | B.G. Code | TN* | Common Name | B.G. Code |
|---|---|---|---|---|---|
| 1 | cateto seda | CA780044 | 46 | 4 meses antigo | CA870109 |
| 2 | maruim | CA780059 | 47 | noventinha | CA870139 |
| 3 | cajueiro liso | CA780158 | 48 | carolina | CA870152 |
| 4 | enche tulha | CA780033 | 49 | arroz do maranhão | CA870175 |
| 5 | formosa | CA780170 | 50 | arroz roxo ou caqui | CA870177 |
| 6 | arroz maranhão | CA780202 | 51 | legitino | CA880010 |
| 7 | paulista dourado | CA780287 | 52 | bico ganga cana roxa | CA880053 |
| 8 | maruim ligeiro | CA780299 | 53 | arroz ligeiro | CNA0005659 |
| 9 | maranhão verdadeiro | CA780301 | 54 | arroz piriquito | CA880093 |
| 10 | amarelo ligeiro | CA780308 | 55 | arroz santa inês | CA870064 |
| 11 | puteca | CA780217 | 56 | catetão | CA880081 |
| 12 | comum creolo | CA780329 | 57 | arroz canela de ferro | CA980023 |
| 13 | pratão goiano | CA780336 | 58 | agulha esav | CNA0000027 |
| 14 | prata branco | CA780261 | 59 | catalão | CNA0000937 |
| 15 | palha murcha | CA790032 | 60 | carreon | CNA0001420 |
| 16 | cano roxo | CA780281 | 61 | makouta | CNA0004487 |
| 17 | chatão vermelho | CA790282 | 62 | beira campo dourado | CNA0005667 |
| 18 | ligeiro | CA790301 | 63 | pico negro | CNA0004623 |
| 19 | santo américo | CA780295 | 64 | douradão | CA800015 |
| 20 | vermelho | CA790328 | 65 | arroz agulhinha | CA800178 |
| 21 | cacho duplo | CA780324 | 66 | arroz comprido | CA870068 |
| 22 | nenén | CA790346 | 67 | japones | CA940003 |
| 23 | amarelão douradão | CA800068 | 68 | agulhinha vermelho | CA970012 |
| 24 | brejeiro nenezinho | CA800081 | 69 | arroz toro graudo | CA980005 |
| 25 | brejeiro | CA800082 | 70 | arroz pindaré | CA980029 |
| 26 | quebra cacho | CA800091 | 71 | rexoro | CNA0002878 |
| 27 | bico de rola | CA800127 | 72 | 64 dias | CNA0003275 |

| | | | | | |
|---|---|---|---|---|---|
| 28 | muruim branco | CA790337 | 73 | piedad | CNA0004510 |
| 29 | douradão/ amarelão | CA800020 | 74 | agulhinha ipameri | CNA0008429 |
| 30 | iguapé sem arista | CA800034 | 75 | araçatuba | CA780357 |
| 31 | vermelhão | CA800150 | 76 | buriti vermelho | CA790176 |
| 32 | samambaia amarela | CA810050 | 77 | brs curinga | CNA8812 |
| 33 | samambaia | CA810038 | 78 | brs pepita | CNA9019 |
| 34 | paulista | CA820069 | 79 | brs monarca | CNA9045 |
| 35 | arroz carolino | CA820103 | 80 | brs sertaneja | CNA11163 |
| 36 | arroz catetão | CA830133 | 81 | bico ganga curto | CA860127 |
| 37 | gergelim | CA840023 | 82 | BRS primavera | CNA8070 |
| 38 | arroz do sul | CA840049 | 83 | chorinho | CNA800100 |
| 39 | arroz branco bico preto | CA860089 | 84 | BRA02601 | BRA02601 |
| 40 | branco 4 meses | CA870050 | 85 | BRA01506 | BRA01506 |
| 41 | arroz cabeludo | CA840058 | 86 | BRA02535 | BRA02535 |
| 42 | carioca/ rabo de carneiro | CA870056 | 87 | BRA042156 | BRA042156 |
| 43 | caiapo | CNA 6187 | 88 | BRA042160 | BRA042160 |
| 44 | meses branco /3 meses | CA870078 | 89 | BRA032051 | BRA032051 |
| 45 | branquinho | CA870092 | 90 | BRA032033 | BRA032033 |

* Treatment number.

Table 2. Averages of the number of days for the flowering (NDF), height of the plants (AP), leaf blast (BF), scald (ESCAL), brown spot (MP), grain stain (MG), panicle blast (BP) and productivity (PROD) in $kg.ha^{-1}$ in the 2007/2008 crop in Formoso do Araguaia-TO

| Treatment Number | NDF | AP | BF* | ESCAL* | MP* | MG* | BP* | PROD* |
|---|---|---|---|---|---|---|---|---|
| 63 | 83 | 104 | 5,0 c | 6,3 b | 5,6 c | 3,0 c | 12,0 e | 2006,6 a |
| 90 | 84 | 90 | 1,0 e | 5,0 b | 3,0 d | 1,0 e | 7,3 g | 1923,3 a |
| 10 | 80 | 100 | 5,6 c | 6,3 b | 4,3 d | 1,3 e | 16,6 c | 1616,6 b |
| 82 | 95 | 110 | 3,0 d | 5,0 b | 3,0 d | 2,0 d | 16,6 c | 1592,0 b |
| 72 | 68 | 90 | 5,0 c | 7,6 a | 4,3 d | 2,3 d | 19,3 b | 1442,0 c |
| 78 | 88 | 98 | 1,0 e | 4,3 b | 5,0 c | 2,0 d | 11,3 e | 1411,3 c |
| 84 | 83 | 78 | 1,0 e | 6,3 b | 3,0 d | 1,0 e | 8,6 f | 1395,3 c |
| 35 | 75 | 95 | 5,0 c | 5,6 b | 5,0 c | 2,3 d | 8,0 f | 1375,3 c |
| 87 | 95 | 99 | 1,0 e | 7,0 a | 5,0 c | 1,0 e | 9,3 f | 1283,3 c |
| 89 | 96 | 98 | 3,0 d | 6,3 b | 3,0 d | 1,6 d | 13,3 d | 1257,6 c |
| 13 | 80 | 112 | 4,3 c | 6,3 b | 4,3 d | 2,3 d | 19,3 b | 1220,0 d |
| 85 | 94 | 99 | 1,0 e | 4,3 b | 3,0 d | 1,3 e | 11,3 e | 1204,3 d |
| 21 | 79 | 108 | 4,3 c | 7,6 a | 7,0 b | 2,0 d | 3,0 h | 1192,3 d |
| 46 | 99 | 111 | 3,6 d | 7,0 a | 3,6 d | 2,0 d | 12,0 e | 1148,6 d |
| 51 | 108 | 112 | 3,6 d | 5,6 b | 3,6 d | 2,0 d | 4,0 h | 1032,0 e |
| 60 | 128 | 120 | 3,0 d | 5,6 b | 3,6 d | 2,6 c | 4,6 h | 1025,3 e |
| 42 | 95 | 110 | 7,6 a | 6,3 b | 3,0 d | 3,3 b | 8,0 f | 1019,6 e |
| 47 | 99 | 111 | 7,6 a | 5,6 b | 4,3 d | 1,6 d | 8,6 f | 1002,0 e |
| 83 | 118 | 122 | 5,0 c | 7,0 a | 3,0 d | 2,3 d | 8,0 f | 985,6 e |
| 71 | 125 | 115 | 7,0 b | 5,0 b | 3,6 d | 2,0 d | 5,3 h | 979,3 e |
| 5 | 100 | 83 | 5,6 c | 5,0 b | 3,0 d | 2,6 c | 7,3 g | 963,6 e |
| 49 | 109 | 112 | 3,6 d | 5,6 b | 5,6 c | 2,0 d | 4,6 h | 944,3 e |
| 39 | 98 | 111 | 4,3 c | 5,6 b | 7,0 b | 3,3 b | 6,6 g | 940,0 e |
| 77 | 95 | 90 | 3,6 d | 5,6 b | 4,3 d | 1,6 d | 5,3 h | 915,3 f |
| 43 | 89 | 100 | 1,0 e | 6,3 b | 3,0 d | 2,3 d | 8,6 f | 903,3 f |
| 40 | 108 | 115 | 5,6 c | 6,3 b | 4,3 d | 2,0 d | 4,6 h | 870,0 f |
| 45 | 77 | 99 | 4,3 c | 7,0 a | 4,3 d | 2,0 d | 11,3 e | 868,6 f |
| 55 | 85 | 88 | 5,0 c | 5,6 b | 5,0 c | 2,0 d | 12,6 e | 846,3 f |
| 26 | 115 | 148 | 3,0 d | 6,3 b | 3,6 d | 1,0 e | 8,6 f | 826,6 f |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 44 | 83 | 98 | 5,0 c | 5,6 b | 5,0 c | 1,3 e | 21,3 b | 825,6 f |
| 68 | 120 | 119 | 6,3 b | 5,6 b | 3,6 d | 2,0 d | 9,3 f | 819,0 f |
| 58 | 113 | 111 | 4,3 c | 6,3 b | 3,6 d | 2,3 d | 6,6 g | 815,3 f |
| 16 | 102 | 125 | 5,0 c | 7,0 a | 4,3 d | 2,0 d | 10,0 f | 812,0 f |
| 9 | 113 | 114 | 5,0 c | 6,3 b | 4,3 d | 2,0 d | 9,3 f | 757,6 g |
| 54 | 115 | 110 | 5,6 c | 6,3 b | 3,6 d | 2,3 d | 8,0 f | 753,0 g |
| 27 | 110 | 130 | 2,3 d | 7,0 a | 3,6 d | 2,0 d | 14,6 d | 728,6 g |
| 86 | 110 | 112 | 1,0 e | 3,0 b | 3,0 d | 1,6 d | 6,0 g | 703,3 g |
| 88 | 98 | 110 | 1,0 e | 8,3 a | 4,3 d | 1,0 e | 4,6 h | 698,0 g |
| 14 | 111 | 100 | 5,6 c | 7,6 a | 7,0 b | 2,6 c | 10,0 f | 653,3 g |
| 62 | 82 | 81 | 4,3 c | 7,6 a | 5,0 c | 2,3 d | 20,0 b | 651,0 g |
| 38 | 112 | 129 | 6,3 b | 5,6 b | 4,3 d | 2,3 d | 8,0 f | 643,3 g |
| 59 | 90 | 98 | 4,3 c | 7,6 a | 9,0 a | 1,0 e | 14,0 d | 640,6 g |
| 11 | 98 | 115 | 5,0 c | 7,6 a | 3,0 d | 2,6 c | 14,0 d | 626,6 g |
| 79 | 84 | 83 | 1,0 e | 7,0 a | 3,0d | 1,6 d | 8,0 f | 606,0 g |
| 6 | 115 | 113 | 1,0 e | 7,6 a | 3,6 d | 2,6 c | 12,0 e | 577,6 g |
| 81 | 120 | 127 | 4,3 c | 7,6 a | 3,6 d | 3,0 c | 9,3 f | 560,0 h |
| 52 | 112 | 125 | 5,6 c | 5,6 b | 3,6 d | 3,0 c | 4,6 h | 553,3 h |
| 24 | 130 | 130 | 4,3 c | 6,3 b | 3,0 d | 2,0 d | 7,3 g | 536,0 h |
| 7 | 80 | 97 | 5,6 c | 6,3 b | 3,6 d | 2,0 d | 15,3 c | 531,0 h |
| 34 | 109 | 120 | 3,6 d | 5,6 b | 3,0 d | 2,0 d | 6,6 g | 528,0 h |
| 12 | 83 | 100 | 7,0 b | 7,6 a | 6,3 c | 2,0 d | 10,0 f | 503,3 h |
| 70 | 115 | 120 | 7,6 a | 6,3 b | 5,6 c | 4,0 a | 1,0 i | 493,0 h |
| 80 | 90 | 90 | 1,0 e | 6,3 b | 3,6 d | 1,0 e | 19,3 b | 492,0 h |
| 8 | 79 | 94 | 6,3 b | 5,0 b | 5,0 c | 2,3 d | 20,0 b | 471,3 h |
| 36 | 113 | 120 | 5,0 c | 7,0 a | 3,0 d | 1,6 d | 8,6 f | 470,0 h |
| 4 | 115 | 140 | 3,0 d | 6,3 b | 3,6 d | 1,3 e | 12,6 e | 468,6 h |
| 17 | 115 | 120 | 5,6 c | 5,6 b | 3,0 d | 2,6 c | 4,6 h | 466,6 h |
| 50 | 88 | 89 | 5,6 c | 7,6 a | 9,0a | 2,0 d | 8,6 f | 453,3 h |
| 67 | 109 | 91 | 7,0 b | 6,3 b | 3,6 d | 3,3 b | 9,3 f | 448,0 h |
| 41 | 105 | 119 | 5,0 c | 6,3 b | 3,6 d | 3,3 b | 8,0 f | 424,3 h |
| 73 | 130 | 120 | 6,3 b | 6,3 b | 3,0 d | 3,0 c | 10,0 f | 422,0 h |
| 48 | 124 | 100 | 5,0 c | 6,3 b | 3,6 d | 2,0 d | 7,3 g | 420,0 h |
| 53 | 80 | 95 | 3,0 d | 7,6 a | 5,0 c | 1,3 e | 30,0 a | 419,6 h |
| 3 | 109 | 130 | 5,0 c | 5,6 b | 3,6 d | 2,6 c | 10,0 f | 398,0 h |
| 61 | 119 | 123 | 3,6 d | 8,3 a | 3,0 d | 2,0 d | 8,6 f | 395,3 h |
| 22 | 110 | 120 | 4,3 c | 7,0 a | 4,3 d | 3,0 c | 7,3 g | 380,0 i |
| 56 | 112 | 120 | 2,3 d | 5,6 b | 3,0 d | 1,0 e | 8,6 f | 355,3 i |
| 25 | 127 | 143 | 7,0 b | 6,3 b | 3,6 d | 2,0 d | 3,3 h | 350,0 i |
| 29 | 135 | 106 | 5,6 c | 5,6 b | 3,0 d | 2,0 d | 14,0 d | 343,3 i |
| 19 | 110 | 124 | 6,3 b | 6,3 b | 3,6 d | 2,6 c | 8,0 f | 342,3 i |
| 64 | 119 | 120 | 5,6 c | 7,0 a | 4,3 d | 3,3 b | 6,6 g | 340,0 i |
| 33 | 114 | 118 | 5,0 c | 7,0 a | 3,6 d | 4,0 a | 6,0 g | 334,6 i |
| 23 | 115 | 123 | 5,0 c | 7,0 a | 3,6 d | 3,0 c | 10,0 f | 315,6 i |
| 31 | 114 | 120 | 6,3 b | 5,6 b | 3,6 d | 3,0 c | 8,0 f | 306,6 i |
| 32 | 118 | 124 | 5,6 c | 6,3 b | 5,0 c | 3,3 b | 4,6 h | 272,6 i |
| 37 | 112 | 119 | 7,0 b | 7,0 a | 3,0 d | 2,3 d | 16,0 c | 244,6 i |
| 69 | 107 | 128 | 3,6 d | 7,6 a | 5,6 c | 3,3 b | 15,3 c | 241,3 i |
| 57 | 88 | 100 | 6,3 b | 7,0 a | 5,6 c | 2,0 d | 12,0 e | 238,3 i |
| 1 | 89 | 110 | 5,0 c | 6,3 b | 3,6 d | 2,0 d | 7,3 g | 219,6 j |
| 15 | 110 | 99 | 5,0 c | 7,6 a | 3,0 d | 1,3 e | 6,0 g | 192,0 j |
| 76 | 120 | 100 | 3,6 d | 6,3 b | 4,3 d | 2,6 c | 6,0 g | 191,0 j |
| 75 | 144 | 130 | 5,0 c | 5,6 b | 3,0 d | 3,0 c | 8,0 f | 161,6 j |
| 30 | 110 | 140 | 6,3 b | 5,6 b | 3,0 d | 2,0 d | 3,3 h | 156,6 j |
| 66 | 108 | 115 | 8,3 a | 5,0 b | 6,3 c | 2,0 d | 7,3 g | 155,6 j |
| 2 | 112 | 120 | 8,3 a | 4,3 b | 3,0 d | 1,6 d | 13,3 d | 155,3 j |
| 18 | 90 | 109 | 3,6 d | 8,3 a | 7,0 b | 3,3 b | 11,3 e | 146,6 j |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20 | 118 | 108 | 5,6 c | 7,6 a | 5,0 c | 2,0 d | 11,3 e | 143,3 j |
| 65 | 139 | 123 | 8,3 a | 5,0 b | 3,6 d | 2,0 d | 21,6 b | 64,3 j |
| 74 | 145 | 120 | 5,0 c | 6,3 b | 3,6 d | 1,0 e | 10,6 e | 56,6 j |

* Averages in the columns, followed by the same letter, do not differ significantly between themselves by the Scott-Knott test, at the level of 1% of probability.

Table 3. Groups with similar behavior standards by the Tocher Method, based on the leaf blast severity, scald, brown spot on the leaves, grain stain, incidence of panicle blast and productivity on 90 genotypes of highland rice, using the Generalized Distance of Mahalanobis ($D_{ii}^2$)

| Group | Genotypes* |
|---|---|
| I | 1, 3, 4, 5, 6, 7, 9, 11, 12, 14, 15, 16, 17, 19, 20 22, 23, 24,25, 26, 27, 29, 30,31, 32, 33, 34,36, 38, 39, 40,41, 43, 45, 48,49, 50, 51,52, 54, 55, 56, 57 ,58, 60, 61, 64, 67, 68, 71, 73, 75, 76,77, 79, 81, 83, 86 |
| II | 2, 8, 28, 37, 62, 65, 69, 74 |
| III. | 10, 13, 35, 46, 72, 78, 82, 84, 85, 87, 89 |
| IV. | 21, 42, 47 |
| V | 44, 59, 80 |
| VI | 18, 66 |
| VII | 63, 90 |
| VIII | 88 |
| IX | 70 |
| X | 53 |

* The identification of the 90 genotypes of highland rice is found on Table 1.

Table 4. Percentage relative contribution of the characters for divergence ($D_{ii}^2$), analyzing based on the criterion of SINGH (1981), in highland rice

| Characters | $S.J.^2$ | Value in % |
|---|---|---|
| Leaf blast | 30223.968119 | 9.3352 |
| Leaf scald | 7028.506952 | 2.1709 |
| Brown spot | 12872.385132 | 3.9759 |
| Grain stain | 22973.682489 | 7.0959 |
| Panicle blast | 82432.728533 | 25.4609 |
| Productivity | 168230.710246 | 51.9612 |

$S.J.^2$.: relative contribution of the characters by the method of Singh (1981).