Genetic Divergence Studies for Gall Midge Incidence, Earliness, Yield and Yield Components in Rice (*Oryza sativa* L.) Genotypes in Telangana State

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Author’s contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The study was carried out with 32 genotypes of rice (*Oryza sativa* L.) under irrigated system in RBD design with three replications at Agricultural Research Station, Kunaram in Telangana State during the rainy season of 2017. In general, major problem is high incidence of gall midge (Biotype 3) in rainy season under early as well as late planting conditions in Northern Zone of Telangana State. Hence, all the 32 genotypes were evaluated with an aim to know the divergence among them for gall midge incidence, earliness, yield and yield components. Based on D2 analysis, 32 genotypes were distributed into twelve clusters with the cluster I (12) containing maximum number of genotypes followed by cluster II (9). Highest inter cluster distances were observed between the clusters X and XII (2469.5) followed by III and XII (2283.3), and VII and XII (2173.6) suggesting wide diversity between the traits. Cluster mean analysis revealed that genotype, WGL 1119 from the cluster V would be used in breeding programme to develop gall midge resistant, high yielding, early duration, non lodging, medium slender grain genotypes as it recorded very low incidence of galls (0.9%) with high yield (4869.7 kg/ha), early duration (84.7 days), short stature (93.7 cm) and less 1000-grain weight (14.8 g). The genotypes, KNM 2305 and MTU 1001 from the clusters viz., VIII and X, respectively were identified as potential lines for developing high yielding, early and medium...
duration, long bold or long slender grain varieties. Among the traits studied, days to 50% flowering (55.8%) and 1000-grain weight (31.9%) manifested highest contribution towards total divergence, thus, these traits could be given due importance by the breeders for development of superior rice genotypes under crop improvement programme.

Keywords: Rice; genetic divergence; gall midge incidence; yield.

1. INTRODUCTION

More than half of the world’s population use rice as an important staple food and Asian countries produce and consume 80% of the world’s rice [1]. It has been referred to as “Global grain” after maize and wheat. In Northern Zone of Telangana State, rice has been occupied larger area, accounts for nearly 5 lakh ha among the cereals during every rainy season. The Asian rice gall midge, Orseolia oryzae (Wood-Mason) is one of the important insect pests in the Northern Telangana region of South India. Recently, gall midge incidence has been increased which results in annual yield loss, amounting to Rs.3300 million in South India alone [2]. Hence, breeding for development of gall midge resistant varieties has been an important strategy with more yield and acceptable grain quality [3].

Knowledge on the nature and magnitude of genetic variation in plant breeding programmes is essential for improving yield and its components and provides promising genotypes that can be selected to develop new varieties or breeding materials. Kumbhar et al. [4] reported that the pace and magnitude of genetic improvement is generally dependent on the amount of genetic diversity present in a population. The breeders are interested to evaluate genetic diversity based morphological traits because they are inexpensive, rapid, and simple to score. It was proved in many cases that wide the divergence between parents, more choice for obtaining wide segregants to enable scope for selection of superior plants with desirable trait combinations [5]. Hence, the selection of desirable segregants from segregating populations could be achieved through the inclusion of most divergent parents in the breeding programmes. Multivariate analysis is an important tool for estimation of genetic divergence in the populations which was reported by several workers [6,7,8,9,10,11,12]. Keeping in view of the importance, present study was undertaken to estimate the genetic diversity present among the genotypes to enable for selection of more divergent, high yielding and gall midge resistant genotypes for further crop improvement.

2. MATERIALS AND METHODS

The material comprised of 32 rice genotypes were evaluated under irrigated system during the rainy season of the year, 2017 at Agricultural Research Station, Kunaram (Table 1). The experiment was laid out in the randomized block design with three replications. The farm is located at 18.6°N Latitude, 79°E Longitude and at an elevation of 231 m asl. The soil is silty loam with pH 7.43 and EC 0.26 dS/m. The recommended agronomic practices and plant protection measures were followed to raise a good crop. The variables measured for quantitative traits were days to 50% flowering, plant height (cm), panicle length (cm), number of productive tillers per m², number of grains per panicle, 1000 grain weight (g) and grain yield (kg/ha) for each entry in each replication. The incidence of gall midge was recorded in percent tillers affected with silver shoots (following Standard Evaluation System for Rice, IRRI, 2002) on 10 tagged random plants. The mean data after computing for each trait was subjected to analysis of variance [13]. Multivariate analysis was done as per the Mahalanobis D² statistics described by Rao [14] and the genotypes were grouped into different clusters following Tocher’s method. Intra and inter-cluster distances and mean performances of clusters for all the traits were also computed.

3. RESULTS AND DISCUSSION

In the present investigation, analysis of variance (Table 2) was carried out to test the significance of variance among 32 diverse genotypes for all the eight traits. Analysis of variance revealed significant differences (P>0.01) among the material, indicating the presence of wide spectrum of variability among the genotypes for gall midge incidence, yield and its component traits for selecting desirable genotypes by the plant breeder.
Table 1. List of genotypes studied along with pedigree and status

| S.No. | Genotype/Variety   | Pedigree                                      | Status       |
|-------|-------------------|----------------------------------------------|--------------|
| 1     | JGL 24497         | JGL 17004 x NLR 3042                        | Not released |
| 2     | RDR 1162          | JGL 11727 x JGL 17004                       | Not released |
| 3     | RNR 15048         | MTU 1010 X JGL 3855                         | Released     |
| 4     | JGLH 169          | IR 62030-54-1-2-2R x IR 42266-29-4-2-2-2R     | Not released |
| 5     | RNR 23595         | Yamini x BM 71                              | Not released |
| 6     | RDR 1188          | JGL 11118 x RNR 2465                        | Not released |
| 7     | IBT R9            | Tellahamsa* 2 x GPP2                        | Not released |
| 8     | MTU 1010          | Krishnaveni x IR 64                         | Released     |
| 9     | JGL 20776         | MTU 1010 x JGL 13595                        | Not released |
| 10    | WGL 1119          | WGL 32100 // B95-1 x Abhaya                  | Not released |
| 11    | IET 26241         | -                                            | Not released |
| 12    | KNM 2305          | JGL 11470 x Himalaya 741                    | Not released |
| 13    | IBT R4            | Tellahamsa* 2 x GPP2                        | Not released |
| 14    | WGL 962           | BPT 5204 x GEB 24 // BPT 5204 x Shatabdi     | Not released |
| 15    | KMPS 6251         | MTU 1001 x NLR 145                         | Not released |
| 16    | KNM 2307          | JGL 11727 x JGL 17004                       | Not released |
| 17    | US 314            | Private company hybrid                       | Released     |
| 18    | IBT R8            | Tellahamsa* 2 x GPP2 // Tellahamsa* 2 x NLR 145 | Not released |
| 19    | KNM 118           | MTU 1010 x JGL 13595                        | Released     |
| 20    | JGL 23746         | JGL 3855 x C 28                             | Not released |
| 21    | WGL 1150          | Tellahamsa // B95-1 x Abhaya                 | Not released |
| 22    | RNR 21225         | MTU 1075 x Kavya                            | Not released |
| 23    | IET 26224         | -                                            | Not released |
| 24    | Krishna           | Chandan x BPT 5204                          | Released     |
| 25    | RNR 17500         | Sumathi x Kavya                             | Not released |
| 26    | WGL 1021          | WGL 32183 x Sheetal                         | Not released |
| 27    | Pusa 1121         | Pusa 614-1-2 x Pusa 614-2-4-3                | Released     |
| 28    | RNR 15435         | RNR 17818 x Vasumathi                       | Not released |
| 29    | Sumathi           | Chandan x Pak Basmathi                      | Released     |
| 30    | MTU 1001          | MTU 5249 x MTU 7014                         | Released     |
| 31    | JGL 18629         | JGL 7046 x Swarna // BPT 5204               | Not released |
| 32    | JGL 11470         | JGL 418 x Gedongibeton                      | Released     |

Table 2. Mean squares corresponding to various sources of variation for eight traits in rice

| Source of variation          | Replications | Treatments    | Error        |
|------------------------------|--------------|---------------|--------------|
| Degrees of freedom           | 2            | 31            | 62           |
| Days to 50% flowering        | 0.07         | 346.26**      | 0.29         |
| Plant height (cm)            | 8.83         | 641.77**      | 3.19         |
| Panicle length (cm)          | 1.33         | 16.99**       | 0.69         |
| Number of productive tillers per m² | 339.29     | 1821.46**     | 241.79       |
| Number of grains per panicle | 275.69       | 12506.50**    | 681.64       |
| 1000- grain weight (g)       | 1.79**       | 65.08**       | 0.14         |
| Grain yield (kg per ha)      | 693712.50    | 2560828.47**  | 286063.15    |
| Gall midge incidence (%)     | 88.09        | 972.83**      | 36.86        |

* Significant at (P>0.05), ** significant at (P>0.01)

In the present investigation, D² analysis was carried out as the chi-square test indicated that the population of rice was divergent. Based on the relative magnitude of D² values, 32 genotypes were grouped into 12 clusters of which cluster I was the largest consisting of 12 genotypes followed by cluster II and III having 9 and 2 genotypes, respectively. However, the remaining clusters comprised of only one genotype each (Fig. 1).
According to Akter et al. [15], the maximum eight entries were grouped into the cluster II followed by seven in cluster IV. Similarly, fifty red rice germplasm with fifteen agro morphological traits were grouped into five clusters [16]. In another study of Ahamdikhah et al. [17], 58 rice varieties were clustered into four groups based on 18 morphological traits. From the pattern of clustering it could be inferred that sufficient divergence was present to enable the formation of individual clusters. The clustering pattern could be utilized in selection of better parents for crossing and deciding the best cross combinations which may generate highest possible variability for the desirable traits. A total of 12 genotypes were grouped in to cluster I namely JGL 24497, KNM 2307, MTU 1010, KNM 118, IBT R 8, US 314, RDR 1188, IBT R9, JGL 20776, JGLH 169, KMPS 6251, RNR 23595; nine genotypes in cluster II namely Telangana Sona, IET 26241, JGL 23746, RNR 17500, RNR 15435, Krishna, RNR 21225, WGL 1021, JGL 18629 and two genotypes in the cluster III namely IET 26224, JGL 11470. The genotypes derived from different pedigrees were grouped in the same clusters viz., I, II and III indicated that selection would be targeted towards desirable plant types in the majority of the breeding programmes for rice crop improvement. Hence, the diversity had been narrowed irrespective of pedigree of the genotype over the process of advancement through segregating generations. The genotypes RDR 1162,WGL 1119, IBT R4, Sumathi, KNM 2305, WGL 962, MTU 1001, Pusa 1121 and WGL 1150 maintained their separate identities by making mono-genotypic groups, that is, clusters, IV, V, VI, VII, VIII, IX, X, XI and XII while forming clusters. It might be due to their different genetic makeup from that of other germplasm lines in the present study (Table 3). Similar results of greater genetic diversity for the genotypes in the monogenotypic clusters were also reported [18,19].

Principal Component Analysis is (PCA) showed two most informative principal components with eigen values of 5144.09 and 2066.31, respectively, which together accounted 90.15% of the total variance for all the characters. According to first principal component, traits such as days to 50% flowering (0.89) and plant height (0.23) had relatively higher contributions.
(64.32%) to the total variation, while principal component 2 accounted for 25.83% of the total variation with number of grains Panicle\(^{-1}\) (0.12) giving the highest contribution. The analysis of eigenvectors recorded the information of morphological traits for percentage of variation to the third principle component, which was 7.35 with days 50% flowering (0.27), grain yield (0.23) and 1000-grain weight (0.21) had higher contribution (Table 4). Similarly, Rajiv et al. [20] reported the first two principal components accounting for 68.6% of total variation in drought stress and 82.1% in control.

The values of intra and inter cluster distances for the 32 rice genotypes based on phenotypic traits was determined (Table 5). According to Pattnaik [21], higher intra-cluster distance also indicated greater heterogeneity of the genotypes. Considerable variation occurred in intra cluster distances ranged from zero to 162, indicating wider diversity prevailing among the germplasm lines within clusters. The maximum intra cluster distance was in cluster II (162.0) followed by clusters I (109.8) and III (19.8), while it was zero for the remaining clusters. Hence, germplasm under the cluster II and I was most heterogeneous and germplasm under cluster III was comparatively homogeneous or less divergent. Genotypes falling in the clusters II, I and III which were having high degree of divergence would produce more desirable segregates to achieve greater genetic divergence, having ample scope to select superior genotype for the trait of interest. Since the cluster I and cluster II consisted of 21 genotypes with highest values of intra-cluster distances, presence of high heterogeneity among the germplasm within these two clusters is expected. Hence, the sub clustering of clusters I and II is an approach towards the effective selection of desired parents for hybridization programme within these clusters.

| Cluster number | Number of genotypes | Genotypes                                                                 |
|----------------|---------------------|---------------------------------------------------------------------------|
| I              | 12                  | JGL 24497, KNM 2307, MTU 1010, KNM 118, IBT R 8, US 314, RDR 1188, IBT R9, JGL 20776, JGL 169, KMPS 6251, RNR 23595 |
| II             | 9                   | Telangana Sona, IET 26241, JGL 23746, RNR 17500, RNR 15435, Krishna, RNR 21225, WGL 1021, JGL 18629 |
| III            | 2                   | IET 26224, JGL 11470                                                     |
| IV             | 1                   | RDR 1162                                                                 |
| V              | 1                   | WGL 1119                                                                 |
| VI             | 1                   | IBT R4                                                                   |
| VII            | 1                   | Sumathi                                                                  |
| VIII           | 1                   | KNM 2305                                                                 |
| IX             | 1                   | WGL 962                                                                  |
| X              | 1                   | MTU 1001                                                                 |
| XI             | 1                   | Pusa 1121                                                                |
| XII            | 1                   | WGL 1150                                                                 |

| Variable                        | Eigenvectors | PC1  | PC2  | PC3  |
|---------------------------------|--------------|------|------|------|
| Eigen value                     | 5144.09      | 2066.31 | 588.39     |
| Variation (%)                   | 64.32        | 25.83 | 7.35 |
| Cumulative (%)                  | 64.32        | 90.15 | 97.51 |
| Days to 50% flowering           | 0.89         | 0.05  | 0.27  |
| Plant height (cm)               | 0.23         | -0.25 | -0.90 |
| Panicle length (cm)             | 0.07         | -0.02 | -0.01 |
| Number of Productive tillers m\(^{-1}\) | -0.17     | 0.01  | -0.12 |
| Number of grains Panicle\(^{-1}\) | -0.17     | 0.12  | -0.01 |
| 1000 - grain weight (g)         | 0.01         | -0.94 | 0.21  |
| Grain yield (kg ha\(^{-1}\))   | -0.24        | -0.18 | 0.23  |
| Gall midge incidence (%)        | -0.13        | -0.06 | -0.05 |

PC: Principal components
Table 5. Average intra (diagonal) and inter cluster distances (Tocher’s method) for 32 rice genotypes

| Clusters | I    | II   | III  | IV   | V    | VI   | VII  | VIII | IX   | X    | XI   | XII  |
|----------|------|------|------|------|------|------|------|------|------|------|------|------|
| I        | 109.8| 533.1| 1097.6| 326.1| 439.2| 250.7| 921.8| 260.5| 391.0| 1097.0| 501.4| 376.4|
| II       | 162.0| 286.0| 713.3| 616.5| 709.7| 344.1| 521.1| 323.6| 500.6| 442.8| 1358.1| 2283.3|
| III      | 19.8 | 1283.8| 970.4| 1223.3| 390.9| 975.6| 577.4| 347.8| 962.6| 2283.3| 1108.7| 283.8|
| IV       | 0.00 | 75.5 | 76.8 | 1492.5| 1223.3| 390.9| 975.6| 577.4| 347.8| 962.6| 2283.3| 1108.7|
| V        | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| VI       |      |      |      |      |      |      |      |      |      |      |      |      |
| VII      |      |      |      |      |      |      |      |      |      |      |      |      |
| VIII     |      |      |      |      |      |      |      |      |      |      |      |      |
| IX       |      |      |      |      |      |      |      |      |      |      |      |      |
| X        |      |      |      |      |      |      |      |      |      |      |      |      |
| XI       |      |      |      |      |      |      |      |      |      |      |      |      |
| XII      |      |      |      |      |      |      |      |      |      |      |      |      |

Table 6. Cluster means and percent contribution of each character towards total divergence of 32 rice genotypes for eight quantitative characters

| Cluster | Days to 50% flowering | Plant height (cm) | Panicle length (cm) | Number of Productive tillers m⁻¹ | Number of grains Panicle⁻¹ | 1000-grain weight (g) | Grain yield (kg ha⁻¹) | Gall midge incidence (%) |
|---------|-----------------------|-------------------|---------------------|----------------------------------|--------------------------|-----------------------|------------------------|-------------------------|
| I       | 83.5                  | 113.9             | 25.6                | 245.9                            | 160.6                    | 23.4                  | 4542.1                 | 60.1                    |
| II      | 98.4                  | 125.2             | 27.8                | 240.1                            | 235.2                    | 16.5                  | 4414.6                 | 46.6                    |
| III     | 109.7                 | 101.6             | 24.9                | 229.9                            | 275.9                    | 14.8                  | 3744.5                 | 45.2                    |
| IV      | 79.7                  | 108.5             | 25.0                | 246.4                            | 213.9                    | 15.5                  | 5564.7                 | 40.8                    |
| V       | 84.7                  | 93.7              | 24.4                | 284.5                            | 225.2                    | 14.8                  | 4869.7                 | 0.9                     |
| VI      | 80.0                  | 94.5              | 24.3                | 299.2                            | 118.7                    | 19.9                  | 3521.7                 | 5.3                     |
| VII     | 105.0                 | 137.9             | 30.8                | 202.4                            | 154.3                    | 22.3                  | 3268.0                 | 45.6                    |
| VIII    | 91.0                  | 122.4             | 27.8                | 243.5                            | 160.7                    | 27.9                  | 6377.7                 | 54.1                    |
| IX      | 90.3                  | 104.4             | 20.9                | 264.0                            | 236.1                    | 13.5                  | 3847.3                 | 58.7                    |
| X       | 110.0                 | 112.1             | 25.1                | 226.6                            | 170.3                    | 23.9                  | 5633.0                 | 32.3                    |
| XI      | 91.0                  | 158.7             | 30.2                | 257.4                            | 83.9                     | 23.7                  | 3049.0                 | 33.1                    |
| XII     | 68.3                  | 110.6             | 25.4                | 244.2                            | 87.7                     | 23.7                  | 3684.7                 | 18.3                    |
| % Contribution of character | 55.8 | 11.1 | 0 | 0.40 | 0.20 | 31.9 | 0.60 | 0 |
Table 7. Mean performance of eight characters for 32 rice genotypes

| Genotype   | Days to 50% flowering | Plant height (cm) | Panicle length (cm) | Number of productive tillers m⁻²¹ | Numbers of grains panicle⁻¹ | 1000-grain weight (g) | Grain yield (kg ha⁻¹) | Gall midge incidence (%) |
|------------|-----------------------|-------------------|---------------------|----------------------------------|------------------------------|-----------------------|------------------------|--------------------------|
| JGL 24497  | 82.3                  | 114.4             | 25.7                | 281.6                            | 122.9                       | 24.6                  | 5096.3                 | 59.6                     |
| RDR 1162   | 79.7                  | 108.5             | 25.0                | 246.4                            | 213.9                       | 15.5                  | 5564.7                 | 40.8                     |
| RNR 15048  | 98.0                  | 127.1             | 26.8                | 266.9                            | 306.8                       | 12.6                  | 3903.4                 | 67.3                     |
| JGLH 169   | 90.3                  | 115.7             | 28.1                | 211.2                            | 165.8                       | 23.9                  | 3093.4                 | 81.4                     |
| RNR 23595  | 85.0                  | 122.5             | 27.5                | 225.9                            | 289.2                       | 17.0                  | 4002.9                 | 59.7                     |
| RDR 1188   | 77.3                  | 115.1             | 25.5                | 228.8                            | 160.1                       | 27.1                  | 3608.2                 | 35.0                     |
| IBT R9     | 87.7                  | 111.1             | 24.0                | 243.5                            | 75.5                        | 25.5                  | 3941.8                 | 53.6                     |
| MTU 1010   | 81.7                  | 107.2             | 24.6                | 272.8                            | 102.5                       | 25.3                  | 5004.0                 | 62.7                     |
| JGL 20776  | 88.3                  | 122.6             | 26.4                | 234.7                            | 204.5                       | 23.4                  | 5433.6                 | 56.3                     |
| WGL 1119   | 84.7                  | 93.7              | 24.4                | 284.5                            | 225.2                       | 14.8                  | 4869.7                 | 0.9                      |
| IET 26241  | 98.3                  | 128.0             | 26.2                | 258.1                            | 228.2                       | 12.2                  | 3868.3                 | 62.2                     |
| KNM 2305   | 91.0                  | 122.5             | 27.8                | 243.5                            | 160.7                       | 27.9                  | 6377.7                 | 54.1                     |
| IBT R4     | 80.0                  | 94.4              | 24.3                | 299.2                            | 118.7                       | 19.9                  | 3521.7                 | 5.3                      |
| WGL 962    | 90.3                  | 104.4             | 20.9                | 264.0                            | 236.1                       | 13.5                  | 3847.4                 | 58.7                     |
| KMP 6251   | 83.0                  | 117.3             | 24.7                | 258.1                            | 216.9                       | 17.3                  | 5040.2                 | 61.7                     |
| KNM 2307   | 82.3                  | 112.2             | 24.7                | 240.5                            | 131.3                       | 25.2                  | 5223.0                 | 67.8                     |
| US 314     | 82.7                  | 112.4             | 26.4                | 234.7                            | 179.2                       | 22.2                  | 4528.3                 | 65.3                     |
| IBT R8     | 80.7                  | 112.9             | 24.4                | 269.9                            | 146.5                       | 23.5                  | 3923.5                 | 69.3                     |
| KNM 118    | 81.0                  | 104.0             | 24.9                | 249.3                            | 133.2                       | 26.0                  | 5609.8                 | 48.6                     |
| JGL 23746  | 95.3                  | 124.0             | 29.8                | 265.1                            | 203.0                       | 17.9                  | 5549.7                 | 41.2                     |
| WGL 1150   | 68.3                  | 110.6             | 25.4                | 244.2                            | 87.7                        | 23.7                  | 3684.7                 | 18.3                     |
| RNR 21225  | 102.0                 | 115.2             | 26.0                | 215.6                            | 205.3                       | 19.7                  | 5445.0                 | 40.8                     |
| IET 26224  | 110.3                 | 99.7              | 24.5                | 215.6                            | 245.6                       | 15.8                  | 3390.3                 | 54.0                     |
| Krishna    | 100.0                 | 101.4             | 24.1                | 222.2                            | 267.3                       | 15.6                  | 4201.1                 | 50.9                     |
| RNR 17500  | 92.0                  | 141.6             | 30.2                | 215.6                            | 205.3                       | 16.9                  | 3988.1                 | 47.5                     |
| WGL 1021   | 100.3                 | 139.4             | 30.9                | 217.8                            | 278.0                       | 19.6                  | 5492.5                 | 36.9                     |
| Pusa 1112  | 91.0                  | 158.6             | 30.3                | 257.4                            | 83.9                        | 23.7                  | 3049.2                 | 33.1                     |
| RNR 15435  | 91.7                  | 139.5             | 30.2                | 279.4                            | 174.2                       | 17.7                  | 3027.2                 | 34.2                     |
| Sumathi    | 105.0                 | 137.9             | 30.8                | 202.4                            | 154.3                       | 22.3                  | 3268.1                 | 45.6                     |
| MTU 1001   | 110.0                 | 112.1             | 25.1                | 226.6                            | 170.3                       | 23.9                  | 5633.0                 | 32.3                     |
| JGL 18629  | 108.0                 | 110.8             | 26.0                | 220.0                            | 248.7                       | 16.5                  | 4255.6                 | 38.6                     |
| Genotype   | Days to 50% flowering | Plant height (cm) | Panicle length (cm) | Number of productive tillers m⁻¹ | Numbers of grains panicle⁻¹ | 1000-grain weight (g) | Grain yield (kg ha⁻¹) | Gall midge incidence (%) |
|------------|------------------------|-------------------|---------------------|----------------------------------|----------------------------|----------------------|----------------------|------------------------|
| JGL 11470  | 109.0                  | 103.6             | 25.4                | 244.2                            | 306.3                      | 13.8                 | 4098.9               | 36.4                   |
| Mean       | 90.9                   | 116.9             | 26.3                | 244.9                            | 188.9                      | 20.1                 | 4423.2               | 47.5                   |
| C.V.       | 0.6                    | 1.5               | 3.2                 | 6.3                              | 13.8                       | 1.9                  | 12.1                 | 12.8                   |
| C.D. (5%)  | 0.9                    | 2.9               | 1.4                 | 25.4                             | 42.6                       | 0.6                  | 872.9                | 9.9                    |
| C.D. (1%)  | 1.2                    | 3.9               | 1.8                 | 33.7                             | 56.7                       | 0.8                  | 1160.5               | 13.2                   |
Fig. 2. Mahalonobis Euclidean distance through Tocher's method among 32 rice genotypes

Maximum inter-cluster distance suggested wider diversity between the groups; while minimum inter cluster distance indicated closer relationship. The inter cluster distances in most of the cases higher than the intra cluster distances suggesting genetic diversity among the genotypes of different clusters. These results are in agreement with the earlier reports [7,19]. From the inter cluster distance values, it is clear that highest divergence occurred between cluster X and XII (2469.5) followed by cluster III and XII (2283.3) and cluster VII and XII (2173.0) indicating the presence of greater diversity between genotypes of these groups which could be exploited in crop improvement. Higher genetic distance was noticed between mono-genotypic cluster X (MTU 1001) and other mono-genotypic cluster XII (WGL 1150). These genotypes may be used for developing early and medium duration bold grain genotypes since both genotypes are bold grained. Moreover, it was interesting to note that in most of the cases, cluster XII produced the highest inter cluster value with all other clusters. This suggests that genotype of cluster XII has the potential to be used for hybridization programme to produce breeding material with high yield and other maximum probability of desirable traits as well. These results are similar with other findings in rice crop [15]. De Reddy et al. [22] and Maurya et al. [9] reported genotypes belonging to clusters separated by high cluster distance could be used in breeding programme for obtaining high heterosis and wide spectrum of variation among the segregants. In contrary to this, lowest inter cluster distance was noticed between cluster IV and V (75.5) indicating that the genotypes of these clusters had genetic resemblance (Fig. 2).

Based on morphological data of eight quantitative traits, it was noticed that there is a considerable amount of variation existing among the cluster means (Table 6) indicating the presence of plenty diversity for these traits in 32 rice genotypes under study. Genotype, WGL
1119 in the mono-genotypic cluster V was characterized with very low incidence of gall midge (0.9%), early in flowering (84.7 days), short stature (93.7 cm), more number of grains per panicle (225.2), effective bearing tillers (284.5) and grain slenderness (14.8 g) including good grain yield (4869.7 kg/ha), hence this genotype could be used for obtaining gall midge tolerant, high yielding, early duration, medium slender grain, non lodging genotypes. Genotypes KNM 2305 and MTU 1001 in the mono-genotypic clusters VIII and X, respectively were found to be accumulated with maximum good characters such as 1000-grain weight (27.9 g and 23.99 g) and number of grains per panicle (160.7 and 170.3) and as a result higher grain yield (6377.7 kg/ha and 5633.0 kg/ha) was obtained in these clusters. However, these genotypes KNM 2305 (54.6%) and MTU 1001 (32.3%) recorded medium incidence of gall midge. Therefore, they could be used as parents for developing high yielding early and medium duration long slender or long bold rice varieties. Genotype RDR 1162 from cluster IV was characterized by good yield (5564.7 kg/ha), early in flowering (79.7 days) and lesser 1000-grain weight (15.5 g) with the medium incidence of gall midge (40.8%); hence, this genotype could be used for obtaining early duration medium slender grain varieties (Table 7). Considerable emphasis should be given to the characters contributing most to the divergence. The traits, 1000-grain weight (31.9%) and days to flowering (55.8%) contributed considerably, accounting for 87.7% of total divergence among all the traits indicating the importance of these traits for effective selections, whereas, panicle length (0.0) and gall midge incidence (0.0) recorded zero contribution towards total divergence which are of less importance in selection of diverse parents. Similarly, according to Mohan et al. [7] and Thippaswamy et al. [23] higher contribution of days to flowering and 1000- grain weight was reported towards total divergence in rice. In contrary to this, the contribution of percent filled grains per panicle was high towards genetic divergence [19]. Least contribution of effective tillers, plant height and panicle length towards total divergence was noticed [12] and panicle length had a good contribution towards total divergence [24]. Since, days to 50% flowering (55.8%), 1000-grain weight (31.9%), plant height (11.1%) and grain yield (0.60%) exhibited more contribution to the divergence, the present experimental material could be used for developing high yielding rice varieties with desirable grain type, maturity duration and plant height (Table 6).

4. CONCLUSION

It is assumed that the maximum amount of heterosis will be expressed in cross combinations involving the parents that belong to most divergent clusters. In the present investigation, maximum distances existed between the clusters X and XII, III and XII and VII and XII would exhibit high heterosis as well as high level of yield potential. Based on the cluster means in the genetic diversity study, gall midge susceptible genotype namely KNM 2305 was identified as a potential genotype for developing early duration, long bold or long slender grain varieties. In view of increasing demand for medium slender fine grain varieties, gall midge resistant genotype WGL 1119 from the cluster V would be used in breeding programme to develop early duration varieties of medium slender, fine grain gall midge resistant varieties as it exhibited earliness, lower test weight and very less damage against gall midge. Further, D² statistics identified days to 50 % flowering, 1000-grain weight, plant height and grain yield similar to PCA in various principal components playing a major role in developing high yielding rice varieties with desirable grain type, maturity duration and plant height.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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