

## SELECTION OF IDEOTYPES TO INCREASE POTENTIAL YIELD OF RICE CULTIVARS USING MULTIVARIATE MODELES

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### ABSTRACT

Using classical breeding, plant breeders envision a plant type whose yield they aim to enhance by selecting for individual traits to create model/ideal plants or ideotypes. The experiment was carried out as a randomized complete blocks design with four replications and 15 local rice cultivars, required were collected for using path coefficient analysis and mahalanobis distance analysis. The results revealed that the higher positive effect on paddy yield was determined by panicle weight and number of spikelet per panicle. The higher negative effect on paddy yield was determined by DFM and FT. The highest genetic distance was observed between *cv.* 'Langroudi' and *cv.* 'Tarom Hashemi' and the least one was between *cv.* 'Gharib Reihani' and 'Ahlami Tarom'. Totally, all local cultivars were close to each other in terms of the genetic distance. This result shows that ideotype, this ideotype yield gap can be compensated. According to the findings, the high level of paddy-yield changes and contribution of each factor affecting it shows that with proper management, a significant part of this change can be compensated and lead to potential yield.

**Keywords:** ideotype, mahalanobis distance, multivariate model, path analysis, plant breeding.

### INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most widely consumed staple food crops in the world (Dastan et al., 2020). A major challenge of the 21<sup>st</sup> century is to achieve food security in climate change and roughly a twice the increase in demand for food by the year 2050, most of them must be met by cereals, especially rice (Rotter et al., 2015). During the last decades, crop simulation has become important to support plant breeding has been important, especially in the design of ideotype, i.e. "the model plant", for different crop and agro-ecosystems (Rotter et al., 2015). Filling the gap between the existing yield in the fields of the yield that can be obtained through the best cultivars compatible with the environment and most appropriate methods for managing water, soil, and plant, is the key to overcoming nutritional challenges of the world's growing population (Hochman et al., 2013). Increasing the yield through genetic improvement of the cultivars is an appropriate strategy for increasing crop production (Meng et al., 2013). Hence, high

yield efficiency plants should be described using existing knowledge. Next, in order to plants breeding, researchers must produce new-generation products with the lowest gaps in their production of new technologies such as genetic engineering and biotechnology. According to this perspective, plants breeders have to take steps toward to achieve an ideal type with the least yield gap using new technologies that are closer to the potential instead of the old methods of selecting for yield. In a comprehensive definition defined by experts, the ideal type defined a combination of morphological and physiological traits or their genetic bases that create the maximum capacity for plant use functions in a biophysical environment with specific agricultural management (Martre et al., 2015). There are several ways for determining the desirable traits and ideotype of crops. Crop modeling method is for recently increased use (Martre et al., 2015). Although the models are a powerful tool for identifying the mechanisms that produce the final yield and combination of simulation and the latest approaches for plant breeding (Yang et al., 2013) can lead to successful

results, components in models can ask the ideal type integrity (Rotter et al., 2015); therefore, where there are tested models, the simpler solution might be used by these models. Field experiments, using models, enable the researcher to select different solutions (Andrivon et al., 2012); however, field experiments can be beneficial when appropriate statistical methods or data mining are used to analyze the responses. In these statistical methods, the relation between different traits and grain yield in different cultivars of a plant has been investigated. The relative contribution of each trait to determining the yield and identification and limitations of access to the maximum yield of a plant in a specific environment

(Soltani et al., 2000). Thus, in this research was to identify the superior traits for selecting the ideotype of local rice cultivars through the regression models.

## MATERIAL AND METHODS

### Description of the site

Experiment was carried out in the paddy fields in Babol region, Mazandaran province between Alborz Mountains and the Caspian Sea in north of Iran (Table 1) in 2017 and 2018. This region is geographically located at 36°26'16" N latitude and 52°39'02" E longitude. The weather conditions are shown in Table 1.

Table 1. Mean climatic parameters in the experiment period (2016-2017 and 2017-2018) and long term period (2001-2017) in the Babol region

| Month         | Average min. temp. (°C) |           | Average max. temp. (°C) |           | Evaporation (mm month <sup>-1</sup> ) |           | Rain (mm month <sup>-1</sup> ) |           | Average relative humidity (%) |           | Average sunshine hours |           | Solar radiation (MJ m <sup>-2</sup> d <sup>-1</sup> ) |           |
|---------------|-------------------------|-----------|-------------------------|-----------|---------------------------------------|-----------|--------------------------------|-----------|-------------------------------|-----------|------------------------|-----------|---|-----------|
|               | 2016-2017               | 2017-2018 | 2016-2017               | 2017-2018 | 2016-2017                             | 2017-2018 | 2016-2017                      | 2017-2018 | 2016-2017                     | 2017-2018 | 2016-2017              | 2017-2018 | 2016-2017   | 2017-2018 |
| Apr.-May      | 9.8                     | 11.1      | 18.5                    | 20.2      | 68.2                                  | 64.1      | 78.1                           | 64.1      | 74                            | 76        | 161                    | 154       | 14.2  | 13.8      |
| May-Jun.      | 11.2                    | 13.4      | 22.2                    | 24.4      | 112.2                                 | 115.1     | 28.0                           | 35.1      | 78                            | 79        | 169                    | 163       | 16.8  | 15.1      |
| Jun.-Jul.     | 14.1                    | 17.2      | 24.2                    | 29.4      | 135.4                                 | 132.2     | 58.2                           | 44.1      | 73                            | 74        | 231                    | 256       | 21.3  | 21.3      |
| Jul.-Aug.     | 18.3                    | 19.3      | 29.2                    | 32.2      | 158.1                                 | 145.1     | 34.2                           | 28.1      | 76                            | 77        | 241                    | 244       | 23.1  | 20.2      |
| Aug.-Sept.    | 23.1                    | 24.2      | 31.2                    | 35.6      | 168.2                                 | 166.1     | 48.1                           | 21.1      | 77                            | 75        | 274                    | 285       | 22.1  | 21.2      |
| Sep.-Nov.     | 25.4                    | 23.8      | 33.2                    | 33.4      | 142.1                                 | 158.3     | 38.4                           | 37.2      | 72                            | 76        | 245                    | 246       | 19.2  | 19.4      |
| Mean 15 years | 17.2                    |           | 26.3                    |           | 138.2                                 |           | 87.6                           |           | 74.2                          |           | 238                    |           | 18.6  |           |

### Description of the experiment

The experiment was carried out in a randomized complete blocks design (RCBD) with four replications and 15 local rice cultivars originally from Iran (RRII<sup>1</sup>). All the investigated cultivars are in the group of tall plant, early maturity, high quality, sensitive to stress, low-yield).

Due to the climatic condition of Mazandaran province (Babol region), the seedling were prepared by traditional method (furrow and basin). Transplanting was done by young seedlings with 3-4 leaves (25 days old). Regarding the type of cultivar, the

transplanting practice was performed in two years with similar situations. The size of each plot was 3×5 m<sup>2</sup>, and planting density was 25 plants m<sup>2</sup> by 20×20 cm<sup>2</sup> planting arrangement. Nitrogen, phosphorous and potassium fertilizers were used in each region according to experimental practices of Rice Research Institute of Iran (RRII) and by considering the result of soil analysis (Table 2).

<sup>1</sup><http://berenj.areeo.ac.ir/homepage.aspx?site=berenj.areeo.ac&tabid=3735&lang=fa-IR>

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Table 2. Soil properties in the experimental site before rice cultivation

| Soil properties    | First year<br>(2016-17) | Second year<br>(2017-18) |
|--------------------|-------------------------|--------------------------|
| Organic matter (%) | 1.12                    | 1.18                     |
| Phosphorous (ppm)  | 9                       | 11                       |
| Potassium (ppm)    | 145                     | 165                      |
| pH                 | 7.1                     | 7.4                      |
| EC (ds/m)          | 0.58                    | 0.61                     |
| Soil texture       | Clay loam               | Clay loam                |

Chemical fertilizers from urea sources have been used (200 kg ha<sup>-1</sup>); triple super phosphate (100 kg ha<sup>-1</sup>); and potassium sulfate (100 kg ha<sup>-1</sup>). Total phosphorus, 50% of the nitrogen and 50% of the potassium fertilizers were used as basic application in the preparation of paddy field. 25% of the nitrogen and 25% of potassium fertilizers were used as top-dressing in panicle initiation. In addition 25% of nitrogen was consumed at the full production stage.

Flood irrigation was carried out with a drainage stage during maximum tillering (initial) stage in growing season period. Moreover, the depth of irrigation was determined at five cm based on agricultural principles. In order to control the weeds growth of weeds and the mixing water and fertilizer in paddy fields, the nylon plastic cover it at the depth of 30 cm. Weed control was carried out, before the pre-emergence weedicide and third stage hand weeding (28, 40 and 50 days after transplanting). Pests control and diseases were done by pesticides. All agricultural practices have been traditionally manipulated. Other agricultural practices and paddy field management were performed on the basis of the standard evaluation system (SES)<sup>2</sup> of the International Rice Research Institute (IRRI).

### Measurement

During growth from days after transplanting to harvesting, after removing the marginal effect, all agronomic traits (phenological and morphological traits, and yield components) were randomly measured according to the IRRI SES.

The phenological traits, including the number of days after transplanting to the beginning of tillering, the initial tillering, the

full heading, 50% of flowering, and the maturity stages, were determined from eight seedling in each hill in each experimental design. In order to determine the morphological traits, sampling was done for 30 days after the end of complete stage of 12 stems selected from four hills in each plot. The number of tillers per hill was counted by 12 tillers per plant. The number of spikelet in each panicle and the number of filled spikelet per panicle were measured by counting 15 panicles.

To calculate the leaf area index (LAI) during the pollination stage, the maximum length and width for all the leaves were measured at 10 plants per plot. LAI estimated by the *LAI\_calc* program using the formula:

$$LAI = 0.75 \times LW$$

Where, the L and W are the length and width of leaf and 0.75 is the coefficient of correction for rice.

Paddy yield (PY) and straw yield (SY) were weighed from each center were used on a scale. The weight was measured in kg per square meter then converted to kg/ha. Harvest index (HI) was calculated by the formula (Fageria et al., 2011, 2014):

$$HI = [PY / (PY + SY)]$$

Measuring the grain baking traits, such as the content of grain amylose, gelatinization temperature, gel consistency, grain length, grain width, grain elongation, milling efficiency, and healthy and broken grain percentage was done by Standard Evaluation System (SES) of International Rice Research Institute (IRRI).

<sup>2</sup><http://www.knowledgebank.irri.org/images/docs/rice-standard-evaluation-system.pdf>

### Statistical analysis

After normalization and Bartlett's test, all statistical analysis were performed using SAS software (version 9.1; SAS institute Inc., Cary NC, USA). Two-way analysis of variance (ANOVA) was used by GLM procedure and the least significant difference (LSD) test was used to compare differences in treatment means at a 5% probability level. In addition, mahalanobis distance were calculated with the pervious software (version 3.22). To determine the traits that had the most effect on yield, after applying regression to eliminate alignment, path analysis was performed using genotype correlation with Path software. Standard error ( $SE = \sqrt{\Sigma (O-P)^2/n}$  where  $O$ ,  $P$  and  $n$  are actual and predicted data and sample size, respectively) was used to evaluate the confidence of interval regression coefficients. To test the ability of the mathematical models used, the coefficient of determination ( $R^2$ ), root mean square error (RMSE) and coefficient of variation (CV) were determined.

## RESULTS AND DISCUSSION

### Path coefficient analysis

The path analysis method was used to determine the direct and indirect effects of the introduced variables in the stepwise regression model in the three regions (Table 3).

Therefore, genetic correlation was used to estimate of direct and indirect traits on paddy yield. The most positive direct effect on paddy yield was with panicle weight and number of spikelet per panicle. The total direct and indirect effects of these traits on paddy yield (genetic correlation with paddy yield) were equal to 0.76 and 0.88. The indirect effect of no. of spikelet per panicle by panicle weight, flag leaf length and panicle per square meter was 1.33, 0.8 and 0.98, respectively (Table 3). Due to the direct effect of fertile tiller on paddy yield, its indirect effect by panicle weight, flag leaf length and panicle per square meter, these traits can be a good attribute to achieving higher yield, which by decreasing the negative indirect effects of days to flowering, days to full maturity and fertile tiller. The maximum negative indirect effect on total spikelet per panicle was achieved by days to full maturity and fertile tiller per hill (Table 3). However, fertile tiller per hill has a direct negative effect on paddy yield, which can be considered as a useful feature to select higher yield and used in indirect selection discussion (Table 3). The most indirect effect on paddy yield is about days to full maturity and fertile tiller per hill. The total direct and indirect effects of these traits were 0.39 and -0.50, respectively. The indirect effect of total spikelet per panicle on all investigated traits obtained was more than one (Table 3).

Table 3. Amount of direct and indirect effect of entered traits of rice cultivars to production model by genetic correlation

| Traits                                 | Direct effect | Indirect effect |       |       |       |       |       |       |        |        | Correlation with PY |
|--|---------------|-----------------|-------|-------|-------|-------|-------|-------|--------|--------|---------------------|
|  |               | DF              | DFM   | PW    | FLL   | FT    | PM    | TS    | FSP    | DMA    |                     |
| Days to flowering (DF)                 | 1.30          |                 | 1.11  | -0.57 | -1.04 | -0.07 | -0.73 | -0.44 | -1.10  | -0.48  | -0.08 <sup>ns</sup> |
| Days to full maturity (DFM)            | -0.47         | -0.40           |       | 0.27  | 0.42  | 0.39  | 0.39  | 0.26  | 0.37   | 0.17   | -0.39 <sup>ns</sup> |
| Panicle weight (PW)                    | -0.17         | 0.01            | 0.01  |       | -0.01 | -0.01 | -0.01 | -0.01 | -0.003 | -0.004 | 0.76 <sup>**</sup>  |
| Flag leaf length (FLL)                 | -0.66         | 0.53            | 0.59  | -0.30 |       | 0.20  | -0.57 | -0.32 | -0.55  | -0.32  | 0.35 <sup>ns</sup>  |
| No. of fertile tiller (FT)             | -0.48         | 0.02            | -0.09 | 0.14  | 0.14  |       | 0.25  | 0.28  | -0.09  | -0.21  | -0.50 <sup>*</sup>  |
| No. of panicle per m <sup>2</sup> (PM) | -0.97         | 0.54            | 0.81  | -0.41 | -0.84 | 0.51  |       | -0.57 | 0.59   | -0.13  | 0.42 <sup>ns</sup>  |
| No. of total spikelet per panicle (TS) | 1.66          | -0.57           | -0.93 | 1.33  | 0.80  | -0.98 | 0.98  |       | 0.03   | -0.15  | 0.88 <sup>**</sup>  |
| Filled spikelet percentage (FSP)       | 1.71          | -1.43           | -1.33 | 0.27  | 1.42  | 0.31  | 1.04  | 0.03  |        | 0.63   | -0.13 <sup>ns</sup> |
| Dry matter accumulation (DMA)          | 0.23          | -0.09           | -0.09 | 0.04  | 0.11  | 0.10  | 0.03  | -0.02 | 0.08   |        | -0.25 <sup>ns</sup> |
| Residual effect                        |               |                 |       |       |       |       |       |       |        |        | 0.381               |

\* and \*\* show the probability at 5 and 1 percent level, respectively.

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According to the findings, there were a negative correlation between no. of fertile tiller per hill with no. of panicle per m<sup>2</sup> and no. of spikelet per panicle. Negative correlation was observed between paddy yield with no. of fertile tiller per plant. The findings of Figures 1 and 2 indicated these relationships between investigated traits. The negative and significant correlation between the no. of fertile tiller per hill with the no. of panicle per m<sup>2</sup> and no. of spikelet per panicle means that with increasing each of these traits, the other decreases. This can prevent the large amounts of these variables from being collected in a single cultivar, especially if this is a negative relationship between a genetic species and a genetic linkage. Traits correlation can be due to the genetic linkage or the existence of a genetic interaction with the environmental component. Therefore, due to the negative correlation between no. of fertile tiller per

hill with no. of panicle per m<sup>2</sup> and no. of spikelet per panicle for determining the ideal type, the amount of variation in paddy yield was calculated according to the final equations of production. The correlation between traits in plant breeding is very important because it measures the magnitude and type of relationship between two or more traits. These correlations depending on weather they are positive or negative. The positive correlations between the two beneficial traits are good because they do not limit the choice of selection. The lack of correlation between the two traits means improving traits without affecting others. In negative correlation, the choice around the average is non-selective. Also, multiple selections for the traits that you choose make simultaneously a more intense selection. In addition, multiple choices for the traits that they choose are simultaneously reducing the amount of time, often chosen.

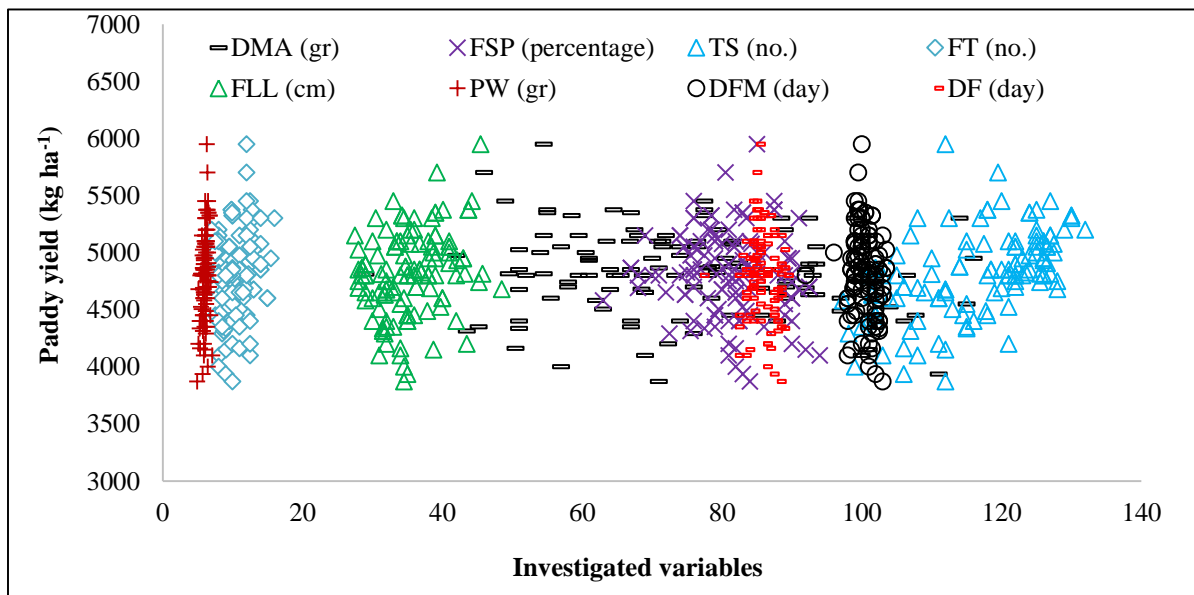


Figure 1. Correlation between paddy yield (PY) with DF, DFM, PW, FLL, FT, TS, FSP and DMA

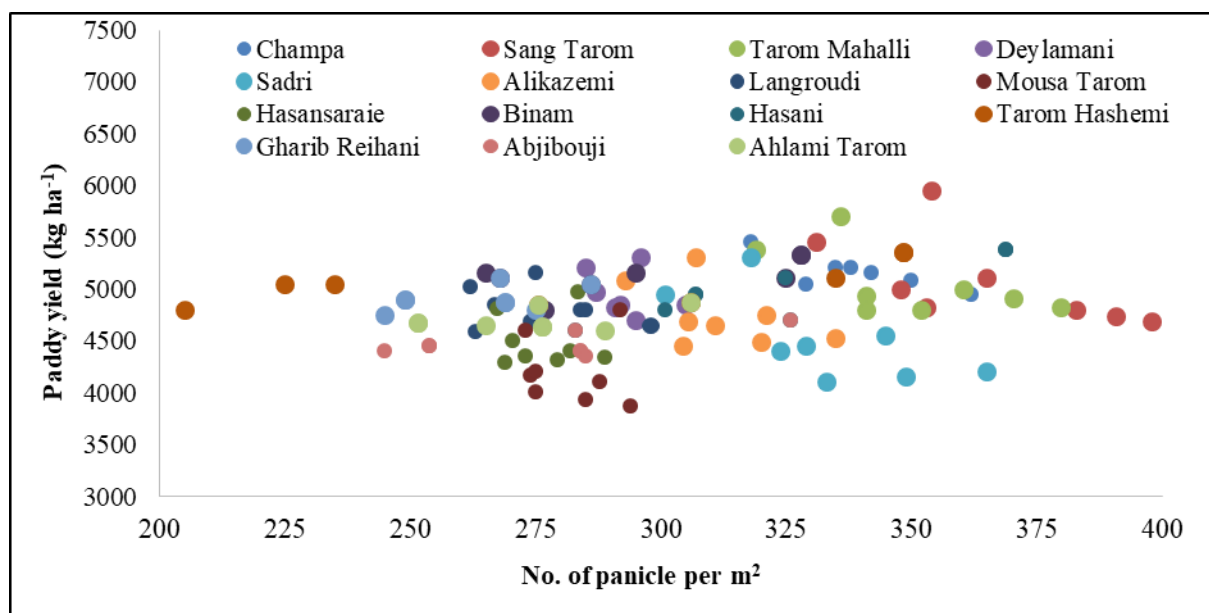


Figure 2. The relationship between no. of panicle per m<sup>2</sup> (PM) and paddy yield (PY)

**Mahalanobis distance**

According to the findings, mahalanobis distance of 15 local cultivars is shown in Table 4. The highest genetic distance was observed between cv. ‘Langroudi’ with cv. ‘Tarom Hashemi’. In addition, ‘Champa’ showed the highest genetic distance with cv. ‘Langroudi’, ‘Tarom Hashemi’ and ‘Hasani’. Moreover, ‘Sang Tarom’ showed a greater genetic distance with ‘Binam’, ‘Hasani’ and ‘Deylamani’. Furthermore, ‘Tarom Mahalli’ revealed the maximum genetic distance with ‘Mousa Tarom’ ‘Hasani’ and ‘Deylamani’.

‘Deylamani’ showed more genetic distance with ‘Hasani’ and ‘Sadri’. After that, genetic distance of cv. ‘Sadri’ with cv. ‘Binam’ and cv. ‘Hasani’ were the highest. ‘Binam’ had the highest genetic distance with ‘Hasani’. The minimum genetic distance was observed between (cv. ‘Alikazemi’ and cv. ‘Ahlami Tarom’); (‘Tarom Hashemi’ and ‘Gharib Reihani’); (cv. ‘Gharib Reihani’ and ‘Ahlami Tarom’); and (cv. ‘Abjibouji’ with ‘Ahlami Tarom’) (Table 4). Totally, all local cultivars were close to each other in terms of the genetic distance.

Table 4. Mahalanobis distance between 15 local rice cultivars

| Cultivars      | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15 |
|----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|----|
| Champa         | 0    |      |      |      |      |      |      |      |      |      |      |      |      |      |    |
| Sang Tarom     | 1.52 | 0    |      |      |      |      |      |      |      |      |      |      |      |      |    |
| Tarom Mahalli  | 1.52 | 1.48 | 0    |      |      |      |      |      |      |      |      |      |      |      |    |
| Deylamani      | 1.57 | 1.57 | 1.61 | 0    |      |      |      |      |      |      |      |      |      |      |    |
| Sadri          | 1.55 | 1.42 | 1.53 | 1.63 | 0    |      |      |      |      |      |      |      |      |      |    |
| Alikazemi      | 1.35 | 1.48 | 1.12 | 1.14 | 0.86 | 0    |      |      |      |      |      |      |      |      |    |
| Langroudi      | 1.63 | 1.40 | 1.55 | 1.52 | 1.53 | 1.29 | 0    |      |      |      |      |      |      |      |    |
| Mousa Tarom    | 1.53 | 1.45 | 1.63 | 1.54 | 1.41 | 1.21 | 1.54 | 0    |      |      |      |      |      |      |    |
| Hasan Saraie   | 1.45 | 1.50 | 1.18 | 1.47 | 1.47 | 1.20 | 1.30 | 1.01 | 0    |      |      |      |      |      |    |
| Binam          | 1.50 | 1.60 | 1.49 | 1.64 | 1.60 | 1.09 | 1.39 | 1.35 | 1.58 | 0    |      |      |      |      |    |
| Hasani         | 1.62 | 1.59 | 1.63 | 1.66 | 1.60 | 1.31 | 1.59 | 1.59 | 1.45 | 1.60 | 0    |      |      |      |    |
| Tarom Hashemi  | 1.63 | 1.33 | 1.43 | 1.44 | 1.47 | 1.28 | 1.66 | 1.46 | 1.29 | 1.31 | 1.53 | 0    |      |      |    |
| Gharib Reihani | 1.20 | 1.49 | 1.53 | 1.46 | 1.25 | 1.17 | 1.22 | 1.44 | 1.05 | 1.40 | 1.47 | 0.98 | 0    |      |    |
| Abjibouji      | 1.54 | 1.54 | 1.53 | 1.58 | 1.56 | 1.35 | 1.55 | 1.41 | 1.52 | 1.58 | 1.60 | 1.48 | 1.46 | 0    |    |
| Ahlami Tarom   | 1.35 | 1.36 | 1.16 | 1.33 | 1.11 | 0.86 | 1.04 | 1.30 | 1.04 | 1.24 | 1.32 | 1.01 | 0.77 | 0.86 | 0  |

In general, the results showed that there is a genetic variation between cultivars. It can be used in corrective programs and the source of the cultivated cultivars. The mahalanobis distance also explains that the resulting groups are different, how different and distinct from the conventional diagnosis of decomposition. The results of this study revealed that the phenological and agronomic traits can be used effectively to group rice cultivars and visualize the existence of natural groups. Although rice cultivars have been widely categorized as local and improved, there were widespread change in plant age, vegetative structures, yield components and grain yield in these groups. When crossing varieties belonging to different clusters from the wide range of mahalanobis distance, the opportunities for continuous segregation can be maximized. Therefore, it is likely that unrelated genotypes of distant clusters of desirable alleles in different loci are used. Considering germplasm collections, a representative collection should include the genetic diversity of rice cultivars with at least repetitiveness. This feature is important because the size of the gene banks of major crops continues to grow nationally and internationally. Therefore, the present study data with from of genetic characterization can be useful, at least to some extent, for selecting the main collections of rice. It also helps to define strategies for further collecting. By comparing these results with other studies, five groups, used mahalanobis  $D^2$  statistic, resonates with Siddique et al. (2013), who reported five and six groups from forty traditional Boro and forty Aman rice germplasm also using  $D^2$  statistics. The clustering pattern in this study demonstrated that germplasm is in the same cluster, albeit it is composed of the same geographical area. Chakravorty et al. (2013) evaluated 51 species of rice landraces and observed no lack of a specific relationship between geographical and genetic variation. The correlation analysis of genotypic and phenotypic traits can provide important information among studied crop species or

different groups of crop accessions (Li et al., 2000). Research has been concentrated on the analysis of the genetic and morphological diversity of a native aromatic rice germplasms in Bangladesh and significant phenotypic variation has been observed in a large number of aromatic rice germplasms (Islam et al., 2016). In Islam et al. (2018) study, the intra- (0.65-1.24) and inter- (3.70-16.31) the cluster distances shows a wide variety of diversity. This result is consistent with Islam et al. (2016), which measures the range of intra- and inter-cluster distances from 0.61 to 1.27 and 3.71 to 16.12 in aromatic rice, respectively. Bhakal and Lal (2015) suggest that having more distant clusters can provide hybridization to achieve a higher heterotic response. The results of this study suggest that crossing between germplasm of cluster III and IV may provide high heterosis as well as transgressive segregation (Islam et al., 2011; Sohrabi et al., 2012).

## CONCLUSIONS

The highest direct effect on PY was observed with panicle weight and no. of spikelet per panicle. The direct and indirect effects of these traits on PY (genetic correlation with paddy yield) were equal to 0.76 and 0.88. The indirect effect of no. of spikelet per panicle by PW, FLL and PM was 1.33, 0.8 and 0.98, respectively. The most indirect effect on paddy yield is about DFM and FT. The highest genetic distance was observed between *cv.* 'Langroudi' and *cv.* 'Tarom Hashemi'. The minimum genetic distance was observed between (*cv.* 'Alikazemi' and *cv.* 'Ahlami Tarom'); ('Tarom Hashemi' and 'Gharib Reihani'); (*cv.* 'Gharib Reihani' and 'Ahlami Tarom'); and (*cv.* 'Abjibouji' and 'Ahlami Tarom'). Totally, all local cultivars were close to each other in terms of the genetic distance. The results showed that genetic variation among cultivars was used in modified programs and the source of the production of modified cultivars.

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