Evaluation of Underutilized Kodo Millet (*Paspalum scrobiculatum* L.) Accessions using Morphological and Quality Traits

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**ABSTRACT**

**Background:** Kodo millet is an important drought tolerant crop and has high nutritional values, dietary fiber and antioxidant properties. It has considerable production potential in marginal and low fertility soils under diverse environmental conditions. Considering the importance of the crop, it is necessary to improve the nutritional quality along with grain yield of the crop. With this background, the investigation was aimed to study the correlation and path coefficient analysis which helps to identify the promising traits for yield and quality improvement.

**Methods:** One hundred and three kodo millet germplasm lines were evaluated for 13 morpho-agronomic and two grain nutritional traits. The crop was raised in randomized block design to select the promising genotypes and to study the association among the traits and the magnitude of direct and indirect effects for fifteen quantitative traits.

**Result:** Based on the overall mean performance the significant genotypes were identified and found wide range of variability for different traits. Character association studies indicated that days to first flowering, days to 50 per cent flowering, plant height, number of productive tillers, peduncle length, inflorescence length, length of the longest raceme and thumb length were significantly positive association with grain yield per plant. Path coefficient analysis revealed that inflorescence length, plant height, length of the longest raceme, flag leaf blade length and number of productive tillers exhibited high direct positive effect on grain yield. Therefore, giving importance of these traits during selections may be useful for developing nutritionally superior high yielding kodo millet genotypes.

**Key words:** Character association, Kodo millet, Path coefficient analysis, Yield.

**INTRODUCTION**

Kodo millet (*Paspalum scrobiculatum* (L.); Family - Poaceae), is a self pollinated crop and the species was domesticated in India about 3000 years ago (Malleshi and Hadimani, 1994). It is grown in India from Kerala and Tamil Nadu in the south, to Rajasthan, Uttar Pradesh and West Bengal in the north (de Wet et al., 1983). It is a traditional, long duration, hardy and drought resistant crop cultivated about 9 lakh hectares in India with an annual production of 3.11 lakh tonnes (Bondale, 1994; Singh, 1994). The seeds have an excellent storage life. It is a staple food for the poor in the marginal agricultural areas and it is nutritionally superior to many other cereal grains and has more dietary fibre, anti-oxidative (Chandrasekara and Shahidi, 2010) and anti-diabetic properties (Hegde et al., 2005). Keeping these views in mind, the present study was undertaken with the objectives of finding promising genotypes for yield and quality traits and to study the associations among traits which enables to identify the characters useful for higher yield and path coefficient analysis is useful in evaluating the causes, effects and relationship between yield and its contributing traits of kodo millet.

**MATERIALS AND METHODS**

**Experimental site and design**

The experiment was conducted with one hundred and three kodo millet accessions and was collected from Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai- 625 104, Tamil Nadu, India.¹Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

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Morphological characters
The following 15 quantitative characters were observed viz., days to first flowering (DF), days to 50 per cent flowering (DFF), plant height (PH), number of basal tillers (NBT), number of productive tillers (PT), flag leaf blade length (FLL), flag leaf blade width (FLW), peduncle length (PL), inflorescence length (IL), thumb length (TL), length of longest raceme (LLR), thousand grain weight (TGW), grain yield per plant (GY) (IBPGR, 1983). Grain quality traits like Zinc content (Zn) and Iron content (Fe) were estimated as per the method of Piper, 1966.

Statistical analysis
The collected quantitative data’s were subjected to correlation and path coefficient analysis.

Correlation coefficient analysis
The correlation coefficient was worked out to find out the relationship between yield and its components. The variance and covariance values were used to calculate the correlation by applying the formula as per Falconer (1964).

\[ r_{xy} = \frac{\text{Cov}_{g,x,y}}{\sqrt{\text{Var}_{g,x} \cdot \text{Var}_{g,y}}} \]

Where,
- \( r_{xy} \) = Genotypic correlation co-efficient.
- \( \text{Cov}_{g,x,y} \) = Genotypic covariance between the characters ‘x’ and ‘y’.
- \( \text{Var}_{g,x} \) = Genotypic variance of x (first trait).
- \( \text{Var}_{g,y} \) = Genotypic variance of y (second trait).

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Table 1: List of 103 kodo millet germplasm accessions used for the study.

| S. No | Name of the accessions | S. No | Name of the accessions | S. No | Name of the accessions |
|-------|------------------------|-------|------------------------|-------|------------------------|
| 1     | Aamo 68                | 35    | Sel 18                 | 69    | TNAU 140               |
| 2     | Aamo 83                | 36    | Sel 19                 | 70    | TNAU 141               |
| 3     | Aamo 89                | 37    | Sel 20                 | 71    | TNAU 145               |
| 4     | Aamo 90                | 38    | Sel 21                 | 72    | TNAU 146               |
| 5     | Aamo 101               | 39    | TNAU 82                | 73    | TNAU 148               |
| 6     | Aamo 126               | 40    | TNAU 84                | 74    | TNAU 149               |
| 7     | Aamo 258               | 41    | TNAU 85                | 75    | TNAU 150               |
| 8     | Aamo 271               | 42    | Sel 16                 | 76    | TNAU 151               |
| 9     | RK 50                  | 43    | TNAU 90                | 77    | TNAU 152               |
| 10    | RK 51                  | 44    | TNAU 91                | 78    | TNAU 153               |
| 11    | RK 82                  | 45    | TNAU 92                | 79    | TNAU 154               |
| 12    | RK 84                  | 46    | TNAU 93                | 80    | TNAU 155               |
| 13    | RK 111                 | 47    | TNAU 96                | 81    | TNAU 162               |
| 14    | RK 162                 | 48    | TNAU 97                | 82    | TNAU 164               |
| 15    | DPS 95                 | 49    | TNAU 98                | 83    | TNAU 165               |
| 16    | DPS 368                | 50    | TNAU 99                | 84    | TNAU 171               |
| 17    | ICK 86                 | 51    | TNAU 100               | 85    | TNAU 172               |
| 18    | ICK 1042               | 52    | TNAU 111               | 86    | TNAU 174               |
| 19    | ICK 7114               | 53    | TNAU 102               | 87    | TNAU 177               |
| 20    | IPS 102                | 54    | TNAU 104               | 88    | TNAU 179               |
| 21    | IPS 113                | 55    | TNAU 105               | 89    | TNAU 180               |
| 22    | IPS 118                | 56    | TNAU 107               | 90    | TNAU 187               |
| 23    | IPS 122                | 57    | TNAU 108               | 91    | TNAU 188               |
| 24    | IPS 123                | 58    | TNAU 109               | 92    | TNAU 190               |
| 25    | IPS 125                | 59    | TNAU 120               | 93    | TNAU 191               |
| 26    | RBK 73                 | 60    | TNAU 121               | 94    | TNAU 194               |
| 27    | RBK 155                | 61    | TNAU 123               | 95    | TNAU 195               |
| 28    | Sel 1                  | 62    | TNAU 124               | 96    | TNAU 197               |
| 29    | Sel 7                  | 63    | TNAU 127               | 97    | TNAU 201               |
| 30    | Sel 11                 | 64    | TNAU 128               | 98    | TNAU 236               |
| 31    | Sel 12                 | 65    | TNAU 129               | 99    | GPUK 3                  |
| 32    | Sel 14                 | 66    | TNAU 130               | 100   | Sel 6                  |
| 33    | Sel 15                 | 67    | TNAU 133               | 101   | CO 3                   |
| 34    | Sel 17                 | 68    | TNAU 137               | 102   | APK 1                  |
|       |                        |       |                        | 103   | TNAU 86                |
**Test of significance**

Significance of correlation coefficients was tested by comparing genotypic correlation coefficients with the correlation table values at (n-2) degrees of freedom where ‘n’ denotes the number of paired observations used in the calculation.

**Path coefficient analysis**

Path coefficient analysis was done as suggested by Wright (1921) and Dewey and Lu (1959). The direct and indirect effects were classified into different scales (Lenka and Mishra, 1973).

**RESULTS AND DISCUSSION**

**Identification of promising genotypes**

Among the studied accessions, the trait days to first flowering ranged from 49.00 to 77.00 with an average of 58.15. Fifty seven genotypes were found significantly earlier to flowering. The genotype TNAU 82 was early in flowering (49 days), whereas TNAU 155 and TNAU 236 were recorded to be late in flowering (77 days). The trait days to fifty per cent flowering varied from 52.00 (IPS 113 and TNAU 82) to 80.00 (TNAU 236) with an average of 61.34 and 57 genotypes were significantly earlier in flowering. The plant height ranged from 36.01 cm to 86.35 cm with an average of 59.42 cm. About 55 genotypes were found significantly dwarf in nature. The genotype, APK 1 (86.35 cm) was the tallest and GPUK 3 (36.01 cm) was at the shortest. These traits can be considered as useful in the breeding programme for developing a short duration with non-lodging plant type.

Number of basal tillers per plant ranged from 11.00 (IPS 122 and TNAU 133) to 25.22 (TNAU 107) with an average of 17.36 and number of productive tillers per plant varied from 3.83 (DPS 95) to 10.73 (Sel 21) and 50 genotypes were found significant for productive tillers with an average of 6.46. The trait flag leaf blade length, IPS 123 recorded the maximum length (17.14 cm) and genotype APK 1 (1.62 cm) recorded the maximum flag leaf width. The trait peduncle length ranged from 3.78 (Sel 19) cm to 8.25 cm (TNAU 86). CO 3 (20.80 cm) registered maximum inflorescence length, TNAU 149 (9.3 cm) recorded the highest length of the longest raceme and the genotype RK 50 (11.6 cm) registered the highest thumb length. Maximum thousand grain weight was registered by APK 1 (4.91 g) with an average of 3.68 and the total of 49 genotypes recorded significant performance.

The genotypes IPS 123 and TNAU 162 witnessed the highest Zinc content (6.87 mg/100g) with an average of 3.61 mg/100g. Significance were observed for Zn content in 55 genotypes. For Iron content, TNAU 84 (25.03 mg/100g) recorded the highest value with fifty significant genotypes.

The range of single plant yield realised in the present study ranged from 5.37 g to 31.37 g with an average of 15.19 g. Fifty one genotypes exhibited significant performance for single plant yield. Among them, the genotype Sel 21 registered as the high yielder (31.37 g). Patil et al. (2019) observed wide range of variation for quantitative traits in finger millet accessions. The identified superior genotypes for 15 traits were given in Table 2.

**Table 2:** Range of variability for 15 quantitative traits.

| Characters | Minimum | Maximum | Mean | Significant genotypes |
|------------|---------|---------|------|-----------------------|
| DF (TNAU 82) | 49.00 | 77.00 | 58.15 | 57 genotypes |
| DFF (IPS 113 and TNAU 82) | 52.00 | 80.00 | 61.34 | 57 genotypes |
| PH (GPUK 3) | 36.01 | 86.35 | 59.42 | 55 genotypes |
| NBT (IPS 122, TNAU 133) | 11.00 | 25.22 | 17.36 | 45 genotypes |
| PT (DPS 95) | 3.83 | 10.73 | 6.46 | 50 genotypes |
| FLL (TNAU 84) | 8.99 | 17.14 | 13.52 | 50 genotypes |
| FLW (TNAU 191) | 0.57 | 1.62 | 0.70 | 34 genotypes |
| PL (Sel 19) | 3.78 | 8.25 | 5.41 | 47 genotypes |
| IL (TNAU 97) | 8.38 | 20.8 | 12.72 | 48 genotypes |
| LLR (TNAU 133) | 3.87 | 9.32 | 6.18 | 39 genotypes |
| TL (TNAU 133) | 3.47 | RK 50 (11.62) | 6.00 | 46 genotypes |
| TGW (TNAU 152) | 2.47 | APK 1 (4.91) | 3.68 | 49 genotypes |
| Zn (Sel 20) | 0.10 | 6.87 (IPS 123 and TNAU 162) | 3.61 | 55 genotypes |
| Fe (TNAU 154) | 5.49 | 25.03 (TNAU 84) | 15.02 | 50 genotypes |
| GY (TNAU 133) | 5.37 | 31.37 (Sel 21) | 15.19 | 51 genotypes |

**Abbreviations used:** DF- Days to first flowering (days); DFF- Days to 50 per cent flowering (days); PH- Plant height (cm); NBT-Number of basal tillers (count); PT- Number of productive tillers (count); FLL- Flag leaf blade length (cm); FLW- Flag leaf blade width (cm); PL- Peduncle length (cm); IL- Inflorescence length (cm); LLR- Length of the longest raceme (cm); TL- Thumb length (cm); TGW- Thousand grain weight (g); Zn- Zinc content (mg/100g); Fe- Iron content (mg/100g); GY- Grain yield per plant (g).
Table 3: Genotypic correlation coefficient among fifteen characters in 103 kodo millet germplasm accessions.

| Character          | DF     | DFF | PH   | NBT  | PT    | FLL  | PL   | IL   | LLR  | TL   | TGW  | Zn   | Fe   |
|--------------------|--------|-----|------|------|-------|------|------|------|------|------|------|------|------|
| DF                 | 1      |     |      |      |       |      |      |      |      |      |      |      |      |
| DFF                | -0.304* | 1   |      |      |       |      |      |      |      |      |      |      |      |
| PH                 | 0.308*  | -1.017 | 1   |      |       |      |      |      |      |      |      |      |      |
| NBT                | 0.305*  | 0.304* | 0.306* | 1    |       |      |      |      |      |      |      |      |      |
| PT                 | -0.114 | -0.119 | 0.313* | -0.119 | 1    |      |      |      |      |      |      |      |      |
| FLL                | 0.112  | 0.117  | 0.312  | 0.117 | -0.114 | 1    |      |      |      |      |      |      |      |
| PL                 | 0.082  | 0.092  | 0.301* | 0.092 | 0.082 | 0.301* | 1    |      |      |      |      |      |      |
| IL                 | -0.276 | -0.276 | 0.431* | -0.276 | 0.276 | 0.431* | -0.276 | 1    |      |      |      |      |      |
| LLR                | -0.109 | -0.109 | 0.431* | -0.109 | 0.109 | 0.431* | -0.109 | -0.276 | 1    |      |      |      |      |
| TL                 | -0.290 | -0.290 | 0.431* | -0.290 | 0.290 | 0.431* | -0.290 | -0.109 | -0.276 | 1    |      |      |      |
| TGW                | 0.097  | 0.097  | 0.431* | 0.097 | 0.097 | 0.431* | 0.097 | 0.097 | 0.431* | -0.276 | 1    |      |      |
| Zn                 | 0.173  | 0.173  | 0.554** | 0.173 | 0.173 | 0.554** | 0.173 | 0.173 | 0.554** | 0.431* | -0.276 | 1    |      |
| Fe                 | 0.058  | 0.058  | 0.431* | 0.058 | 0.058 | 0.431* | 0.058 | 0.058 | 0.431* | 0.173 | 0.173 | -0.276 | 1    |

**Significant at 5% level; ***Significant at 1% level.

Correlation coefficient analysis

Association of yield and other component traits helps plant breeders to focus on yield improvement in the desired direction. Among fifteen characters studied, the characters viz., days to first flowering \((r = 0.304)\), days to 50 per cent flowering \((r = 0.305)\), plant height \((r = 0.313)\), number of productive tillers \((r = 0.482)\), peduncle length \((r = 0.208)\), inflorescence length \((r = 0.406)\), length of the longest raceme \((r = 0.508)\) and thumb length \((r = 0.278)\) were positively and significantly correlated with grain yield per plant (Table 3).

Number of basal tillers \((r = 0.162)\), thousand grain weight \((r = 0.157)\), flag leaf length \((r = 0.090)\), flag leaf width \((r = 0.069)\), Fe content \((r = 0.035)\) and Zn content \((r = 0.014)\) expressed positive but non-significant association with grain yield. Similar results have also been reported earlier by Vishnuprabha and Vanniarajan (2018) for Zn content in barnyard millet. Hence, it might be inferred that these traits could be considered as most important yield contributing traits in kodo millet. This is in accordance with the findings of Plawani Panda (2015) who found that positive correlation of yield with days to first flowering, days to 50 per cent flowering, plant height, peduncle length and inflorescence length in barnyard millet; Jadhav et al. (2015) for days to 50% flowering, plant height and productive tillers per plant in finger millet. While Verma and Singh (1982) opined that plant height was positively correlated with grain yield in early and medium maturing genotypes in kodo millet. Yadava and Jain (2006) indicated that plant height was significantly and positively correlated with grain yield in early and late maturing genotypes of kodo millet. In foxtail millet, Pavithra (2015) registered positive correlation of yield with plant height, peduncle length and inflorescence length. Prakash and Vanniarajan (2014) in proso millet and Suryanarayana et al. (2014) in finger millet had similar findings in days to 50 per cent flowering and plant height; Rameshwarlakumar (2009) for peduncle length in little millet.

In terms of inter correlation among components studied, number of productive tillers revealed significant positive association with thumb length, length of the longest raceme, thousand grain weight, inflorescence length and peduncle length. Peduncle length showed significant and positive association with inflorescence length, thumb length, length of the longest raceme, and thousand grain weight. Similar results were reported by Plawani Panda (2015) for inflorescence length and thousand grain weight in barnyard millet; Anantharaju and Ganesan (2005) for thousand grain weight in finger millet.

Inflorescence length showed positive and significant association with thumb length, length of the longest raceme and thousand grain weight. Similar results were reported by Plawani Panda (2015) for thousand grain weight in barnyard millet. Length of the longest raceme showed a significant and positive association with thumb length and thousand grain weight. Thumb length showed positive association with thousand grain weight.
Table 4: Path analysis direct (diagonal) and indirect effects of fourteen characters on grain yield in kodo millet.

| DF  | DFF | PH   | NBT  | PT   | FLL  | FLW  | PL   | IL   | LLR  | TL   | TGW  | Zn  | Fe  | Correlation coefficient |
|-----|-----|------|------|------|------|------|------|------|------|------|------|-----|-----|------------------------|
| 0.2855 | -0.7351 | 0.9840 | 0.0223 | 0.1140 | 0.0752 | -0.1658 | -0.8729 | 0.7466 | 0.3405 | -0.4595 | -0.0006 | -0.0127 | -0.0180 | 0.304** |
| 0.2868 | -0.7317 | 0.9957 | 0.0206 | 0.1140 | 0.0682 | -0.1848 | -0.8878 | 0.7836 | 0.3418 | -0.4746 | -0.0006 | -0.0110 | -0.0157 | 0.305** |
| 0.2382 | -0.6178 | 1.1792 | 0.0150 | 0.1112 | 0.0982 | -0.2281 | -1.2655 | 0.9927 | 0.3083 | -0.4854 | -0.0006 | -0.0131 | -0.0200 | 0.313** |
| 0.0347 | -0.0821 | 0.9066 | 0.1836 | 0.1017 | -0.0230 | -0.1259 | -0.1322 | 0.1094 | 0.0769 | -0.0741 | -0.0003 | 0.0058 | -0.0094 | 0.162 |
| 0.0880 | -0.2256 | 0.3547 | 0.0505 | 0.3698 | 0.0265 | -0.1171 | -0.4147 | 0.4013 | 0.1991 | -0.2114 | -0.0005 | 0.0094 | 0.2899 | 0.482** |
| 0.0478 | -0.1112 | 0.2579 | -0.0094 | 0.0218 | 0.4492 | -0.0425 | -0.4906 | 0.0772 | -0.1300 | 0.0565 | 0.0002 | -0.0272 | -0.0097 | 0.090 |
| 0.0650 | -0.1857 | 0.3694 | 0.0317 | 0.0595 | 0.0262 | -0.7281 | -0.3259 | 0.7679 | 0.2439 | -0.2360 | -0.0006 | 0.0063 | -0.0243 | 0.069 |
| 0.1475 | -0.3846 | 0.8835 | 0.0143 | 0.0908 | 0.1304 | -0.1405 | -1.6891 | 1.3182 | 0.2328 | -0.3726 | -0.0005 | -0.0107 | -0.0116 | 0.208* |
| 0.1327 | -0.3570 | 0.7290 | 0.0125 | 0.0924 | 0.0216 | -0.3482 | -1.3866 | 1.6058 | 0.3345 | -0.4080 | -0.0006 | 0.0035 | -0.0182 | 0.406** |
| 0.1575 | -0.4052 | 0.5890 | 0.0229 | 0.1193 | -0.0946 | -0.2877 | -0.6370 | 0.8701 | 0.6173 | -0.4327 | -0.0008 | 0.0002 | -0.0094 | 0.508** |
| 0.2190 | -0.5796 | 0.9555 | 0.0227 | 0.1305 | -0.0424 | -0.2868 | -1.1056 | 1.0935 | 0.4458 | -0.5991 | -0.0007 | 0.0053 | -0.0239 | 0.278** |
| 0.1068 | -0.2799 | 0.4243 | 0.0318 | 0.1109 | 0.0565 | -0.2725 | -0.5296 | 0.5913 | 0.2819 | -0.2434 | -0.0017 | -0.0112 | -0.0175 | 0.157 |
| 0.0373 | -0.0823 | 0.1582 | 0.0109 | 0.0356 | 0.1251 | 0.0474 | -0.1849 | 0.0580 | 0.0017 | 0.0329 | 0.0002 | -0.0978 | -0.0404 | 0.014 |
| -0.038 | 0.0857 | -0.1753 | -0.0128 | -0.0797 | -0.0327 | 0.1316 | 0.1468 | -0.2181 | -0.0435 | 0.1066 | 0.0002 | 0.0294 | 0.1344 | 0.035 |

Residual effect = 0.34

**Significant at 1% level
*Significant at 5% level

Abbreviations used: DF- Days to first flowering (days); DFF- Days to 50 per cent flowering (days); PH- Plant height (cm); NBT-Number of basal tillers (count); PT- Number of productive tillers (count); FLL- Flag leaf blade length (cm); FLW- Flag leaf blade width (cm); PL- Peduncle length (cm); IL- Inflorescence length (cm); LLR- Length of the longest raceme (cm); TL- Thumb length (cm); TGW- Thousand grain weight (g); Zn- Zinc content (mg/100g); Fe- Iron content (mg/100g); GY- Grain yield per plant (g).
Examination of correlation among component characters revealed that strong associations are present among desirable component characters viz., number of productive tillers, peduncle length, inflorescence length, length of the longest raceme and thumb length. Hence, selection criteria should consider all these characters for the improvement of grain yield. Undesirable association of some of the component characters might act as deterrent for the formulation of a comprehensive selection programme involving these traits. So, during selection programme, these factors might be considered with a caution.

Path coefficient analysis

Path coefficient analysis was undertaken to study the direct and indirect effects of the different traits on yield. The direct and indirect effects of fifteen characters on grain yield are presented in Table 4 and Fig 1. Path analysis revealed that inflorescence length (1.606) and plant height (1.179) had the highest positive direct effect on grain yield per plant which was followed by length of the longest raceme (0.617), flag leaf length (0.449) and number of productive tillers (0.370). Hence, direct selection for these traits would be rewarding for yield improvement, which will also reduce the undesirable effect of the component traits studied. The results were similar to the findings reported by Plawani Panda (2015) for plant height and inflorescence length; Prakash and Vanniarajan (2015) for plant height in barnyard millet; Shalini et al. (2010) for plant height and number of productive tillers in proso millet. Andualem and Tadesse (2011) and Suryanarayana et al. (2014) for plant height in finger millet. It is known to contribute grain yield via more number of grains per panicle which were in conformity with the findings of Sonnad et al. (2008) in finger millet.

Regarding the indirect effect of component traits on grain yield, inflorescence length had high indirect effect through peduncle length (1.318), thumb length (1.094) and plant height (0.993). Whereas for plant height had high indirect effect through days to first flowering (0.984), days to fifty percent flowering (0.996) and thumb length (0.956). High and positive indirect effect of plant height through days to 50 per cent flowering was earlier reported by Thakur and Saini (1995) and Mishra (1996) in finger millet.

CONCLUSION

On the basis of above findings it can be concluded that the characters, days to first flowering, days to 50 per cent flowering, plant height, number of productive tillers, peduncle length, inflorescence length, length of the longest raceme and thumb length exhibited highly significant positive correlation with grain yield per plant indicating the usefulness of these traits for improving upon grain yield in kodo millet. Path coefficient analysis revealed that the highest direct effect on grain yield per plant was exerted by inflorescence length followed by plant height, length of the longest raceme, flag leaf blade length and number of productive tillers, showing its more accountability for higher grain yield. Therefore, it may be possible to improve the yield and quality by selecting the genotypes based on the above characters.

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