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Research Note

# Genetic variability among B & R lines on *milo* and *maldandi* cytoplasm across the years in *rabi* sorghum [*Sorghum bicolor* (L.) Moench]

**Lokesh Kumar Verma[1*] and B. D. Biradar[2]**

[1]University of Agriculture Sciences, Dharwad, Karnataka
[2]Department of Genetics and Plant Breeding, University of Agriculture Sciences, Dharwad, Karnataka
***E-Mail**:vermal@uasd.in

**Abstract**
The genetic study was conducted among 68 genotypes comprising restorers and maintainers on *milo* and *maldandi* cytoplasm. Among the lines, IS 12735, DSMR-8, IS 33353 and IS 24175 exhibited full restoration on *milo* and DSMR-4 and DSMR-8 on *maldandi*. The lines *viz*., IS 30383, IS 29335, IS 29914, IS 8012 and IS 12308 exhibited perfect maintainer reaction on both *milo* & *maldandi*. High heritability and genetic advance were observed for most of the traits. G x E interaction was also found to be high for the majority of the traits. A high amount of genetic variability among the population indicated an increased opportunity for the selection of restorers, maintainers as the variation is heritable.

**Keywords**: *Milo*, *Maldandi*, *Rabi*, Heritability, Genetic advance, Pooled analysis.

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the important cereal crops cultivated globally for food, fodder, feed and fuel. It ranks fifth after wheat, rice, maize and barley in area and production. Globally, sorghum is grown in 42.50 million hectares to produce 59.91 million tonnes, with a productivity of around 1.60 tonnes per hectare. In India, the yield level has reached a plateau (9.00 to 10.00 q/ha). One of the saturation in productivity is due to limited genetic diversity among B & R, lines in the development of hybrids. This is mainly due to the single source of male sterility system *viz*., *milo*, which restricts nuclear diversity among B & R apart from creating cytoplasmic uniformity among hybrids. To overcome this, it is required to introduce diverse sterility systems ($A_2$, $A_3$, maldandi, $G_1$ and VZM, etc.) and potential restorers on these sources. Keeping these things in view, 68 diverse lines were selected from the mini core on sorghum received from ICRISAT, Patencheru studied for the genetic variability of 19 quantitative traits.

The experimental material consisted of 68 germplasm lines, to study the variability, heritability, and genetic advance for the nineteen traits. The experiment was conducted in Complete Randomized Block Design with two replications. Each genotype was sown in two rows of 3 m at Botany garden, Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad in *rabi* 2017 and 2018. All recommended agronomic packages of practices were followed to raise a good crop expression and the crop was raised in the protected irrigation. Observations on traits, namely, days to 50 % flowering, peduncle length (cm), panicle length (cm), panicle breadth (mm), primaries per panicle, whorls per panicle, leaves per plant, nodes per plant, plant height (cm), stem girth (mm), panicle weight per plant (g), grain yield per plant (g), test weight (g), grains per panicle, 1000 grains volume (cc), grain density, grain length (mm), grain width (mm) and grain thickness were recorded on randomly selected five competent plants in each

replication. The replication-wise mean values from both years were subjected to statistical analysis (Snedecor and Cochran, 1967). Pooled analysis across years was carried out by following Comstock and Robinson's (1952). The GCV and PCV were estimated as per the procedure suggested by Burton and De Vane (1953). Heritability in the broad sense was estimated as per the procedure given by Hanson *et al.*(1956). Genetic advance as per cent of the mean was categorized as given by Johnson *et al*.(1955).

Highly significant differences between genotypes for all the studied traits were observed in both years. The pooled ANOVA for combined analysis over two years was estimated. The results showed significant differences between the two years for almost all the traits under study except for grain width, plant height, stem girth and panicle weight. A similar result was obtained by Jimmy *et al*. (2017), where plant height was observed as non-significant. The G x E interaction was also highly significant for almost all the traits which showed a differential response and differential performance of the genotypes in different environments (year). This outcome agrees with the findings of Almeida *et al*. (2014). The results of pooled variance towards grain yield were due to genotypes followed by G x E interaction and a small proportion was contributed by the years. The treatments exhibited highly significant differences for all the traits.

Genotype x Environment was found to be significant for all the studied traits except for nodes per plant, stem girth, and grain width. The significant differences of these traits reveal inconsistencies in the performances of sorghum genotypes for these traits over the years environments. The non-significant traits *viz.,* nodes per plant, stem girth, and grain width reveal their consistent performance in both years.

The year 2017 was observed favorable for grain yield and panicle weight per plant with mean values of 63.41 g and 73.85 g per plant, respectively, indicating that the year 2017 was more favorable for sorghum production.

The mean grain yield over the two years was 59.75 g per plant, with genotype mean grain yield ranged from 28.15 g (IS 24492) to 112.81 g (PKV Kranti), indicating a wide difference in yield potential across two years. The identified restorers *viz*., IS 12735, DSMR-8, IS 33353 and IS 24175 were also found to be superior for grain yield and yield attributes. The lines *viz*., IS 30383, IS 29335, IS 29914, IS 8012 and IS 12308 were recorded as perfect maintainers on both *milo* and *maldandi* (**Table1**). These maintainers also exhibited superiority for yield and yield contributing traits among identified maintainers. The identified restorers and maintainers can be useful for the diversification of the nuclear base. The identified maintainers had high mean values for grain yield and yield contributing traits along with the short stature *viz*., IS 30383 (147.01 cm) and IS 29335 (162.80 cm) were most suited for conversion into new male sterile lines. By pooling all the maintainers as well as restorers, more diverged and productive maintainers and restorers can be exploited.

High GCV and PCV were recorded for the traits *viz*., panicle length, panicle weight, grain yield, grains per panicle, 1000 grain volume in the year 2017, the year 2018 and for pooled analysis as well (**Table 2**). Santhiya *et al.* (2021) and Shivaprasad *et al.* (2019) also reported the high GCV and PCV for the above traits. For most of the traits *viz*., peduncle length, primaries per panicle, grain length and grain thickness the high and moderate GCV and PCV were recorded in the year 2017 and across the years. However, during the year 2018, these estimates were found to be moderate to low.

All the traits exhibited a high level of broad sense heritability in the pooled data and the years 2017 & 2018. If a trait has high heritability, selection for such traits could be easy, and the selection of genotypes based on grain yield and contributing traits would be sufficient to increase the yield in sorghum. Ranjith *et al*. (2018) also recorded high heritability for grain yield, test weight and plant height. The density of the seeds exhibited low GCV across the years and in the pooled analysis as well. It

**Table 1. List of agronomically superior restorers and maintainers on *Milo* and *Maldandi* sources of male sterility**

| S. No. | Genotypes | Origin | Grain yield (g) | S. No. | Genotypes | Origin | Grain yield (g) |
|---|---|---|---|---|---|---|---|
| **Restorers on *milo*** | | | | | | | |
| 1 | IS 12735 | Yemen | 96.39 | 3 | IS 33353 | Kenya | 55.59 |
| 2 | DSMR-8 | India | 76.31 | 4 | IS 24175 | Tanzania | 68.90 |
| **Restorers on m*aldandi*** | | | | | | | |
| 1 | DSMR-8 | India | 76.31 | 2 | DSMR-4 | India | 56.47 |
| **Maintainers on *milo* and *maldandi*** | | | | | | | |
| 1 | IS 30383 | China | 88.60 | 4 | IS 8012 | Japan | 75.03 |
| 2 | IS 29335 | Swaziland | 72.05 | 5 | IS 12308 | Zimbabwe | 67.79 |
| 3 | IS 29914 | Zimbabwe | 64.91 | | | | |

**Table 2. Genetic variability parameters for grain yield and its attributes**

| Parameters | Days to 50 % flowering | | | Peduncle length (cm) | | | Panicle length (cm) | | | Panicle breadth (mm) | | | Primaries per panicle | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled |
| Vg | 34.44 | 24.98 | 56.52 | 136.75 | 88.68 | 206.77 | 40.15 | 25.67 | 58.07 | 57.14 | 56.52 | 107.83 | 174.08 | 69.20 | 224.91 |
| Vp | 38.76 | 27.78 | 60.08 | 154.03 | 108.24 | 225.19 | 45.33 | 29.44 | 62.55 | 73.21 | 82.49 | 128.84 | 233.22 | 70.00 | 288.68 |
| GCV (%) | 8.38 | 7.58 | 11.06 | 26.49 | 19.29 | 30.94 | 27.20 | 22.82 | 33.50 | 19.03 | 16.70 | 24.51 | 21.63 | 84.60 | 23.89 |
| PCV (%) | 8.89 | 7.99 | 11.40 | 28.12 | 21.31 | 32.29 | 28.90 | 24.45 | 34.77 | 21.54 | 20.18 | 26.79 | 25.04 | 39.00 | 27.06 |
| $h^2_{bs}$ (%) | 88.87 | 89.92 | 94.08 | 88.78 | 81.93 | 91.82 | 88.57 | 87.17 | 92.84 | 78.05 | 68.52 | 83.69 | 74.64 | 70.00 | 77.91 |
| GAM | 16.27 | 14.80 | 22.09 | 51.43 | 35.97 | 61.07 | 52.73 | 43.90 | 66.49 | 34.64 | 28.48 | 46.19 | 38.50 | 64.00 | 43.44 |
| Mean | 75.53 | 69.98 | 70.75 | 44.14 | 48.82 | 46.48 | 23.30 | 22.20 | 22.75 | 39.71 | 45.01 | 42.36 | 60.99 | 64.57 | 62.78 |
| Minimum | 56.50 | 58.00 | 59.00 | 23.10 | 28.00 | 26.90 | 10.24 | 10.98 | 10.61 | 22.90 | 28.41 | 26.61 | 34.90 | 37.90 | 40.05 |
| Maximum | 84.00 | 80.00 | 82.00 | 69.10 | 70.49 | 69.79 | 51.67 | 35.11 | 42.30 | 59.90 | 67.77 | 61.62 | 90.50 | 99.70 | 92.25 |

Table 2 continued….

| Parameters | Whorls per panicle | | | Leaves per plant | | | Nodes per plant | | | Plant height (cm) | | | Stem girth (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled |
| Vg | 1.84 | 10.80 | 1.82 | 1.50 | 1.60 | 2.98 | 1.81 | 1.77 | 3.54 | 1737.83 | 1198.87 | 2752.58 | 1.08 | 0.96 | 1.99 |
| Vp | 3.54 | 10.40 | 3.16 | 1.98 | 2.00 | 3.42 | 2.16 | 2.10 | 3.87 | 2033.34 | 1398.92 | 3000.36 | 2.80 | 1.68 | 3.21 |
| GCV (%) | 14.96 | 12.40 | 13.68 | 14.50 | 16.55 | 21.45 | 15.04 | 16.04 | 21.81 | 18.72 | 15.42 | 23.46 | 7.72 | 7.33 | 10.52 |
| PCV (%) | 20.78 | 11.40 | 18.03 | 16.68 | 18.48 | 22.98 | 16.42 | 17.43 | 22.81 | 20.24 | 16.65 | 24.49 | 12.40 | 9.70 | 13.36 |
| $h^2_{bs}$ (%) | 51.84 | 10.00 | 57.56 | 75.56 | 80.25 | 87.15 | 83.93 | 84.66 | 91.37 | 85.47 | 85.70 | 91.74 | 38.70 | 57.07 | 0.62 |
| GAM | 22.20 | 10.80 | 2.11 | 25.96 | 30.54 | 41.26 | 28.38 | 30.40 | 42.94 | 35.64 | 29.40 | 46.28 | 9.89 | 11.41 | 17.07 |
| Mean | 9.06 | 10.65 | 9.85 | 8.44 | 7.65 | 8.05 | 8.94 | 8.30 | 8.62 | 222.73 | 224.61 | 223.67 | 13.48 | 13.34 | 13.41 |
| Minimum | 5.00 | 6.60 | 7.30 | 5.90 | 5.30 | 5.95 | 6.70 | 6.40 | 6.60 | 130.26 | 137.66 | 135.85 | 9.90 | 11.16 | 10.75 |
| Maximum | 11.70 | 12.40 | 11.70 | 12.00 | 12.10 | 12.05 | 12.60 | 12.60 | 12.60 | 329.18 | 287.50 | 304.01 | 16.20 | 16.84 | 16.44 |

Table 2 continued….

| Parameters | Panicle weight/plant (g) | | | Grain yield/plant (g) | | | 1000 grain weight (g) | | | Grains/panicle | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled |
| Vg | 554.61 | 390.24 | 756.52 | 541.31 | 266.30 | 611.8 | 57.85 | 34.85 | 86.46 | 189576.20 | 245778.47 | 322284.8 |
| Vp | 611.13 | 498.05 | 838.69 | 580.00 | 333.75 | 664.60 | 60.89 | 38.85 | 89.97 | 250787.69 | 347142.23 | 403572.4 |
| GCV (%) | 31.89 | 27.01 | 37.42 | 36.56 | 29.10 | 41.40 | 24.83 | 19.34 | 30.41 | 21.19 | 26.43 | 28.89 |
| PCV (%) | 33.48 | 30.51 | 39.40 | 37.84 | 32.58 | 43.15 | 25.47 | 20.42 | 31.02 | 24.38 | 31.41 | 32.33 |
| $h^2_{bs}$ (%) | 90.75 | 78.35 | 0.90 | 93.33 | 79.79 | 92.06 | 95.01 | 89.71 | 96.09 | 75.59 | 70.80 | 79.86 |
| GAM | 62.58 | 49.24 | 73.22 | 72.75 | 53.54 | 81.83 | 49.86 | 37.74 | 61.41 | 37.96 | 45.80 | 53.18 |
| Mean | 73.85 | 73.15 | 73.50 | 63.41 | 56.08 | 59.75 | 30.63 | 30.52 | 30.58 | 2054.40 | 1876.05 | 1965.23 |
| Minimium | 32.85 | 34.34 | 36.84 | 24.80 | 26.48 | 28.15 | 17.15 | 16.42 | 16.79 | 1291.55 | 977.17 | 1219.44 |
| Maximum | 145.57 | 147.30 | 129.66 | 139.66 | 119.60 | 112.81 | 45.92 | 40.71 | 41.33 | 3041.75 | 3063.26 | 2824.34 |

Table 2 continued….

| Parameters | 1000 grain volume (cc) | | | Grain density | | | Grain length (mm) | | | Grain width (mm) | | | Grain thickness (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled |
| Vg | 37.85 | 28.78 | 62.92 | 0.01 | 0.01 | 0.013 | 0.20 | 0.12 | 0.271 | 0.20 | 0.15 | 0.313 | 0.09 | 2.56 | 0.13 |
| Vp | 41.72 | 31.53 | 66.24 | 0.03 | 0.01 | 0.021 | 0.23 | 0.17 | 0.308 | 0.22 | 0.18 | 0.346 | 0.11 | 2.81 | 0.15 |
| GCV (%) | 25.55 | 20.71 | 35.32 | 8.90 | 7.15 | 9.12 | 10.72 | 7.61 | 11.88 | 11.80 | 10.21 | 14.59 | 11.44 | 2.59 | 13.70 |
| PCV (%) | 26.82 | 21.68 | 36.24 | 12.75 | 8.32 | 11.69 | 11.50 | 8.90 | 12.67 | 12.31 | 10.95 | 15.35 | 12.39 | 2.53 | 14.47 |
| $h^2_{bs}$ (%) | 90.72 | 91.27 | 95.00 | 48.81 | 73.77 | 60.89 | 86.92 | 73.18 | 87.87 | 91.92 | 86.96 | 90.30 | 85.25 | 2.71 | 89.58 |
| GAM | 50.13 | 40.76 | 70.91 | 12.82 | 12.65 | 14.67 | 20.59 | 13.42 | 22.94 | 23.30 | 19.62 | 28.56 | 21.75 | 2.87 | 26.71 |
| Mean | 24.08 | 25.90 | 24.99 | 1.28 | 1.18 | 1.27 | 4.18 | 4.59 | 4.38 | 3.81 | 3.86 | 3.83 | 2.62 | 2.69 | 2.66 |
| Minimum | 12.00 | 13.75 | 12.88 | 0.79 | 1.02 | 1.00 | 3.13 | 3.45 | 3.29 | 3.13 | 2.67 | 2.62 | 1.95 | 2.18 | 2.14 |
| Maximum | 36.00 | 36.00 | 35.00 | 1.82 | 1.66 | 1.50 | 5.21 | 5.18 | 5.19 | 5.21 | 4.60 | 4.63 | 3.38 | 3.20 | 3.28 |

shows that the grain density is under the strong influence of the environment. Whorls per panicle and stem girth were also influenced by the environments as they exhibited low GCV and selection for these traits would not be much effective.

All the traits exhibited high genetic advance across the year and for pooled analysis as well, except for days to 50 % flowering and grain density in the year 2017, days to 50 % flowering, whorls per panicle, stem girth, grain density, grain length, grain width and grain thickness in the year 2018 and stem girth and grain density for pooled analysis, which showed a moderate level of genetic advance. The trait, stem girth was found to be low for genetic advance in the year 2017. The effectiveness of selection depends upon genetic advance over a mean (GAM) of the trait selected along with high heritability. All the traits except stem girth and grain density showed high heritability along with high GAM in pooled data. A similar higher estimate of GAM for grain yield per plant, plant height, test weight and panicle length was reported by Gebremedhn and Firew (2020). The stem girth showed moderate heritability and low GAM, whereas grain density exhibited moderate heritability and moderate GAM. Chalachew *et al*. (2019) also observed similar findings for days to flowering and grain yield. High heritability with high GAM indicates the control of additive genes and early selection may be effective for these characters. It is evident that high GCV along with high heritability and genetic advance is an effective selection criterion. Based on the results of the present study, the traits, namely, peduncle length, panicle length, primaries per panicle, leaves per plant, panicle weight, grain yield, test weight, grains per panicle and 1000 grain volume noticed to high GCV, high heritability and high GAM in the pooled analysis.

However, days to 50 % flowering, panicle breadth, whorls per panicle, nodes per plant, plant height, grain length, grain width, and grain thickness exhibited moderate GCV along with high heritability and GAM. These are the most important traits for effective selection in sorghum, as indicated by this study. Heritability in a broad sense was observed high by Chalachew and Semahegn (2020) for all important quantitative traits. High GAM was revealed by plant height, panicle length, primaries per panicle, grain yield, test weight, seed volume, grain length, grain width, and grain thickness. This indicates that early selection for these traits will enhance the grain yield. The traits possessing low genetic advance with high or moderate heritability like stem girth in this study indicated non-additive gene action; thus, a simple selection procedure in early segregating generations will not be much effective for these traits.

Sorghum is one of the major important cereal crops, for millions of people across nations. The G x E interaction revealed that the genotypes were significantly different across the year for grain yield and yield contributing traits. Environmental conditions of *rabi*-2017 were found favorable for the majority of genotypes. The restores on *milo viz*., IS 12735, DSMR-8, IS 33353, and IS 24175 had the highest grain yield and yield contributing traits and on *maldandi viz*., DSMR-8 & DSMR-4. Among the maintainers, IS 30383, IS 29335, IS 29914, IS 8012, and IS 12308 were found superior for grain yield and yield contributing traits across years. A high amount of genetic variability among the population indicated an increased opportunity for the selection of restorers, and maintainers as the variation is a heritable one.

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