Studies on Genetic Variability and Low Nitrogen Tolerance of S1 Lines Derived from Local Maize (Zea mays L.) Germplasm

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A B S T R A C T

Ten S1 lines along with three hybrids were evaluated in randomized block design at Instructional-cum-Research (ICR) Farm of Assam Agricultural University, Jorhat. The aim to study the genetic variability, heritability, genetic advance and low nitrogen tolerance of S1 lines derived from local maize germplasms. The experiment consisted of two trials with the same set of genotypes in two different nitrogen levels, viz., 80 kg N ha⁻¹ and 0 kg N ha⁻¹. Analysis of variance revealed presence of sufficient amount of variation among the genotypes for the traits except ears per plant at both N₀ and N₈₀ levels. At both N₀ and N₈₀ levels moderate to high estimates of GCV and PCV recorded for grain yield per plant, ear height, number of kernels per row, ear length, days to 50% pollen-shed, 100 KW, NRA and NUE indicated sufficient variability in the set of germplasms. For grain yield and nitrogen use efficiency, the S1 lines viz., MIZ-2 and MEG-11 were identified as promising at N₈₀ level and MEG-11 and TR-1 were identified as promising at N₀ level. MIZ-2, AR-1, MIZ-7 and TR-1 had less ASI at N₀ level. It indicates that those lines could be tolerant to low N-stress.

Keywords: Maize, Low nitrogen, S1 lines, Local germplasms, Genetic variability

Introduction

Maize (Zea mays L.) is the third most important cereal crop next to rice and wheat and it is mainly used as staple food and animal feed in most of the developing countries. Farmers of North East India usually grow maize and many other crops under low input situation. Higher productivity in maize can be easily achieved by application of chemical fertilizers and other improved agro-techniques. Continuous application of large quantity of fertilizers year after year causes reduction in soil health and has negative impact on environment in addition to adverse economic stress on the farmers. Local maize germplasm are adapted to adverse soil and climatic situations such as low input conditions of soil. These situations include various biotic and abiotic stresses. Among the
abiotic stresses, low nitrogen (N) is a major constraint to the productivity and production of the crop. The Indian soils are mainly low in organic matter and cation exchange capacity (Jones and Wild, 1975) resulting in low N availability. Considering the low soil N in maize production, it would be desirable to develop maize cultivars capable of fully exploiting available nutrients in soil, or productive under low soil nitrogen levels. This would further broaden the cultivation of maize and also offer economic and environmental benefits (Omoigui et al., 2007).

Nitrogen is an important element of maize production as it promotes vegetative growth, maximizes both kernel initiation and kernel set. Nitrogen deficiency interferes with protein synthesis, induces leaf senescence and therefore, reduces the general growth of the maize plant (Bruns and Abel, 2003) thereby limiting yield. The low N tolerant cultivars are superior in the utilization of available N, either due to enhanced uptake capacity or because of more efficient use of absorbed N in grain production (Laffitte and Edmeades., 1994). N-use efficiency (NUE) is defined as grain production per unit of N available in the soil (Moll et al., 1982).

Systematic investigation of germplasm for issues like tolerance to low-nitrogen and other stresses is important to identify appropriate material. Development and evaluation of inbreds from local maize germplasm may possess genes for one or more important biotic and abiotic stresses although they may possess fewer genes for grain yield. Inbreds developed from certain germplasm may possess unique alleles for yield and resistance to different stresses and such inbreds may be used for improving the parents of an elite hybrid through recycling methodology. S1 lines may be tested for per se performance for grain yield and other important traits. Once identified, the number of S1 lines may be minimised for their advancement to S2 and subsequent selfed generations. Early testing of inbreds either for per se performance or general combining ability helps the breeders minimise expenditure to be incurred, space to be utilized and time to be spent. Favourable alleles for various traits are dispersed in local germplasm. It is necessary to know the nature and magnitude of genetic variation in a set of local germplasm under study. Methodology for genetic improvement of plants differ depending upon mode of pollination, nature of traits whether qualitative or quantitative and other factors. Therefore, genetic variation and its various parameters are necessary to take an appropriate decision in plant breeding strategies.

Materials and Methods

Experimental site

The experimental site is located at Instructional-cum-Research (ICR) Farm of Assam Agricultural University, Jorhat at 26°46′ N latitude, 94°13′ E longitude and 86.6 m above the mean sea level (MSL). The climate of the area is sub-tropical humid.

Experimental material

Local maize germplasms were collected from different areas of North East India. Ten S1 lines derived from local maize germplasm were used in present study. Three hybrids namely, P-3399, P-3522 and KMH25K45 were also included (Table 1). The entries from Sl. No. 1 to Sl. No. 10 were different S1 lines derived from different maize germplasm.

S1 lines derived from local maize germplasm (rabi, 2015-2016)

During the rabi season (2015-16), all the ten germplasms were planted in a nursery under optimal NPK fertility condition (80 kg N ha⁻¹,
40 kg P ha\(^{-1}\) and 40 kg K ha\(^{-1}\)). The entries were grown for selfing operation. The plot of each entry had four rows with a row length of 4 m, spacing being 0.60 m between rows and 0.20 m between plants. The nursery was maintained clean of weeds by hand weeding. Operation of planting, self-pollination and harvesting was done by hand. All harvested S\(_1\) cobs were dried properly and stored separately.

**Experimental environment**

The experimental site was prepared during *Kharif*, 2016 and a maize hybrid was grown in that site for reducing the variability in the soil heterogeneity resulting primarily from residual as well as inherent nutrient of the soil. All the ten S\(_1\) lines along with three hybrid varieties were planted for evaluation in randomized block design (RBD) with two replications under two different levels of applied nitrogen i.e. N\(_{80}\) (80 kg N ha\(^{-1}\)) and N\(_{0}\) (0 kg N ha\(^{-1}\)) during *rabi*, 2016-17. The amount of P\(_2\)O\(_5\) and K\(_2\)O fertilizers and other recommended practices used (excluding organic manures) were the same in both the levels of nitrogen.

**Statistical analysis**

Observation of all morphological and most of the physiological parameters will be performed as per standard procedures. The plot means were subjected to the statistical and biometrical analysis and all statistical analyses and biometrical analysis were done. The variability was estimated as per procedure for analysis of variance suggested by fisher, GCV and PCV by Burton and Devane (1953) and heritability and genetic advance by Allard (1960).

**Results and Discussion**

Mean sum of squares due to genotypes showed significant differences for all the characters except number of ears per plant at both N\(_0\) and N\(_{80}\) levels. This indicates the presence of sufficient genetic variation among the genotypes. Similar results were reported by Saikia and Sharma (2000) for different maize characters *i.e.* plant height, ear height and grain yield per plant. By Vashistha *et al.*, (2013) for all the characters except number of ears per plant and Selassie (2015) for the characters *viz.*, plant height, shelling percentage and 1000 grain weight.

**Mean performance**

**Morphological traits**

The comparison of the mean performance of the genotypes with respect to various morphological traits revealed that, among the S\(_1\) lines, the highest grain yield per plant was observed in MEG-11 and TR-1 which had few other favourable traits at N\(_0\) level. MEG-11 showed highest grain yield along with shorter duration at N\(_0\) level.

Such a line, if advanced to S\(_2\) generation, would produce potential inbred progeny with high yield and short duration. TR-1, which was a high yielder S\(_1\) line, also had the attributes higher ear length and low ear placement.

Among the S\(_1\) lines, MIZ-7, AR-1, MIZ-3, MIZ-2 and TR-1 were *at par* for low ASI at N\(_0\) level which was followed by MEG-11 and MAN-8. It indicates that these lines could be tolerant to low N-stress. Again, the lines *viz.*, MAN-4, MIZ-3, MEG-11 and MAN-8 topped the S\(_1\) entries tested under N\(_{80}\) level for low ASI.

Thus, the S\(_1\) entries *viz.*, MAN-4 and MIZ-3 had lower ASI at both the levels. MAN-4 was also the earliest of all genotypes. The S\(_1\) lines *viz.*, MEG-11, TR-1, MIZ-3, AR-1 and MIZ-2 exhibiting high grain yield at N\(_0\) level could be
considered tolerant to low N. However, at N₀ level, the high yielding lines viz., TR-1, MIZ-3, AR-1 and MEG-11 had lower estimates of ASI which is a secondary trait of low nitrogen tolerance. Thus, these S₁ lines could be considered tolerant to low-N based on both grain yield and ASI (Table 2a–2c).

Among the hybrids, P-3399 having high grain yield, low ASI and better performance for other important traits viz., ear length, 100 KW and kernels per row at N₀ level could be an important entry for tolerance to low N (Table 3).

**Physiological traits**

The comparison of the mean performance of the genotypes with respect to various physiological traits was made. Among the entries, MAN-8 at N₀ level had the highest mean performance for the traits viz., chlorophyll content and Leaf Area. Among the S₁ lines, MEG-11 and TR-1 gave the highest mean performance for the traits plant nitrogen, NRA and NUE at both levels of nitrogen. Similar result was found by Sindhi et al., (2016) (Table 4).

**Table 1** List of S₁ lines and hybrids used in the evaluation

| Sl. No. | Name of the entries | Entry code | Place /source |
|---------|---------------------|------------|---------------|
| S₁ entries: | | | |
| 1 | Mimban -1 | MIZ-1 | Mizoram |
| 2 | Medziphema Collection-2 | NAG-4 | Nagaland |
| 3 | Mizoram collection-1 | MIZ-2 | Mizoram |
| 4 | Manipur local | MAN-8 | Manipur |
| 5 | Yerto | AR-1 | Arunachal Pradesh |
| 6 | Mimban-2 | MIZ-7 | Mizoram |
| 7 | Imphal collection | MAN-4 | Manipur |
| 8 | Mimpui | MIZ-3 | Mizoram |
| 9 | Meghalaya-11 | MEG-11 | Meghalaya |
| 10 | TR-1 | TR-I | Tripura |
| Hybrids entries: | | | |
| 11 | P-3399 | P-3399 | M/S Pioneer Seeds Pvt. Ltd. |
| 12 | P-3522 | P-3522 | M/S Pioneer Seeds Pvt. Ltd. |
| 13 | KMH25K45 | KMH25K45 (Kavery Bumper) | M/S Aditya B Enterprise |
### Table 2a Mean performance of maize genotypes for morphological traits at individual nitrogen levels

| Genotypes | Days to 50% pollen-shed | Days to 50% silk | ASI | Days to 75% dry husk | Plant height (cm) | Ear height (cm) | Ear length (cm) | Ear diameter (cm) |
|------------|--------------------------|-----------------|-----|----------------------|-------------------|----------------|----------------|------------------|
|            | N₀                       | N₈₀             | N₀  | N₈₀                 | N₀               | N₈₀           | N₀             | N₈₀              |
| MIZ-1      | 105.50                   | 111.50          | 113.00 | 116.50              | 7.50             | 5.00          | 149.00         | 151.00           |
|            | N₈₀                      | N₀              | N₈₀  | N₀                  | N₈₀              | N₀            | N₈₀            | N₀              |
| NAG-4      | 70.50                    | 74.50           | 77.00 | 79.50               | 6.50             | 5.00          | 116.50         | 118.00           |
| MIZ-2      | 62.50                    | 66.50           | 67.00 | 71.50               | 4.50             | 5.00          | 114.50         | 120.50           |
| MAN-8      | 71.00                    | 80.00           | 76.50 | 83.50               | 5.50             | 3.50          | 111.00         | 122.00           |
| AR-1       | 73.50                    | 74.00           | 77.00 | 78.00               | 3.50             | 4.00          | 115.00         | 125.50           |
| MIZ-7      | 67.50                    | 68.50           | 70.50 | 73.00               | 3.00             | 4.50          | 110.50         | 112.50           |
| MAN-4      | 62.00                    | 63.50           | 66.00 | 66.00               | 4.00             | 2.50          | 108.50         | 114.50           |
| MIZ-3      | 71.00                    | 73.00           | 74.50 | 76.50               | 3.50             | 3.50          | 110.50         | 114.00           |
| MEG-11     | 71.00                    | 75.50           | 76.00 | 79.00               | 5.00             | 3.50          | 119.00         | 125.00           |
| TR-I       | 72.00                    | 74.50           | 76.00 | 79.00               | 4.00             | 5.00          | 121.50         | 125.50           |
| P-3399     | 104.50                   | 107.50          | 107.50 | 111.50              | 3.00             | 4.00          | 147.50         | 153.50           |
| P-3522     | 98.00                    | 101.50          | 104.00 | 106.00              | 6.00             | 4.50          | 146.50         | 150.50           |
| KMH25K45   | 99.00                    | 104.00          | 105.50 | 108.50              | 6.50             | 4.50          | 144.50         | 149.50           |
| Grand Mean | 79.08                    | 82.73           | 83.88 | 86.92               | 2.40             | 2.09          | 124.19         | 129.38           |
| S.Ed(±)    | 3.04                     | 2.32            | 2.57  | 2.25                | 0.68             | 0.60          | 3.97           | 2.91             |
| CD (5%)    | 6.08                     | 5.06            | 5.61  | 4.78                | 1.49             | 1.32          | 5.81           | 2.25             |
| CV%        | 3.84                     | 2.80            | 3.07  | 2.82                | 14.23            | 14.42         | 2.78           | 2.25             |
Table 2b Mean performance of maize genotypes for morphological traits at individual nitrogen levels

| Genotypes | Kernel rows per ear | Kernels per row | 100 kernel weight (g) | Grain yield (g) |
|-----------|---------------------|-----------------|-----------------------|-----------------|
|           | $N_0$               | $N_{80}$        | $N_0$                 | $N_{80}$        | $N_0$ | $N_{80}$ |
| MIZ-1     | 9.70                | 14.80           | 12.80                 | 17.44           | 20.51 | 23.45   | 62.20 | 74.590  |
| NAG-4     | 9.10                | 15.00           | 12.20                 | 15.49           | 14.12 | 26.27   | 75.25 | 99.025  |
| MIZ-2     | 10.40               | 15.40           | 15.50                 | 18.99           | 16.06 | 26.10   | 82.19 | 115.515 |
| MAN-8     | 10.80               | 14.40           | 11.60                 | 19.68           | 15.54 | 25.94   | 69.44 | 90.015  |
| AR-1      | 9.20                | 12.70           | 16.80                 | 19.33           | 13.32 | 31.79   | 82.62 | 88.785  |
| MIZ-7     | 10.10               | 14.40           | 13.05                 | 21.94           | 17.30 | 29.95   | 76.28 | 96.270  |
| MAN-4     | 10.60               | 13.80           | 15.45                 | 20.03           | 18.17 | 28.21   | 75.03 | 93.735  |
| MIZ-3     | 10.50               | 12.20           | 15.10                 | 21.24           | 16.96 | 27.40   | 84.72 | 88.215  |
| MEG-11    | 9.90                | 12.00           | 12.50                 | 19.31           | 16.38 | 31.44   | 91.73 | 109.905 |
| TR-I      | 8.20                | 12.30           | 12.35                 | 21.37           | 17.37 | 33.71   | 89.12 | 96.855  |
| P-3399    | 11.20               | 14.00           | 17.95                 | 29.49           | 19.38 | 41.82   | 124.23| 168.565 |
| P-3522    | 11.60               | 14.20           | 19.30                 | 29.05           | 20.95 | 41.50   | 107.13| 155.765 |
| KMH25K45  | 13.20               | 16.00           | 19.20                 | 29.26           | 24.50 | 40.95   | 116.15| 136.115 |
| Grand Mean| 10.35               | 13.93           | 14.90                 | 21.73           | 17.73 | 31.42   | 87.39 | 108.72  |
| S.Ed(±)   | 0.80                | 0.62            | 2.13                  | 1.59            | 0.47  | 0.99    | 11.54 | 12.59   |
| CD(5%)    | 1.74                | 1.35            | 4.64                  | 3.46            | 1.02  | 2.17    | 25.14 | 27.43   |
| CV%       | 7.70                | 4.43            | 14.30                 | 7.31            | 2.63  | 3.16    | 13.20 | 11.58   |
### Table 2c: Mean performance of maize genotypes for physiological traits at individual nitrogen levels

| Genotypes | LA (cm²) | Chl. content (mg g⁻¹) | NRA(μmolNO₂⁻ /h/gm. of fresh wt) | PN (%) | GS (μmol/h/gm of fresh wt) | NUE (g g⁻¹) |
|-----------|----------|------------------------|-----------------------------------|--------|-----------------------------|--------------|
|           | N₀       | N₈₀                    | N₀      | N₈₀                 | N₀      | N₈₀          | N₀     | N₈₀       | N₀      | N₈₀       | N₀      | N₈₀       | N₀      | N₈₀       |
| MIZ-1     | 191.89   | 352.00                 | 3.97    | 5.13                | 1.00    | 1.43         | 0.60   | 0.83      | 315.50  | 332.31    | 260.11  | 74.06      |
| NAG-4     | 237.62   | 360.04                 | 4.34    | 6.22                | 0.96    | 1.40         | 0.70   | 0.84      | 401.34  | 422.42    | 314.66  | 98.32      |
| MIZ-2     | 253.22   | 368.05                 | 5.23    | 7.89                | 0.87    | 1.62         | 0.71   | 0.98      | 346.17  | 373.12    | 343.71  | 114.69     |
| MAN-8     | 273.00   | 390.57                 | 5.64    | 6.44                | 0.95    | 1.07         | 0.53   | 0.83      | 351.37  | 363.91    | 290.39  | 89.38      |
| AR-1      | 235.16   | 368.42                 | 3.07    | 9.21                | 1.61    | 2.46         | 0.43   | 0.91      | 429.28  | 459.05    | 345.50  | 88.15      |
| MIZ-7     | 230.00   | 374.76                 | 3.24    | 9.93                | 1.43    | 2.34         | 0.57   | 1.08      | 331.57  | 381.44    | 318.99  | 95.59      |
| MAN-4     | 224.77   | 371.23                 | 4.77    | 7.10                | 1.27    | 3.28         | 0.72   | 0.84      | 331.95  | 364.73    | 313.77  | 93.07      |
| MIZ-3     | 224.00   | 414.44                 | 5.85    | 7.39                | 1.46    | 3.18         | 0.85   | 0.90      | 351.76  | 383.11    | 354.27  | 87.59      |
| MEG-11    | 240.00   | 456.23                 | 7.12    | 8.34                | 1.28    | 2.64         | 0.88   | 1.15      | 362.23  | 379.78    | 383.58  | 109.12     |
| TR-I      | 240.15   | 470.00                 | 4.34    | 7.84                | 1.82    | 2.80         | 0.75   | 0.96      | 329.23  | 355.94    | 372.67  | 96.17      |
| P-3399    | 348.50   | 480.39                 | 5.78    | 8.67                | 1.53    | 2.41         | 0.70   | 0.84      | 392.24  | 423.23    | 519.51  | 167.37     |
| P-3522    | 347.08   | 479.88                 | 6.34    | 7.55                | 1.75    | 3.43         | 0.74   | 0.95      | 417.71  | 440.95    | 448.00  | 154.66     |
| KMH25K45  | 342.32   | 477.79                 | 5.94    | 8.01                | 1.00    | 3.17         | 1.14   | 1.23      | 409.39  | 437.50    | 485.67  | 135.15     |
| Grand Mean| 260.59   | 412.60                 | 5.05    | 7.67                | 1.37    | 2.40         | 0.72   | 0.94      | 366.90  | 393.65    | 365.44  | 107.95     |
| S.Ed(±)   | 21.22    | 20.45                  | 0.73    | 0.93                | 0.22    | 0.47         | 0.09   | 0.11      | 20.66   | 15.78     | 48.24   | 12.50      |
| CD(5%)    | 46.23    | 44.56                  | 1.60    | 2.02                | 0.47    | 1.03         | 0.19   | 0.24      | 45.01   | 34.38     | 105.11  | 27.24      |
| CV%       | 8.14     | 4.96                   | 14.54   | 12.08               | 15.68   | 19.71        | 11.94  | 11.53     | 5.63    | 4.01      | 13.20   | 11.58      |
Table 3: Estimates of genetic parameters for different morphological traits at N₀ and N₈₀ level

| Genetic Parameters | GCV (%) | PCV (%) | h² (%) | Gₛ (% of Mean) | Mean±SE |
|-------------------|--------|---------|--------|----------------|---------|
| Traits            | N₀     | N₈₀    | N₀     | N₈₀           | N₀     | N₈₀    | N₀     | N₈₀    |
| D 50% PS          | 20.49  | 20.35  | 20.85  | 20.54         | 96.06  | 98.13  | 41.49  | 41.52  | 79.08±3.04 | 82.73±2.32 |
| D 50% S           | 20.02  | 19.67  | 20.25  | 19.83         | 97.70  | 98.38  | 40.76  | 40.19  | 83.88±2.57 | 86.92±2.20 |
| ASI               | 29.08  | 12.02  | 32.38  | 12.23         | 80.69  | 96.63  | 53.82  | 24.35  | 4.81±0.68  | 4.19±0.60  |
| D 50% DH          | 12.93  | 15.52  | 13.10  | 21.18         | 97.31  | 53.66  | 26.27  | 23.41  | 124.19±2.67 | 129.38±2.91 |
| PH (cm)           | 22.41  | 13.55  | 23.06  | 14.17         | 94.45  | 91.47  | 40.76  | 40.19  | 83.88±2.57 | 115.69±4.79 |
| ASI               | 27.51  | 17.90  | 28.81  | 18.83         | 91.16  | 90.38  | 54.10  | 35.05  | 28.28±2.42 | 43.08±2.51 |
| ED (cm)           | 16.37  | 22.69  | 18.32  | 24.05         | 79.88  | 89.02  | 30.15  | 44.10  | 124.19±2.67 | 129.38±2.91 |
| K/R               | 10.84  | 8.66   | 13.29  | 9.73          | 66.44  | 79.26  | 18.20  | 15.88  | 10.35±0.80  | 13.93±0.62  |
| 100 KW (g)        | 23.89  | 20.54  | 27.84  | 21.80         | 73.63  | 88.77  | 42.23  | 39.87  | 14.90±2.13  | 21.73±1.59  |
| GY(q)             | 18.79  | 24.61  | 22.96  | 27.20         | 66.95  | 81.87  | 31.67  | 45.87  | 87.39±11.54 | 108.72±12.59 |

Table 4: Estimates of genetic parameters for different physiological traits at N₀ and N₈₀ level

| Genetic Parameters | GCV (%) | PCV (%) | h² (%) | Gₛ (% of Mean) | Mean±SE |
|-------------------|--------|---------|--------|----------------|---------|
| Traits            | N₀     | N₈₀    | N₀     | N₈₀           | N₀     | N₈₀    | N₀     | N₈₀    |
| Leaf Area (cm²)   | 19.09  | 12.13  | 20.75  | 13.10         | 84.60  | 85.69  | 36.17  | 23.13  | 260.59±21.22 | 412.42±20.45 |
| Chlorophyll content (mg g⁻¹) | 21.80  | 14.32  | 26.20  | 18.74         | 69.20  | 58.45  | 37.35  | 22.56  | 5.05±0.73  | 7.67±0.93  |
| Nitrate Reductase Activity (µmolNO₂⁻/hr/gm of fresh wt) | 22.93  | 30.07  | 27.78  | 35.96         | 68.13  | 69.96  | 38.99  | 51.82  | 1.37±0.22  | 2.40±0.47  |
| Plant Nitrogen (%) | 23.24  | 11.26  | 26.13  | 16.11         | 79.10  | 48.82  | 42.58  | 16.21  | 0.72±0.09  | 0.94±0.11 |
| Glutamine Synthetase (µmol/hr/gm of fresh wt) | 9.64   | 9.40   | 11.16  | 10.22         | 74.55  | 84.61  | 17.14  | 17.81  | 366.90±20.66 | 393.65±15.78 |
| Nitrogen Use Efficiency (g g⁻¹) | 18.79  | 24.61  | 22.96  | 27.20         | 66.94  | 81.87  | 31.66  | 45.87  | 365.44±48.24 | 107.94±12.50 |
All entries having high grain yield showed high nitrogen use efficiency and those showing low grain yield had low NUE at both the nitrogen levels. This relationship was based on the formula of NUE. The S₁ lines namely, MIZ-2 and MEG-11 recorded the highest NUE along with high yield at N₈₀ level while MEG-11 and TR-1 recorded the highest NUE along with high yield at N₀ level. Another important S₁ lines, AR-1 had few good traits viz., high GS, NRA and NUE. Among the hybrids, P-3399 had high LA, chlorophyll content and high nitrogen use efficiency at both levels of nitrogen. Another hybrid P-3522 had the good traits namely, GS, NRA and high NUE at both levels of nitrogen.

**Genotypic variation and other related parameters**

**Morphological traits**

Variability plays an important role in crop breeding. The magnitude of variability present in a crop species is important as it provides the basis of selection. The present study revealed high to moderate estimates of GCV and PCV for all the traits except ear diameter and kernel rows per ear at N₈₀ level in the set of germplasm studied indicating scope for genetic improvement through selection in respect of these traits. The estimates of genotypic coefficient of variation (GCV) reflect the total amount of genotypic variability in a population under study for a trait. In the present investigation, the PCV was estimated to be high compared to GCV for all the traits considered. Kumar et al., (2014) and Abirami et al., (2005) reported high PCV and GCV values for grain yield per plant and ear height in the materials studied by them. Heritability estimates were found to be high for all the traits except ASI (53.66%) indicating that genes governing these characters were less influenced by environment. Since heritability alone cannot predict the nature of genetic variation the knowledge about genetic advance coupled with heritability is most useful. Heritability coupled with expected genetic advance as per cent of mean indicates the mode of gene action in the expression of a trait which helps in choosing an appropriate breeding method. High heritability accompanied with by high to moderate expected genetic advance as per cent of mean in case of grain yield per plant, plant height, ear length, ear height, kernels per row, 100-KW, days to 50% pollen-shed, days to 50% silk, ASI and days to 75% dry husk indicated the preponderance of additive gene effects in their inheritance and simple selection may be effective for improvement of these traits. Ear diameter and kernel rows per ear exhibited moderate to high heritability along with low genetic advance indicating more role of non-additive gene action and provides limited scope for improvement of traits through simple selection. Similar results were reported by Mahmood et al., (2004), Vashistha et al., (2013) and Kumar et al., (2014).

High to moderate estimates of GCV and PCV were recorded for all the traits at N₀ level indicating sufficient variability for the traits and suggesting scope for genetic improvement through selection. High heritability accompanied with high expected genetic advance as per cent of mean observed in case of plant height, ear height, kernels per row, ASI, days to 50% pollen-shed and days to 50% silk indicated the preponderance of additive gene effects.

**Physiological traits**

In the present investigation, high values of both GCV and PCV were recorded for chlorophyll content, NRA, plant nitrogen at N₀ level, and for NRA and NUE at N₈₀ level. High estimates of GCV for these traits indicate...
indicated a considerable amount of genetic variability, thus suggesting the potentiality of the material for further improvement. LA and NUE showed moderate magnitude of GCV and high estimates of PCV at N₀ level. Makhiziah et al., (2013) stated that chlorophyll content demonstrated high genotypic variation at all N level.

The present investigation revealed that the heritability estimates were high for all the physiological traits at N₀ level of nitrogen indicating the potential for transmission of genes from parent to offspring in respect to these traits. The estimates of high heritability (>60%) for all the traits except chlorophyll content (58.45%) and plant nitrogen (48.82%) at N₈₀ level. Similar results were found by Li et al., (2014). Expected genetic advance as per cent of mean was high for plant nitrogen at N₀ level and for NRA and NUE at N₈₀ level. LA, chlorophyll content, NRA and NUE gave moderate estimates of expected genetic advance at N₀ level while LA and chlorophyll content gave moderate magnitude of expected genetic advance of genetic advance as per cent of mean indicating the role of additive gene effects for the traits at N₀ level and simple selection may be effective for improvement of these traits. High heritability with low genetic advance indicated preponderant role of non-additive gene actions for GS at both levels, suggested that recurrent selection methods with progeny testing would be appropriate in exploitation of such traits.

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