Genetic Variability Studies Based on Morpho-Physiological Traits Related to Temperature; Seedling Growth; Development and Phenology of Soybean [(Glycine max (L.) Merrill]

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

ABSTRACT

The present experiment was conducted with an aim to understand genetic variability and heritability among 30 soybean genotypes of different geographical locations during Kharif 2019 at TCA, Dholi, Bihar in Randomized Complete Block Design accommodating 30 genotypes randomly in three replicates. These genotypes evaluated for twenty-seven traits: five phenological, nine agromorphological, eight physiological traits (from field trial) and five physiological traits from laboratory experiment recorded and subjected to statistical and biometrical analyses. Considerable variability was observed for these traits which revealed usefulness of existing genetic variability for all 27 attributes amongst which vigour index II, seedling dry weight, specific leaf weight and 100-seed weight was trustworthy (GCV in close correspondence with PCV; high $h^2$bs & high GAM reflecting additive gene action) for selection criteria.

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1. INTRODUCTION

Golden bean and miracle crop are most commonly used synonym for soybean [(Glycine max (L.) Merrill]. A fast horizontally expanding, protein + oil source miracle crop, increasingly adopted by farmers, offers opportunity under diverse growing situations in different cropping systems, against abiotic stresses and also as contingent crop, utilized for diversified food and feed purposes. Although it had 40% quality protein (glycine, tryptophan and lysine) and comparatively lesser quantity of (20%) quality oil, it is mainly popular as oilseed crop rather than a pulse crop because of its extraordinary oil qualities viz., no cholesterol, essential heart friendly omega-3 fats etc. Soybean, is globally oldest cultured plant. Historical evidences indicate its use for over 5000 years by human [1].

At present, soybean has acquired global importance and India is the fourth largest country in the world after United States of America, Brazil and Argentina regarding area but fifth regarding total production after China. The productivity of soybean is quite low in our country as compare to top soybean producing countries of the world which is probably due to narrow genetic base of the released varieties as well as their lower genetic yielding potential are the major reasons for low genetic yielding potential. Development of stable genotypes with enhanced seed yield is the most important goal of many soybean breeding programmes. Morphological traits/markers indicate the genetic composition of the cultivar and also the interaction of the genotype with the environment in which it is expressed. The information on genetic variability helps in selecting parents out of new land races, local selection, elite cultivars and exotic germplasm of crop plants for development of new varieties, continuous evaluation for important traits, which in earlier days was exclusively based on the available morphological data [2].

2. MATERIALS AND METHODS

The experiment was carried out during kharif 2019 at the farm of Tirhut College of Agriculture, Dholi (25.5°N, 35.40°S and 52.2m MSL) in Muzaffarpur District (North Bihar) located in eco-geographical region I Sub region IV of Bihar. Thirty entries (including 3 checks) were sown in Randomized Complete Block Design. Each plot consisted three rows of 3-meter length. The row to row and plant to plant distance was 45cm and 5cm, respectively. Trial laid out for 27 (22 field based on the ant differences among 0

2. MATERIALS AND METHODS

3. RESULTS AND DISCUSSION

The ANOVA of various traits (Table 1) revealed that there were significant differences among genotypes for all the traits under study. This indicates that exploitable level of genetic variability has been created and genetic base is broadened for most of the important characters among different genotypes developed through hybridization and selection involving diverse parents. The utilization of these diverse genotypes may lead to development of potential and suitable genotypes in future. Similar results have been reported by [4-9] for number of pods per plant and seed yield per plant.

Genetic variability: The results (Table-3) revealed that the phenotypic coefficient of variation was found higher in magnitude than that of genotypic coefficient of variation for all the characters under study. Vigour index II recorded the highest genotypic coefficient of variance and phenotypic coefficient of variance followed by seedling dry weight, specific leaf weight, grain yield per plant, effective rainfall use efficiency, leaf area index, 100-seed weight (g), harvest-index (%), dry matter efficiency, effective rainfall use efficiency, seed yield plant-1 (g). Data for individual characters observed, replication-wise and mean data was used for statistical analyses. Genetic variability parameters were calculated as per Burton and de vane [3].
for improvement of these characters through selection programme. In agreement with the present findings [4,7,10] for number of pods per plant and seed yield per plant, [5] for plant height, [11] for plant height, seed yield per plant and number of pods per plant and [12] for seed yield per plant.

Mean and range of 27 character (Table 2) exhibited considerably wide range of variation among 30 genotypes for studied traits. Many different genotypes in variable number were significantly superior over best check for each character. Harvest index, dry matter efficiency and cluster per plant accommodated highest 7 different genotypes which were significantly superior over best check. Genotype NRC-142 and SL-688 were significantly superior over best check for 8 characters which was highest, followed by both SL-955, VLS-94 for 6 characters.

Low genotypic coefficient of variance and phenotypic coefficient of variance were recorded for dry matter efficiency, days to tubercle, days to flower budding, days to cessation, days to physiological maturity, days to first flowering, and growing degree days indicating that they are very difficult to improve via selection programme.

These results are in confirmation with the findings of [11] for days to 50% flowering and days to maturity.

**Heritability and genetic advance as percentage of mean:** To adjust the variation over environment heritability was calculated and presented in Table 3. High heritability coupled with high genetic advance as percentage of mean was observed for seedling dry weight, vigour index-II, specific leaf weight and 100-seed weight whereas high heritability along with moderate genetic advance was recorded for plant height, main shoot length, secondary branches, seed per pod, leaf area index, effective rainfall use efficiency, vigour index-I and seed yield per plant these results indicate the preponderance of additive gene action may be responsible in the inheritance of the above traits.

**Table 1. ANOVA for all the 27 traits of soybean [Glycine max (L.) Merrill]**

| SL. No. | Character | Replications (df = 2) | Genotypes (df = 29) | Error (df = 58) |
|---------|-----------|-----------------------|---------------------|----------------|
| 1       | DT        | 0.63                  | 12.67**             | 1.01           |
| 2       | DFB       | 0.57                  | 18.81**             | 0.58           |
| 3       | DFF       | 0.41                  | 11.05**             | 0.50           |
| 4       | DC        | 0.87                  | 39.22**             | 0.59           |
| 5       | DPM       | 1.43                  | 130.37**            | 2.51           |
| 6       | PH (cm)   | 40.13                 | 423.18**            | 31.27          |
| 7       | MSL (cm)  | 5.03                  | 551.13**            | 31.72          |
| 8       | PB        | 5.30                  | 5.22**              | 1.50           |
| 9       | SB        | 1.36                  | 2.09**              | 0.44           |
| 10      | C/P       | 2.29                  | 46.25**             | 5.07           |
| 11      | P/C       | 0.08                  | 0.32**              | 0.04           |
| 12      | P/P       | 50.84                 | 438.82**            | 92.80          |
| 13      | PL (cm)   | 0.03                  | 0.68**              | 0.03           |
| 14      | S/P       | 0.02                  | 0.96**              | 0.07           |
| 15      | GDD (°C)  | 35x10^4               | 0.21**              | 41x10^4        |
| 16      | SLW (g/cm²)| 5x10^7              | 83x10^6**           | 4x10^6         |
| 17      | LAI       | 0.25                  | 11.09**             | 1.78           |
| 18      | SW(g)     | 74x10^4               | 9.84**              | 0.03           |
| 19      | HI (%)    | 0.49                  | 129.47**            | 9.76           |
| 20      | DME       | 26x10^6               | 0.03**              | 11x10^4        |
| 21      | ERUE (kg/ha) | 0.45               | 0.93**              | 0.13           |
| 22      | GYPP (g)  | 18.62                 | 36.67**             | 5.05           |
| 23      | GER       | 57.70                 | 212.37**            | 15.34          |
| 24      | SL (cm)   | 19.33                 | 98.98**             | 25.34          |
| 25      | SDW (g)   | 13x10^3               | 0.19**              | 44x10^4        |
| 26      | V1        | 27565.47              | 1077907.94**        | 244787.37      |
| 27      | V2        | 127.54                | 1551.38**           | 46.34          |

**& * Significant of P = 0.01 and P = 0.05 F-value at .01=5.42 & .05=3.33**
Table 2. Range and mean performance of 30 soybean genotypes for 27 characters

| CHARACTERS | DT | DFB | DFF | DC | DPM | PH | MSL | PB | SB |
|------------|----|-----|-----|----|-----|----|-----|----|----|
| Mean       | 30.067 | 37.889 | 43.289 | 55.222 | 107.733 | 65.167 | 54.700 | 7.479 | 3.425 |
| Range      | 25.667-32.667 | 40.000-50.000 | 93.667-116.333 | 42.667-92.667 | 33.667-81.000 | 4.683-1.527 | 10.447 | 4.930 |
| Minimum    | 25.667 | 32.667 | 40.000 | 50.000 | 93.667 | 42.667 | 33.667 | 4.683 | 1.527 |
| Genotype   | VLS-94 | VLS-94 | NRC 142 | NRC 142 | Shalimar Soy 1 | VLS-94 | RKS-18 | PS - 1374 |
| Maximum    | 35.000 | 41.667 | 47.000 | 66.333 | 116.333 | 92.667 | 81.000 | 10.447 | 4.930 |
| Genotype   | RSC 11-17 | RSC 1071 | NRC-128 | AMS-12 | SL 1074 | NRC-137 | RSC-1071 | SL 955 | SL 955 |
| No. of significantly Superior Genotypes (vis-à-vis best check) | 3 | 4 | 4 | 3 | 3 | 4 | 5 | 3 | 4 |
| Name(s) of Genotypes | VLS-94 | VLS-94 | NRC-142 | NRC-142 | NRC-137 | NRC-137 | RSC-1071 | SL 955 | SL 955 |
| Best Check | JS-9752, RKS-18 | JS-9752 | JS-335 | RKS-18 | JS-335 | JS-9752 | JS-9752 | JS-9752 | JS-335 |

Cont...
| CHARACTERS | C/P | P/C | P/P  | PL  | S/P  | GDD | SLW | LAI | SW  |
|-----------|-----|-----|------|-----|------|-----|-----|-----|-----|
|           | 10  | 11  | 12   | 13  | 14   | 15  | 16  | 17  | 18  |
| Mean      | 26.227 | 3.120 | 78.756 | 3.328 | 2.797 | 18.244 | 0.015 | 6.819 | 7.179 |
| Range     | 19.733-34.057 | 2.467-4.200 | 62.399-105.041 | 2.400-4.400 | 1.773-3.887 | 17.891-18.812 | 0.007-0.031 | 4.790-4.500 | 11.007-11.197 |
| Minimum   | 19.733 | 2.467 | 62.399 | 2.400 | 1.773 | 17.891 | 0.007 | 4.790 | 4.500 |
| Genotype  | NRC 142 | PS-1572 | RSC 1103 | AMS-2014 | RSC 11-7 | SL 1074 | NRC-12 | RKS-18 | Shalimar Soy-1 |
| Maximum   | 34.057 | 4.200 | 105.041 | 4.400 | 3.887 | 18.812 | 0.031 | 11.007 | 11.197 |
| Genotype  | SL 955 | NRC-136 | NRC-136 | NRCSL-1 | Pusa 9712 | NRC 142 | RSC 1071 | SL 955 | SL 1028 |
| No. of significantly Superior Genotypes (vis-à-vis best check) | 7 | 6 | 6 | 6 | 2 | 5 | 1 |
| Name(s) of Genotypes | SL-688 | NRC-136 | NRC-136 | NRCSL-1 | Pusa 9712 | NRS-142 | RSC-1071 | SL 955 | SL 1028 |
|           | MACS-1493 | VLS-94 | ShalimarSoy1 | ShalimarSoy1 | NRCSL-1 | RSC 11-7 | RSC 11-7 | SL 688 |
|           | AMS-2014 | PS-1092 | SL-688 | NRC-12 | PS-1092 | RSC 1103 | Pusa 9712 | JS 9305 |
|           | Pusa 9712 | RSC-117-17 | NRC-137 | PS-1092 | RSC 1071 | ShalimarSoy1 | JS 9305 |
|           | ShalimarSoy1 | SL-688 | MACS-1493 | PS-1572 | SL 955 | RSC 11-17 | SL-1074 |
|           | NRC-128 | SL-1028 | AMS-2014 | PS-1347 | PS-1572 | VLS-94 |
| Best Check | NRC-137 | JS-335 | JS-335 | RKS-18 | JS-9752 | RKS-18 | JS-335 | JS-9752 | JS-335 |

Cont...
| CHARACTERS | HI | DME | ERUE | GYPP | GER | SL | SDW | V1 | V2 |
|------------|----|-----|------|------|-----|----|-----|----|----|
| Mean       | 39.85 | 1.33 | 1.89 | 11.53 | 86.76 | 28.24 | 0.56 | 2463.34 | 49.27 |
| Range      | 29.27-50.34 | 1.18-1.52 | 1.21-3.51 | 6.54-21.00 | 62.66-96.33 | 15.83-38.70 | 0.17-1.05 | 1495.60-3503.70 | 6.05-93.17 |
| Minimum    | 29.27 | 1.18 | 1.21 | 6.54 | 62.66 | 15.83 | 0.17 | 1495.60 | 6.05 |
| Genotype   | NRCSL1 | NRCSL1 | RKS-18 | RSC 11-17 | NRCSL1 | RSC | RSC 1052 | VLS-94 | NRCSL-1103 |
| Maximum    | 50.34 | 1.52 | 3.51 | 21.00 | 96.33 | 38.70 | 1.05 | 3503.70 | 93.17 |
| Genotype   | NRC-136 | ShalimarSoy1 | NRC-136 | NRC-136 | JS-9752 | SL 955 | NRC 142 | SL 955 | NRC 142 |
| No. of significantly Superior Genotypes (vis-à-vis best check) | 7 | 7 | 5 | 5 | 4 | 3 | 4 | 3 | 1(At par) |
| Name(s) of Genotypes | NRC-136 | Shalimar soy 1 | NRC-136 | NRC-136 | PS-1572 | SL-955 | NRC-142 | SL-955 | NRC-142 |
|            | RSC-11-17 | SL-955 | SL-955 | PS-1347 | NRC-137 | NRC-137 | JS-20-116 | NRC-137 |
|            | PS-1092 | RSC-11-7 | NRC-137 | NRC-137 | JS-20-116 | NRC-137 | MACS1493 | NRC-137 |
|            | RSC-11-17 | RSC-11-03 | NRC-128 | MACS1493 | RSC11-03 | RSC1071 | |
|            | RSC 11-15 | NRC-136 | MACS1493 | NRC-128 | |
| Best Check | JS-9752 | JS-9752 | JS-9752 | JS-9752 | JS-9752 | JS-335 | JS-9752 | JS-335 | JS-9752 |
Table 3. Genetic parameters of 27 morpho-physiological parameters of soybean [Glycine max (L.) Merrill]

| SN | Character          | Genotypic Variance ($\sigma^2_g$) | Phenotypic Variance ($\sigma^2_p$) | Genotypic coefficient of Variance (GCV) | Phenotypic coefficient of Variance (PCV) | Heritability Broad Sense (h²) | Genetic Advance (G A) at 5% | Genetic advance as per cent of Mean |
|----|-------------------|----------------------------------|-----------------------------------|----------------------------------------|----------------------------------------|-------------------------------|-------------------------------|-----------------------------------|
| 1  | DT                | 3.888                            | 4.900                             | 6.558                                  | 7.363                                  | 79.30                         | 3.618                         | 12.033                            |
| 2  | DFB               | 6.074                            | 6.664                             | 6.505                                  | 6.813                                  | 91.20                         | 4.847                         | 12.794                            |
| 3  | DFF               | 3.516                            | 4.019                             | 4.332                                  | 4.631                                  | 87.50                         | 3.613                         | 8.346                             |
| 4  | DC                | 12.879                           | 13.469                            | 6.499                                  | 6.646                                  | 95.60                         | 7.229                         | 13.090                            |
| 5  | DPM               | 42.621                           | 45.135                            | 6.060                                  | 6.236                                  | 94.40                         | 13.069                        | 12.131                            |
| 6  | PH                | 130.64                           | 161.911                           | 17.539                                 | 19.526                                 | 80.70                         | 21.150                        | 32.455                            |
| 7  | MSL               | 173.137                          | 204.860                           | 24.055                                 | 26.166                                 | 84.50                         | 24.919                        | 45.556                            |
| 8  | PB                | 1.242                            | 2.745                             | 14.901                                 | 22.153                                 | 45.20                         | 1.544                         | 20.648                            |
| 9  | SB                | 0.549                            | 0.997                             | 21.641                                 | 29.158                                 | 17.539                        | 6.523                         | 33.087                            |
| 10 | C/P               | 13.727                           | 18.798                            | 14.127                                 | 16.532                                 | 73.00                         | 6.522                         | 24.868                            |
| 11 | P/C               | 0.094                            | 0.140                             | 9.833                                  | 12.010                                 | 67.00                         | 0.517                         | 16.583                            |
| 12 | P/P               | 115.34                           | 208.149                           | 13.637                                 | 18.319                                 | 55.40                         | 16.469                        | 20.911                            |
| 13 | PL                | 0.216                            | 0.249                             | 13.956                                 | 14.999                                 | 86.60                         | 0.890                         | 26.749                            |
| 14 | S/P               | 0.296                            | 0.372                             | 19.449                                 | 21.808                                 | 79.50                         | 1.000                         | 35.732                            |
| 15 | GDD               | 0.069                            | 0.074                             | 1.444                                  | 1.486                                  | 94.50                         | 0.528                         | 2.892                             |
| 16 | SLW               | 3.101                            | 4.888                             | 25.823                                 | 32.421                                 | 85.90                         | 0.010                         | 65.120                            |
| 17 | LAI               | 3.271                            | 3.308                             | 25.191                                 | 25.334                                 | 98.90                         | 3.705                         | 51.600                            |
| 18 | SW                | 39.903                           | 49.666                            | 15.851                                 | 17.683                                 | 80.30                         | 11.664                        | 29.268                            |
| 19 | HI                | 0.008                            | 0.009                             | 6.868                                  | 7.311                                  | 88.30                         | 0.177                         | 13.291                            |
| 20 | DME               | 0.266                            | 0.404                             | 27.194                                 | 33.535                                 | 65.80                         | 0.861                         | 45.426                            |
| 21 | ERUE              | 10.538                           | 15.593                            | 28.132                                 | 34.221                                 | 67.60                         | 5.498                         | 47.642                            |
| 22 | GYPP              | 65.676                           | 81.020                            | 9.340                                  | 10.374                                 | 81.10                         | 15.031                        | 17.323                            |
| 23 | GER               | 24.545                           | 49.893                            | 17.538                                 | 25.004                                 | 49.20                         | 7.158                         | 25.340                            |
| 24 | SL                | 501.679                          | 548.025                           | 45.458                                 | 47.512                                 | 84.50                         | 44.146                        | 89.597                            |
| 25 | SDW               | 277706.800                      | 522494.200                        | 21.393                                 | 29.344                                 | 91.50                         | 32.128                        | 39.912                            |

Note: DT=Days to tubercle formation, DFB=Days to flower budding, DFF=Days to cessation, DPM=Days to Physiological maturity, PH=Plant height (cm), MSL=Main shoot length (cm), PB=Number of primary branches per plant, SB=Number of secondary branches per plant, C/P=Number of cluster per plant, P/C=Number of pods per cluster, P/P=Number of pods per plant, PL=Pod length (cm), S/P=Seed per pod, GDD=Growing degree days, SLW=Specific leaf weight, LAI=Leaf area index, SW = 100 - seed weight (g), HI = Harvest index (%), GY = Grain yield per plant (g), DME=Dry matter efficiency, ERUE=Effective rainfall use efficiency, GER=Germination relative index, SL=Seedling length, SDW=Seedling dry weight, VI=Vigour index I, VII=Vigour index II
High heritability with low genetic advance for days to tubercle formation, days to first flowering, days to flowering, days to physiological maturity, growing degree days, pods per cluster, pods per plant, pod length, harvest index, dry matter efficiency and germination relative index and medium heritability with low genetic advance was recorded for primary branches and seedling length. These findings indicate that in the inheritance of these traits non-additive gene action may be involved. In agreement with the present investigation, high heritability was also reported by [13] high heritability coupled with high genetic advance have also been reported by [6] for plant height, 100 seed weight, pod length, seeds per pod, seed yield per plant, harvest index and biological yield. [14] for seed yield per plant and biological yield per plant. [15] for plant height, number of seeds per plant, 100-seed weight. [6] observed high heritability for seed yield, seed dry weight, days to maturity, and 100-seed weight. [17] for days to 50% flowering observed, high heritability and moderate genetic advance.

On the basis of heritability and genetic advance as % of mean, the present investigation suggests that selection may be effective for the improvement of traits viz., plant height, main stem length, cluster per plant, pod length, seed per pod, specific leaf weight, 100-seed weight, harvest index, seedling dry weight and vigour index I, days to tubercles formation, days to flowering, days to cessation, days to physiological maturity, dry matter efficiency, germination relative index, secondary branches per plant, pod per plant, leaf area index, effective rainfall use efficiency, grain yield per plant, vigour index I, pod per cluster because these traits are governed by additive gene action. Whereas, later generation selection may be effective for days to first flowering, growing degree days, no. of primary branches and seedling length because in the inheritance of these traits preponderance of non-additive gene action was found.

4. CONCLUSION

Present study offers scope for utilizing variability present in studied 30 soybean genotypes, including three checks, for 27 pheno-morphophysiological traits for genetic enhancement of soybean. Variability, in general and its heritable part, in particular is important than total phenotypic variability for any selection targeted trait. Vigour index-I, seedling dry weight, specific leaf weight and 100-seed weight were predominantly governed by additive gene action (GCV in close correspondence with PCV, high h^2bs and high GAM). Selection for these traits would be more realistic as both h^2bs and GAM explain the genetic gain over unselected base population.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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