Genetic diversity studies for pod yield and nutrient uptake related traits in groundnut

Mohammad Raza1, M. Reddi Sekhar1, M. Shanthi Priya, T.N.V.K.V. Prasad2 and V. Rajarajeswari3

Department of Genetics and Plant Breeding, Sri Venkateshwara Agricultural College, Tirupati-517 502, Chittoor, Andhra Pradesh, India. Received: 15-02-2018 Accepted: 31-05-2018 DOI: 10.18805/IJARe.A-4995

ABSTRACT

Divergence analysis using Mahalanobis’s D² statistics grouped 40 groundnut genotypes into eight clusters. The maximum inter-cluster distance was found between clusters II and VIII (D=183.23) followed by cluster VI and VIII indicating that the genotypes of these groups were highly divergent from each other. Among all the characters, pod yield per plant contributed the maximum to the diversity followed by leaf iron content (ppm) at 60 DAS, seed iron content (ppm) at maturity, seed calcium uptake (Kg ha⁻¹) and seed calcium content (%) at maturity. The genotypes of above clusters revealed a substantial difference in the means for important yield contributing characters and form ideal parents for genetic improvement in groundnut.

Key words: Clusters, Genetic divergence, Groundnut, Nutrient uptake.

INTRODUCTION

Groundnut (Arachis hypogaea L.) is one of the foremost important oilseed crops which is a major source of vegetable oil and plant protein. It is the World’s fourth most important source of edible oil and the third most important source of vegetable protein (Arntez 1994). In India, it occupies an area of 4.68 M ha producing 6.55 Mt with an average productivity of 1400 kg ha⁻¹ (Anonymous, 2015). Identification and development of nutrient efficient genotypes could be helpful in enhancing the production potential of groundnut and necessitates the germplasm evaluation for pod yield and nutrient uptake traits. The success of plant breeding programme depends largely on the choice of appropriate parents. It is expected that the utilization of divergent parents in hybridization results in promising recombinants.

Genetic improvement mainly depends upon the amount of genetic variability present in the population. Thus, for improving the pod yield, selection of parents based on a number of characters having quantitative divergence is required which can be assessed by D²-statistic developed by Mahalanobis (1936). Therefore, the present study was carried out to ascertain the nature and magnitude of genetic divergence among the 40 groundnut genotypes for pod yield and nutrient uptake related traits.

MATERIALS AND METHODS

The present investigation on genetic diversity for pod yield and its attributes in groundnut (Arachis hypogaea L.) was carried out during Kharif 2015 at the dry land farm of S. V. Agricultural College, Tirupati. The experimental material consisted of forty genotypes of groundnut. The experiment was laid out in a randomized block design with three replications having each genotype sown in a row length of 5 meters with a spacing of 30 cm × 10 cm. The recommended dose of fertilizer 20:40:50 N: P: (kg ha⁻¹) as basal dose and gypsum @ 500 kg ha⁻¹ at peak flowering stage was applied. All recommended agronomic practices and plant protection measures were adopted in order to exploit the full potential of genotypes. Observations were recorded on randomly chosen five competitive plants in each genotype in each replication for all the 22 characters as listed in Table 1. The values of five competitive plants were averaged and expressed as the mean of the respective character for that replication. Protein content and oil content in the seed sample were estimated with the help of Universal Grain analyzer (FOSS: Infratech 1241 Grain Analyzer) by feeding about 100 g of sun-dried seed sample into the analyzer for each genotype per replication. Sample digestion for nutrient estimation was carried out using Di-acid digestion method. Calcium was estimated by Versenate method (Jackson 1967). Estimation of sulphur was done by turbidimetric method (Bhargava and Raghupati, 1993) while, estimation of iron was carried out by using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). The data thus obtained was subjected to analysis of genetic divergence using Mahalanobis’s D² statistics (1936) as described by Rao (1952) for all the 22 characters of forty
Table 1: Analysis of variance for twenty-two quantitative characters in 40 genotypes of groundnut.

| Character                           | Mean sum of squares | Error(df:78) |
|-------------------------------------|---------------------|--------------|
| Replications(df:2)                  | Genotypes(df:39)    |              |
| Days to 50% flowering               | 0.06                | 16.18**      | 0.65          |
| Days to maturity                    | 0.08                | 24.26**      | 0.70          |
| Plant height (cm)                   | 0.55                | 126.91**     | 11.30         |
| No. of primary branches per plant   | 0.78                | 3.73**       | 0.46          |
| No. of pods per plant               | 1.08                | 62.06**      | 7.13          |
| No. of seeds per pod                | 0.06                | 0.19**       | 0.03          |
| Hundred seed weight (g)             | 0.06                | 230.62**     | 4.47          |
| Pod yield per plant (g)             | 0.01                | 66.44**      | 1.92          |
| Kernel yield per plant (g)          | 0.32                | 40.69**      | 0.86          |
| Shelling percentage                 | 1.63                | 315.15**     | 13.53         |
| Harvest index (%)                   | 0.97                | 219.40**     | 8.02          |
| Protein (%)                         | 0.18                | 1.77**       | 0.14          |
| Oil (%)                             | 0.36                | 2.56**       | 0.20          |
| Leaf Calcium (%) at 60 DAS          | 0.15                | 0.67**       | 0.00          |
| Leaf Sulphur (%) at 60 DAS          | 0.00                | 0.00**       | 0.00          |
| Leaf Iron (ppm) at 60 DAS           | 0.05                | 18419.06**   | 3.67          |
| Seed Calcium (%) at maturity        | 0.00                | 0.00**       | 0.00          |
| Seed Sulphur (%) at maturity        | 0.00                | 0.00**       | 0.00          |
| Seed Iron (ppm) at maturity         | 0.13                | 4306.56**    | 2.73          |
| Seed Calcium uptake (kg ha\(^{-1}\))| 0.00                | 0.17**       | 0.00          |
| Seed Sulphur uptake (kg ha\(^{-1}\))| 0.00                | 1.92**       | 0.00          |
| Seed Iron uptake (kg ha\(^{-1}\))   | 0.00                | 0.01**       | 0.00          |

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

The intra- and inter-cluster D\(^2\) values among the eight clusters are presented in Table 3. The Intra-cluster average D\(^2\) values ranged from 0.00 to 88.8. Among the clusters, cluster I had the maximum intra cluster distance (88.8) followed by cluster VII (82.36), cluster VI (24.12), cluster V (21.67), cluster IV (20.57), cluster III (19.38) and cluster II (17.02) while the clusters VIII recorded zero values as it included only single genotype in it (Table 3).

The maximum inter-cluster D\(^2\) value was recorded between II and VIII followed by cluster VI and VIII, IV and VIII, III and VIII, I and III, VII and VIII, I and VI, I and IV, IV and VI and I and VII in the decreasing order of inter-cluster D\(^2\) values. The genotypes from diverse clusters can be utilized as potential parents and crossing between them would result in the high heterotic expression for yield and its component traits. Thus, selection of parents from such clusters for hybridization programmes would result in novel recombinants. John et al. (2012) and Raghuvanshi et al. (2015) made similar studies in groundnut to identify genotypes resulting in a heterotic expression for yield components and corroborates the findings of present study.

Cluster means for yield, component traits and nutrient uptake traits are given in Table 4. Considerable differences between clusters means were observed for most of the characters under study. The genotypes of cluster I registered maximum values for a number of seeds per pod, hundred seed weight and shelling percent whereas the genotypes of cluster III exhibited high cluster mean for seed calcium uptake.
Table 2: Cluster composition of 40 groundnut genotypes based on Tocher’s method.

| Cluster number | No. of genotypes | Genotypes |
|----------------|------------------|-----------|
| I              | 4                | TPT-3, Bheema, ICGV-03128, K-1621 |
| II             | 2                | K-1814, J-86 |
| III            | 2                | Greeshma, VG-315 |
| IV             | 2                | LGN-163, Dh-235 |
| V              | 2                | MLTG(SB)-3, K-1696 |
| VI             | 2                | ICGS-76, K-1501 |
| VII            | 25               | K-9, K-1741, TPT-4, TPT-1, AVT(D)-1412, MLTG (VB)-2, K-1648, AVT(D)-1415, K-1930, MLTG(SB)-6, MLTG (VB)-11, CTMG-11, AVT(D)-1425, K-7, JCG-3005, K-6, K-1622, Harithandhra, K-1662, JSSP-49, K-1628, K-1976, Narayani, Abhaya, TCGS-1157 |
| VIII           | 1                | Dharani |

Table 3: Intra-cluster (diagonal) and inter-cluster distances of eight clusters in groundnut.

| I Cluster     | II Cluster     | III Cluster    | IV Cluster     | V Cluster     | VI Cluster     | VII Cluster    | VIII Cluster   |
|---------------|----------------|----------------|----------------|---------------|---------------|----------------|----------------|
| 7885.69       | 5974.85        | 6948.10        | 9409.76        | 6355.64       | 9553.26       | 7127.00        | 22606.03       |
| (88.8)        | (77.30)        | (83.35)        | (97.00)        | (79.72)       | (97.74)       | (84.42)        | (150.35)       |
| 289.73        | 1999.15        | 2436.06        | 1355.74        | 2582.95       | 6727.90       | 33574.60       |
| (17.02)       | (44.71)        | (49.35)        | (36.82)        | (50.82)       | (182.02)      | (183.23)       |
| 375.73        | 1107.39        | 1133.601       | 2582.95        | 6727.90       | 33574.60      | 26212.53       |
| (19.38)       | (44.71)        | (49.35)        | (36.82)        | (50.82)       | (182.02)      | (183.23)       |
| 423.30        | 1966.18        | 615.83         | 7650.99        | 31326.66      |
| (20.57)       | (33.23)        | (33.67)        | (87.47)        | (176.99)      |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |
| 582.04        | 1648.35        | 5800.93        | 28373.21       |
| (21.67)       | (40.59)        | (76.16)        | (168.44)       |

Similarly, genotypes of cluster IV and cluster VIII were early in flowering whereas genotypes of cluster VI were late to flower. The genotypes of cluster V recorded high value for harvest index and seed calcium (%) at maturity. In the similar fashion, genotypes of cluster VI recorded low value for plant height. Similarly, low value for days to maturity and high values for number of primaries per plant, number of pods per plant, pod yield per plant, kernel yield per plant, protein %, oil %, leaf calcium (%) at 60 DAS, leaf sulphur (%) at 60 DAS, leaf iron (ppm) at 60 DAS, seed sulphur (%) at maturity, seed iron (ppm) at maturity, seed sulphur uptake and seed iron uptake were registered by the genotypes of cluster VIII. Inter-crossing of the genotypes from these clusters could be suggested to generate a wide spectrum of variability followed by effective selection for these characters.

Superior genotypes based on their performance with respect to a particular trait, belonging to different clusters have been enlisted in Table 5. It shows the best genotype for a trait which can be chosen for improvement in groundnut. Narayani, belonging to cluster VII can be selected for plant height which is positively correlated with pod yield. Similarly, genotype Dharani of cluster VIII has a good potential for increasing kernel yield per plant, seed sulphur content at maturity and seed iron uptake whereas Harithandhra can be used for improving seed calcium uptake in groundnut.

Among all the characters studied, pod yield per plant contributed maximum (30.13 %) to the diversity followed by leaf iron (ppm) at 60 DAS (27.95 %), seed iron (ppm) at maturity (18.33 %), seed calcium uptake (17.31 %) and seed calcium (%) at maturity (3.46 %) as shown in Table 6.

The characters viz., hundred seed weight, seed sulphur uptake, seed iron uptake, leaf sulphur (%) at 60 DAS, harvest index, number of primary branches plant and days to maturity contributed 0.77, 0.64, 0.64, 0.38, 0.13, 0.13 and 0.13 percent to the total genetic divergence in decreasing order respectively.

The characters, viz., days to 50 % flowering, plant height, number of pods per plant, number of seeds per pod, kernel yield per plant, shelling per cent, protein per cent, oil per cent, leaf calcium (%) at 60 DAS and seed sulphur (%) at maturity had little contribution to the total genetic diversity.
Table 4: Cluster means with respect to pod yield and its component traits in 40 genotypes of groundnut.

| Character                  | Days to 50% flowering | Days to maturity | Plant height (cm) | No. of primary branches per plant | No. of pods per plant | No. of seeds per pod | Hundred seed weight (g) | Pod yield per plant (g) | Kernel yield (g) | Shelling percentage (%) | Harvest Index (%) |
|----------------------------|------------------------|------------------|-------------------|-----------------------------------|----------------------|----------------------|------------------------|------------------------|-------------------|------------------------|---------------------|
| 1 Cluster                 | 29.83                  | 103.08           | 45.75             | 5.50                              | 26.02                | 2.05                 | 39.88                  | 14.28                  | 11.40             | 66.37                  | 43.73               |
| 2 Cluster                 | 31.83                  | 105.17           | 39.10             | 4.90                              | 24.97                | 1.97                 | 27.05                  | 16.85                  | 8.02              | 50.12                  | 48.45               |
| 3 Cluster                 | 30.00                  | 103.00           | 38.38             | 4.63                              | 20.30                | 1.67                 | 31.20                  | 20.00                  | 10.09             | 51.06                  | 51.20               |
| 4 Cluster                 | 28.67                  | 105.00           | 45.07             | 4.28                              | 23.83                | 1.80                 | 26.32                  | 18.02                  | 10.17             | 56.75                  | 49.70               |
| 5 Cluster                 | 32.00                  | 103.50           | 45.60             | 6.70                              | 24.17                | 1.90                 | 38.18                  | 16.98                  | 15.13             | 66.17                  | 57.47               |
| 6 Cluster                 | 32.67                  | 107.17           | 35.60             | 4.27                              | 19.77                | 1.80                 | 32.57                  | 13.85                  | 5.65              | 43.44                  | 42.04               |
| 7 Cluster                 | 30.16                  | 103.99           | 43.13             | 5.01                              | 21.86                | 1.88                 | 34.80                  | 19.30                  | 10.99             | 56.76                  | 49.63               |
| 8 Cluster                 | 28.67                  | 100.67           | 53.47             | 7.43                              | 28.00                | 1.80                 | 36.37                  | 29.13                  | 18.29             | 63.04                  | 51.24               |

Contd...

Table 4 contd....

| Character                  | Protein (%) | Oil (%) | Leaf Calcium (%) at 60 DAS | Leaf Sulphur (%) at 60 DAS | Leaf Iron (ppm) at 60 DAS | Seed Calcium (%) at maturity | Seed Sulphur (%) at maturity | Seed Iron at maturity (Kg ha⁻¹) | Seed Calcium uptake (Kg ha⁻¹) | Seed Sulphur uptake (Kg ha⁻¹) | Seed Iron uptake (Kg ha⁻¹) |
|----------------------------|-------------|---------|---------------------------|---------------------------|--------------------------|-----------------------------|-------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------|
| 1 Cluster                  | 25.48       | 47.11   | 1.76                      | 0.21                      | 138.25                   | 0.05                        | 0.17                          | 71.29                           | 0.53                           | 1.58                         | 0.10                      |
| 2 Cluster                  | 24.18       | 47.95   | 0.80                      | 0.19                      | 60.21                    | 0.05                        | 0.16                          | 79.58                           | 0.46                           | 1.35                         | 0.07                      |
| 3 Cluster                  | 25.48       | 47.23   | 1.55                      | 0.22                      | 74.62                    | 0.06                        | 0.18                          | 135.37                          | 0.73                           | 2.16                         | 0.16                      |
| 4 Cluster                  | 24.38       | 48.02   | 0.93                      | 0.28                      | 56.89                    | 0.05                        | 0.14                          | 139.45                          | 0.36                           | 1.35                         | 0.09                      |
| 5 Cluster                  | 25.78       | 46.92   | 1.30                      | 0.23                      | 75.75                    | 0.09                        | 0.21                          | 116.01                          | 0.69                           | 1.53                         | 0.09                      |
| 6 Cluster                  | 25.47       | 46.05   | 1.70                      | 0.21                      | 54.56                    | 0.06                        | 0.18                          | 146.42                          | 0.48                           | 1.27                         | 0.09                      |
| 7 Cluster                  | 25.49       | 47.34   | 1.43                      | 0.24                      | 142.07                   | 0.06                        | 0.19                          | 111.17                          | 0.65                           | 1.98                         | 0.12                      |
| 8 Cluster                  | 26.27       | 48.13   | 1.88                      | 0.31                      | 321.83                   | 0.04                        | 0.23                          | 182.03                          | 0.69                           | 4.24                         | 0.33                      |

Table 5: List of selected genotypes from diverse characters for hybridization in groundnut for genetic improvement of pod yield and nutrient uptake related traits.

| Name of genotype | Cluster number | Superior characters |
|------------------|----------------|---------------------|
| CTMG-11          | VII            | Traits              |
| Narayani         | VII            | Days to maturity    |
| K-7              | VII            | Plant height (cm)   |
| ICGV-03128       | I              | No. of primary branches per plant |
| Dharani          | VIII           | Kernel yield per plant (g) |
| K-1648           | VII            | Shelling percentage |
| TCGS-1157        | VII            | Harvest index (%)   |
| Dharani          | VIII           | Leaf Iron (ppm) at 60 DAS after sowing |
| Dharani          | VIII           | Seed Sulphur (%) at maturity |
| Dharani          | VIII           | Seed Iron (ppm) at maturity |
| Harithandhra     | VII            | Seed Calcium uptake (kg ha⁻¹) |
| TCGS-1157        | VII            | Seed Sulphur uptake (kg ha⁻¹) |
| TCGS-1157        | VII            | Seed Iron uptake (kg ha⁻¹) |

Divergence which is suggestive of lack of diversity for these traits in the present genetic material which might be due to the operation of directional selection adopted by the breeders in the development of these genotypes.

It was observed that pod yield per plant, leaf iron (ppm) at 60 DAS, seed iron (ppm) at maturity, seed calcium uptake and seed calcium (%) at maturity were the major contributors towards divergence (Table 6). The performance of genotypes and the characters with a maximum contribution towards divergence should also be considered for improvement of groundnut.

The maximum contribution of pod yield per plant to genetic diversity is in consonance with the report of Garjappa et al. (2005), Suneetha et al. (2007) and Bhakal and Lai (2015). The maximum contribution of days to maturity to genetic diversity is in consonance with the reports of Garjappa et al. (2005) and Lakshmidevamma et al. (2006). Least contribution of a number of pods per plant towards
Table 6: Contribution of pod yield and its component traits to total diversity in 40 genotypes of groundnut.

| Character                                      | Times ranked first | Contribution (%) |
|------------------------------------------------|-------------------|------------------|
| Days to 50% flowering                         | 0                 | 0.00             |
| Days to maturity                               | 1                 | 0.13             |
| Plant height (cm)                              | 0                 | 0.00             |
| No. of primary branches per plant              | 1                 | 0.13             |
| No. of pods per plant                          | 0                 | 0.00             |
| No. of seeds per pod                           | 0                 | 0.00             |
| Hundred seed weight (g)                        | 6                 | 0.77             |
| Pod yield per plant (g)                        | 235               | 30.13            |
| Kernel yield per plant (g)                     | 0                 | 0.00             |
| Shelling percentage                            | 0                 | 0.00             |
| Harvest index (%)                              | 1                 | 0.13             |
| Protein (%)                                    | 0                 | 0.00             |
| Oil (%)                                        | 0                 | 0.00             |
| Leaf Calcium (%) at 60 Days after sowing       | 0                 | 0.00             |
| Leaf Sulphur (%) at 60 Days after sowing       | 3                 | 0.38             |
| Leaf Iron (ppm) at 60 Days after sowing        | 218               | 27.95            |
| Seed Calcium (%) at maturity                   | 27                | 3.46             |
| Seed Sulphur (%) at maturity                   | 0                 | 0.00             |
| Seed Iron (ppm) at maturity                    | 143               | 18.33            |
| Seed Calcium uptake (Kg ha\(^{-1}\))           | 135               | 17.31            |
| Seed Sulphur uptake (Kg ha\(^{-1}\))           | 5                 | 0.64             |
| Seed Iron uptake (Kg ha\(^{-1}\))              | 5                 | 0.64             |

diversity was reported earlier by Suneetha et al. (2007) which is in conformity with the results of the present study.

From the foregoing discussion, it is to conclude that genotypes from divergent clusters namely Bheema (Cluster-I), K-1696 (Cluster V), K-9, TPT-4, K-1648, AVT (D)-1415, K-6, Harithandhra, Abhaya and TCGS-1157 (cluster VII) and Dharani (cluster VIII) can be utilized as potential parents and crossing among themselves would result in high heterotic expression for yield component traits and wider segregation among the progenies. The superior recombinants can be obtained by involving such genotypes as parents in hybridization programmes.

CONCLUSION

In the recent past, nutrient deficiencies have increased due to a generalized decrease in the quality of poor people’s diet and nutritional security is a major issue in world’s food scenario. With increasing thrust on proper nutrition, developing high yielding varieties with desirable quality traits, adapted to local conditions would be extremely helpful for successful groundnut improvement programmes and will equally bridge the nutritional gap in human diet especially among the poor.

In the present experiment, the D\(^2\) analysis revealed the presence of considerable diversity among 40 genotypes and grouped them into eight clusters. The characters viz., pod yield per plant, leaf iron (ppm) at 60 DAS, seed iron (ppm) at maturity, seed calcium uptake and seed calcium (%) at maturity contributed maximum towards genetic divergence. Based on inter-cluster distances, genotypes drawn from divergent clusters namely Bheema (Cluster-I), K-1696 (Cluster V), K-9, TPT-4, K-1648, AVT (D)-1415, K-6, Harithandhra, Abhaya and TCGS-1157 (cluster VII) and Dharani (cluster VIII) are suggested for inclusion in hybridization programme for obtaining superior and desirable recombinants in terms of higher nutrient uptake and higher nutrient assimilation into pods.

REFERENCES

Anonymous (2015). Annual Report. AICRP-Groundnut. Directorate of Groundnut research, Junagarh, Gujarat, India.
Arnetz (1994). Encyclopedia of Agricultural Science. Groundnut (Arachis hypogaea L.). Academic Press. 3:112.
Bhakal, M and Lal, G.M. (2015). Studies on genetic diversity in groundnut (Arachis hypogaea L.) Germplasm. Journal of Plant Science & Research. 2(2): 1-4.
Bhargava, B.S and Raghupati, H.B. (1993). Analysis of Plant Materials for Macro and Micronutrients. In: Methods of Analysis of Soils, Plants, Waters and Fertilizers. Edited by: Tandon, H.L.S. 1993. Fertilizer Development and Consultation Organisation, New Delhi. Pp: 144-166.
Garjappa., Reddy, C.D.R., Naik, K.S.S and Rao, V.S. (2005). Genetic divergence in groundnut (Arachis hypogaea L.). The Andhra Agricultural Journal. 52(3&4): 424-436.
Jackson, M.L. (1967). Soil Chemical Analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi. Pp. 114.
John, K., Reddy, P.R., Reddy, K.H, Sudhakar. P and Reddy, N. P.E. (2012). Estimation of heterosis for certain morphological, yield and yield attributes in groundnut (Arachis hypogaea L.). Legume Research. 35 (3):194-201.
Lakshmidevamma, T.N., Byregowda, M., Mahadeva, P and Lakshmi, G. (2006). Genetic divergence for yield and its component traits in groundnut germplasm. *Indian Journal of Plant Genetic Resources*. **19**(1): 77-79.

Lindsay, W.L and Norvell, W.A. (1978). Development of DTPA Soil test for Zinc, Iron, Copper and Manganese. *Soil Science Society of American Journal*. **42**: 421-428.

Mahalanobis, P.C. (1936). On the generalized distance in statistics. *In: Proceedings of the National Academy of Science, (India).* **2**: 49-55.

Raghuwanshi, S.S., Kachhadia, V.H., Vachhani, J.H., Jivani, L.L. and Patel, M.B. (2015). Genetic divergence in groundnut (*Arachis hypogaea* L.) *Electronic Journal of Plant Breeding*. **10**: 145-151.

Rao, C.R. (1952). *Advanced Statistical Methods in Biometrical Research*. John Wiley and sons. New York, Pp. 236-272.

Sharma, N.K., Singh, R.J and Kumar, K. (2012). Dry Matter Accumulation and Nutrient Uptake by Wheat (*Triticum aestivum* L.) under Poplar (*Populus deltoides*) Based Agroforestry System. *International Scholarly Research Notices Agronomy*. Pp 1-7.

Suneetha, N. (2007). Morphological and RAPD based genetic diversity studies among released cultivars and pre-release cultures of groundnut (*Arachis hypogaea* L.). *M.Sc. (Ag.) Thesis* submitted to Acharya N.G. Ranga Agricultural University, Hyderabad.