

NUMERICAL TAXONOMIC STUDIES IN WILD *Arachis* GERMPLASM OF THE SECTION *Arachis*

K. CHANDRAN¹ AND S.M. PANDYA²

¹National Research Centre for Groundnut, P.B.No.5, Ivnagar road, Junagadh-362001, Gujarat, India.

²Department of Biosciences, Saurashtra University, Rajkot, Gujarat, India.

ABSTRACT

Systematic studies on genus *Arachis* have been attempted by taxonomists based on morphological, cytological and biochemical studies and different species are reported as progenitor of *Arachis hypogaea* L. Studies based on numerical relationships are mainly restricted to biochemical characterization. Only fragmentary evidence could be evolved from this numerical analysis, as most of the results depend on a few characters and a holistic approach was lacking in studying the relationships. In the present study we have tried to collate morphological data with anatomical and palynological data to draw conclusions on species relationships. High intra-specific variation was observed for most of the traits studied and in cluster analysis at 13 clusters stage accessions of *A. batizocoi*, *A. correntina*, *A. stenosperma*, *A. monticola*, and *A. hypogaea* formed independent clusters showing their similarity within the species. However, *A. duranensis* accessions form four clusters indicating the necessity of further taxonomic separation of this population. Similarly accessions of *A. kempff-mercadoi* also formed two clusters, which are distinct in morphological, anatomical and palynological characters and also require a taxonomic revision. Systematic studies based on numerical relationships proved to be a system for finding taxonomical relationships and by collating characters derived from palynological and anatomical studies with the morphological characters an effective description for the taxa could be prepared.

KEY WORDS : *Arachis*, Morphology, Anatomy, Palynology, Numerical taxonomy

INTRODUCTION

Numerical taxonomy is carried out by the conversion of information on taxonomic entities into numerical quantities and ordering of units into taxa on the basis of their affinities. The ideal taxonomic system is that which has maximum information based on characters derived from all branches of science and every character is of equal weightage in forming a taxon. Numerical taxonomic studies in the genus *Arachis* limited to a few reports. Stalker (1990) used cluster analysis on morphological characters in some species of the Section *Arachis* to establish species. Other reports available on studies of numerical taxonomic relationship were based on coefficient of

association, RFLP variability on peanut cultivars and wild relatives (Kochert *et al.*, 1991) and seed protein profile (Singh *et al.*, 1991). Isozyme variation among cultivated and wild relatives of *Arachis* (Lu and Pickersgill, 1993) and DNA amplification and fingerprinting (He *et al.*, 1997) also showed some insight to the inter-specific relationship based on numerical analyses. In all previous studies only fragmentary evidence could be evolved, as most of the results depended on few characters and a holistic approach is lacking in studying relationship. In the present investigation, data on the morphological, palynological, pollen physiological, and anatomical characters were used for deducing taxonomic relationship.

SYSTEMATIC STUDIES IN THE GENUS *Arachis*

MATERIALS AND METHODS

Morphological characterization

Thirty five accessions belonging to 13 species of *Arachis* (section *Arachis*) including four accessions of *A. hypogaea* belonging to four habit types were procured from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and grown in an unreplicated plot of (2.8 m x 3.5 m) during 1996-97 and 1997-98 at Jungadh, Gujarat, India. The accessions studied have been listed in Table 1. Seeds were sown in June and harvested next May except for the cultivated species where the harvesting was done 120-130 days after sowing. Observations were recorded on 105-110 day old plants using Preliminary Descriptors for *Arachis* (IBPGR, 1990). Additional descriptor and descriptor states were used wherever necessary. Thirty-two qualitative characters (20 vegetative and 12 reproductive) and 33 quantitative characters (22 vegetative and 11 reproductive) were recorded randomly from three plants and the data were pooled over the years for analysis. Leaf characters on the main stem were recorded on the 3rd leaf and 5th leaf on lateral branches from the apex, to get full expression of the character. Floral characters were recorded on 30 flowers of each accession and length of style beyond anther column was measured using an ocular micrometer. The Methuen handbook of colour (Kornerup and Wanscher, 1963) was used as reference colour chart. Peg length was recorded on 15 pegs and pod and seed characters from 10 mature pods.

Palynological and pollen physiological characterization

Pollen grains were collected from unopened flowers of 105-110 day old plants

and acetolyzed by Erdtman's method (1966). Permanent slides were prepared from acetolyzed pollen grains by mounting in glycerin jelly (Nair, 1970). For describing and classifying the pollen grains the terminologies and methods were adopted from Erdtman (1966) and Nair (1964). The apertural morphoforms were studied under a light microscope. The polar and equatorial length of 50 pollen grains at random was measured using an ocular micrometer. The thickness of the sexine and nexine were measured using Image Analyzer. The pollen grains were germinated in the medium described by Malik and Chhabra (1976) and the germination and pollen tube growth were observed after 30 min and 120 min using ocular micrometry.

Anatomical characterization

All the leaf anatomical characters were recorded on the 3rd leaf from the apex on the main stem of 110 days old plants. Number of trichomes/mm of leaf margin was counted from five microscope fields in three replications and for trichome length an average of 10 trichomes at random was measured. Stomatal length and width (when the guard cells were fully turgid) were measured from epidermal peels of a fresh leaf. Twenty stomata, each from both surfaces of the leaf, were measured in three replications to compute the average. Epidermal impressions on a thin layer of fevicol film from both abaxial and adaxial surfaces was used for studying stomatal frequency and for counting number of epidermal cells. Five microscope fields with an area of 0.3315mm² in three replications were observed on both surfaces and number of cells/ mm² was calculated. Stomatal index was calculated by using the formula $SI = \frac{\text{no. of stomata}}{(\text{no. of stomata} + \text{no. of epidermal cells})} \times 100$. For studying the internal striation of various

tissues of the leaflet, the midrib region leaving 1 cm from the base of the leaflet was sampled and fixed in formaldehyde: acetic acid and ethanol (5:5:90). The Paraffin embedding method was used to prepare permanent serial transverse sections (TS) with safranin/fast green double staining. For anatomical studies of the stem, the first internode above the cotyledonary node was sampled. Hand sectioning followed by dehydrating in an alcohol/xylene series was done to prepare permanent slides. Double staining with safranin and fast green was used to distinguish striation of tissues. Observations were taken at random from five slides in three replications. Twenty-six recorded variables (trichome length, trichome density, stomatal length and width at abaxial and adaxial surfaces, stomatal frequency at abaxial and adaxial surfaces, number of epidermal cell/mm² at abaxial and adaxial surfaces, thickness of leaf epidermis, palisade tissue layer, breadth of palisade cell, number of palisade cells/0.35 mm length at TS, thickness of spongy tissue layer, thickness of water storage tissue layer, thickness of midrib and lamina, number of tannin cells/mm², thickness of stem epidermis, cortex, vascular tissue and pith, number of tannin cells in pith and bundle caps, and distance between bundle caps) and 6 calculated variables (stomatal index at abaxial and adaxial surfaces, palisade index {no. of palisade cells x average breadth of palisade cell}, palisade tissue ratio, spongy tissue ratio, water storage tissue ratio) were used for numerical analysis. Tissue ratio was calculated with the thickness of the specific layer to the total thickness of the lamina.

Numerical analysis

Unweighted pair group method based on arithmetic averages (UPGMA) was used for cluster analysis (Sokal and Michener, 1958). Quantitative characters were standardised by the formula

$$X'_{ij} = \frac{X_{ij} - \bar{X}_i}{S_i}$$

where:

X'_{ij} = the standardised character state code for character i and OTU j

X_{ij} = raw score

$\bar{X}_i$ and S_i are the mean and standard deviation for the character respectively.

Squared euclidian distance was used for cluster formation and the formula for the distance is given as,

$$\Delta^2 = \sum (X_{ij} - X_{ik})^2$$

Where X_{ij} stands for the character state value of the character 'i' in OTU 'j', X_{ik} the character state value of the character 'j' in OTU 'k'.

RESULTS AND DISCUSSION

Morphology

Members of the section *Arachis* shared a few common morphological characteristics like number of primary branches, branching pattern, flowering and pegging. However they possessed high intra and inter-specific variation for most of the morphological traits studied. The highly variable morphological characters include the height of the main stem, number and length of secondary branches and size of the leaves and leaflets. Leaves of both main stem and lateral branches are pinnately compound with four leaflets with an exception of *A. stenosperma*, which consistently showed four to six leaflets. However, the additional leaflet size was much smaller than the normal. There was difference in shape between the apical and basal leaflet of the same leaf for most of the accessions.

Among the reproductive characters the length of hypanthium, length, width and

SYSTEMATIC STUDIES IN THE GENUS *Arachis*

colour of the standard petal, and length of the pistil beyond anther column showed high inter-specific variation. The colour of standard petal ranged from yellow (3 A7) to dark orange (5 A8). *A. stenosperma* was found to possess both yellow and dark orange flowers in different seasons. In *A. helodes* flowers were vivid yellow (3 A8) and in all accessions of *A. batizocoi* it was yellow. In *A. batizocoi* the petal marking on front face was not distinct. *A. hypogaea*, *A. stenosperma*, many accessions of *A. duranensis* (ICGs 8196, 8957, 8207, 8205 and 8139), *A. helodes*, *A. kempff-mercadoi* and in *A. monticola* the colour of the standard petal marking was garnet brown (9 D8) and in others it was dark orange. Hypanthium was generally short in *A. hypogaea*, *A. duranensis* and *A. batizocoi*. In *A. diogoi*, *A. hoehnei* and *A. correntina* the flowers were large with long hypanthium and bigger standard petal. Development of gynophore after fertilization is a unique character of the genus, but *A. cardenasii* showed a distinct gynophore prior to fertilization. The pod shell possesses a beak and reticulate pattern with varying degree. The pods in *A. hypogaea* were the largest, followed by the other amphiploid species (*A. monticola*). *A. stenosperma* showed highest pod and seed length among wild species, but pod and seed width was less than that of many other species.

Palynology and pollen viability

Pollen morphological traits common to all species were nature of colpi and exine ornamentation. The shape of the pollen grain and the shape of the grain in polar view showed similarity between *A. hypogaea* and *A. monticola*. Since intra-specific variation for many of the traits were also observed, distinction at species level was very vague. Tetraploid species are reported to have very

large pollen grains compared to diploid species (Raman, 1965). The present study showed that many diploid species (*A. batizocoi*, *A. kempff-mercadoi*, *A. hoehnei* and *A. correntina*) also had almost same length of the grain but equatorial axis was shorter than that of *A. hypogaea* and *A. monticola* accessions. Based on apertural morphoforms and exine ornamentation, the genus *Arachis* was described as stenopalynous (Chaturvedi *et al.*, 1990). Our studies based on light microscopy showed that variation exists in other palynological traits.

Pollen germination *in vitro* is a direct and easy method of assessing pollen viability (Heslop-Harrison *et al.*, 1984). All accessions of *A. stenosperma* showed more than 90 per cent pollen germination. In *A. hypogaea* the range was from 88.8 (ICG 5770) to 95.4 per cent (ICG 3704). In cultivated groundnut, the pollen tube growth in the stylar tissue was reported to be 1 cm 3h⁻¹ (Lim and Gumpil, 1983). However, *in vitro* the maximum growth rate was found to be 1.28 mm 2 h⁻¹ in ICG 8198 (*A. monticola*), which indicated the slow growth of pollen tube under *in vitro* condition. Malik and Chhabra (1976) reported the enhancement of the pollen tube growth *in vivo*, due to the production of ethylene like substances when treated with Indole-3-Acetic acid prior to pollination. The differences in pollen tube growth under *in vivo* system may be due to the differences in optimum conditions required for different species. This in turn increases the incompatibility among them.

Anatomy

Among the anatomical characters the length and density of trichome at leaf margin, stomatal index and stomatal size showed wide variation. *A. helodes* was near glabrous and

A. correntina was characterized by high pubescence. The *A. hypogaea* ssp. *fastigiata* accession showed more resemblance to the wild species *A. batizocoi*, *A. diogoi*, and *A. stenosperma* in having long and high-density trichomes. Number and length of trichomes on leaf margins were positively correlated with other regions of the leaf and its positive correlation with Jassid resistance was reported by Dwivedi *et al.* (1986).

The stomatal type was mainly paracytic with one subsidiary cell distinctly smaller than the other in all the accessions studied. Anisocytic type and abnormal type of sharing a common subsidiary cell by two or more stomata were also observed at random. In sectional view the guard cells showed an outer ledge made of wall materials. Tetraploid species had longer stomata than diploid species. Suryakumari *et al.* (1989) reported the occurrence of longer stomata at abaxial surface in some wild and cultivated species. In the present studies, though the wider range was observed at abaxial surface, the F-test showed that there is no significant difference between the stomatal lengths of the two surfaces. In general, the accessions having larger leaflet size showed lower stomatal frequency. The lowest frequency was shown by *A. monticola* accessions. Mayee and Suryawanshi (1995) reported the occurrence of fewer stomata in the genotypes resistant to late leaf spot disease. Though the stomatal frequency was very low in the large-foliaged accessions, the stomatal index was high as compared to other species, which is explained by the larger size of the epidermal cells in these accessions. There was significant variation for stomatal index between abaxial and adaxial surface but the variation was not consistent in either of the surfaces. Out of 35 accessions, 23 showed higher stomatal index at the abaxial surface than adaxial. The

stomatal index ranged from 11.8 to 26.7 at abaxial surface and 17.0 to 27.0 at the adaxial surface. These corroborate the study of Suryakumari *et al.* (1989).

The width of the parenchyma cells and compactness in arrangement varied much amongst the accessions. The most compact arrangement was observed in ICG 8207 (*A. duranensis*) whereas *A. hoehnei* showed the most loosely arranged palisade cells. The accessions of *A. hypogaea* also showed loose arrangement with larger intercellular space. Godoy *et al.* (1985) reported that the genotypes resistant to pod rot exhibited most compact arrangements of palisade cells in cultivated groundnut. Hence the species with higher index (*A. duranensis*, *A. correntina* and *A. kempff-mercadoi*) can probably be donors for pod rot resistance. Only one-layered water storage tissue was observed and rarely two layers near the main vein. The presence of these specified tissues is assigned to the xerophytic nature of plants and the thickness of the layer may be assumed to be of better drought resistance. The thickness ranged from 24.5 to 49.4 μm . The highest value was shown by ICG 5813 (*A. hypogaea*) and the lowest by ICG 8125 (*A. stenosperma*). The water storage tissue ratio was highest in *A. kempff-mercadoi* accession followed by *A. duranensis*. The range was from 0.12 (ICG 8957) to 0.28 μm (ICG 8208). Though the thickness of water storage tissue layer was higher for *A. hypogaea*, *A. kempff-mercadoi* had the highest ratio because the former also had a thick lamina. Tannin cells were found in the palisade layer immediately below the upper epidermis. The number of tannin cells in unit length (1.1 mm) showed significant differences between accessions. The average number ranged from 3.0 to 11.3, which was lowest in accessions of *A. hypogaea* and highest in *A. valida*. The high number of

SYSTEMATIC STUDIES IN THE GENUS *Arachis*

tannin sacs is reported to be associated with rust resistance in groundnut (Suryakumari *et al.*, 1984).

The number of tannin cells in the pith, number and distance between bundle caps and the thickness of stele and pith varied significantly. The tannin cells were found only in the pith region just opposite the protoxylem. The number against each protoxylem group varies between the species and accessions, which reflected in the total number of tannin cells. In general *A. hypogaea* accessions showed high number of tannin cells in pith. Among wild species ICG 8208 (*A. duranensis*) had the highest number (43.5) followed by ICG 8210 (*A. batizocoi*). Many anatomical traits, especially trichome density, trichome length, stomatal index, thickness of the palisade layer, compactness in arrangement of the palisade layer, thickness of the water storage layer and number and depth of bundle caps in the stem were reported to be contributing to various biotic and abiotic stresses. Hence, these anatomical traits will be helpful in preliminary screening of the germplasm at laboratory level.

Cluster analysis

The cluster membership has been given in the Table 2. Each accession is treated as OTU (operational taxonomic unit) as intra specific variation was observed and the clustering was stopped at 13 clusters stage, which is equivalent to the number of species studied. At this clustering stage, accessions of *A. batizocoi*, *A. correntina*, *A. stenosperma*, *A. monticola*, and *A. hypogaea* form independent clusters showing their similarity within the species. However, *A. duranensis* accessions form four clusters with seven accessions in one cluster and the other two in a separate cluster and one accession joins with the perennial species in cluster III, which was

having lanceolate leaves like most of the other species in the cluster. *A. kempff-mercadoi* forms two clusters with one accession each clearly visible on morphological, anatomical and palynological characters, especially leaflet shape, leaflet size, trichome length, trichome density, stomatal frequency, and pollen size.

Accessions *A. duranensis* ICGs 8201 and 8205 showed the minimum distance ($D^2 = 43.5$) and they formed the first cluster followed by *A. stenosperma* accessions ICGS 8137 and 8906. The first two accessions were collected from almost the same longitude and latitude at the primary centre of diversity in Bolivia and the *A. stenosperma* accessions were collected from the secondary centre of diversity in Brazil. The morphological and anatomical similarities among the accessions are also supported by the cent percent similarity in isozyme and protein banding patterns (Chandran, 1999). Hence, one of the accessions from each pair may be duplicates and can be removed from the germplasm collection.

A. batizocoi is found closely related to *A. duranensis* accessions belonging to the cluster IV (Table 2). *A. stenosperma* combined with the perennial species *A. correntina*, *A. diogoi*, *A. khulmanii* and *A. kempff-mercadoi*, rather than with the annuals because of its long lateral branches, long hypanthium with bigger standard petal and leaflet shape and size. *A. monticola* found closely related to one of the *A. duranensis* accession (ICG 8208) and with *A. cardenasii* at slightly higher distance (Fig. 1). *A. cardenasii* showed close resemblance with *A. monticola* and with *A. hypogaea* in having triangular oblate shape for the pollen grains in polar view. One accession of *A. correntina* also showed triangular oblate pollen grains. However, *A. hypogaea* clustered with *A. monticola* group only at the later stage of hierarchical clustering. The presence of triangular oblate pollen grains in the diploid species

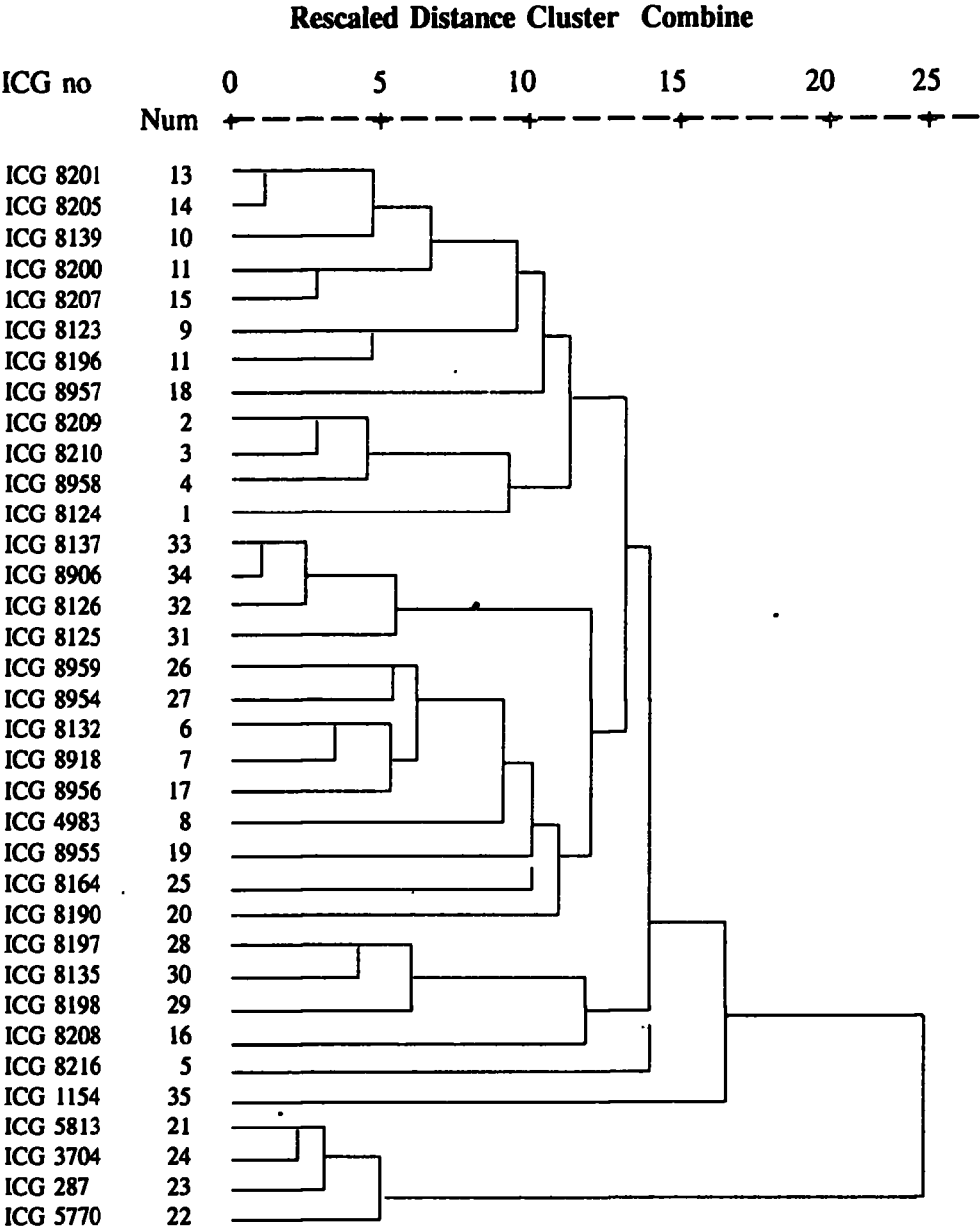


Fig. 1. Dendrogram for the 35 accessions of *Arachis* spp. based on 105 taxonomical traits

SYSTEMATIC STUDIES IN THE GENUS *Arachis*

Table 1. Accessions studied under the section *Arachis*

S.no	Species Name	Icg No	Origin	Latitude	Longit-ude
1.	<i>A. batizocoi</i> Krapov.& W.C. Gregory	8124	Bolivia	20Y50'S	63Y10'W
2.	-do-	8209	Bolivia	20Y17'S	63Y28'W
3.	-do-	8210	Bolivia	19Y40'S	63Y41'W
4.	-do-	8958	Bolivia	19Y44'S	63Y36'W
5.	<i>A. cardenasii</i> Krapov.&W.C. Gregory <i>nom.nud.</i>	8216	Bolivia	18Y20'S	59Y46'W
6.	<i>A. correntina</i> Krapov.&W.C. Gregory <i>nom.nud.</i>	8132	Argentina	27Y33'S	58Y46'W
7.	-do-	8918	Argentina	NA	NA
8.	<i>A. diogoi</i> Hoehne	4983	Paraguay	NA	NA
9.	<i>A. duranensis</i> Krapov.& W.C. Gregory <i>nom.nud.</i>	8123	Argentina	22Y19'S	63Y43'W
10.	-do-	8139	Argentina	24Y47'S	65Y32'W
11.	-do-	8196	Argentina	24Y16'S	65Y12'W
12.	-do-	8200	Argentina	23Y03'S	63Y56'W
13.	-do-	8201	Bolivia	21Y48'S	63Y33'W
14.	-do-	8205	Bolivia	21Y18'S	63Y27'W
15.	-do-	8207	Bolivia	20Y37'S	63Y13'W
16.	-do-	8208	Bolivia	20Y45'S	63Y08'W
17.	-do-	8956	Argentina	23Y04'S	63Y53'W
18.	-do-	8957	Bolivia	21Y26'S	63Y27'W
19.	<i>A. helodes</i> Martius ex Krapov.& Rigoni	8955	Brazil	16Y03'S	57Y13'W
20.	<i>A. hoehnei</i> Krapov.& W.C. Gregory <i>nom.nud.</i>	8190	Brazil	18Y08'S	57Y30'W
21.	<i>A. hypogaea</i> L. ssp. <i>hypogaea</i> var. <i>hypogaea</i> , bunch type	5813	Argentina	NA	NA
22.	<i>A. hypogaea</i> L. ssp. <i>hypogaea</i> var. <i>hypogaea</i> runner type	5770	Argentina	NA	NA
23.	<i>A. hypogaea</i> ssp. <i>fastigiata</i> var. <i>vulgaris</i> Harz	287	Argentina	NA	NA
24.	<i>A. hypogaea</i> ssp. <i>fastigiata</i> Waldron var. <i>fastigiata</i>	3704	Argentina	NA	NA
25.	<i>A. kempff-mercadoi</i> Krapov.& W.C. Gregory & Simpson <i>nom.nud.</i>	8164	Bolivia	NA	NA
26.	-do-	8959	Bolivia	17Y19'S	63Y18'W
27.	<i>A. khulmannii</i> Krapov.& W.C. Gregory <i>nom.nud.</i>	8954	Brazil	16Y05'S	57Y15'W
28.	<i>A. monticola</i> Krapov. & Rigoni	8197	Argentina	24Y07'S	65Y23'W
29.	-do-	8198	Argentina	24Y04'S	65Y24'W
30.	-do-	8135	Argentina	24Y07'S	65Y24'W
31.	<i>A. stenosperma</i> Krapov.& W.C. Gregory <i>nom.nud.</i>	8125	Brazil	25Y24'S	48Y44'W
32.	-do-	8126	Brazil	25Y31'S	48Y31'W
33.	-do-	8137	Brazil	25Y24'S	48Y44'W
34.	-do-	8906	Brazil	25Y31'S	48Y31'W
35.	<i>A. valida</i> Krapov.& W.C. Gregory <i>nom.nud.</i>	11548	Brazil	19Y11'S	57Y29'W

ICG No= ICRISAT germplasm collection number; Origin= Country of collection, NA= not available.

Table 2. Cluster membership based on squared euclidean distance matrix

Cluster No.	OTU's in each cluster
I	ICGs 8124, 8209, 8210, 8958 (<i>A. batizocoi</i>)
II	ICGs 8216 (<i>A. cardenasii</i>)
III	ICG 8132, 8918 (<i>A. correntina</i>), ICG 4983 (<i>A. diogoï</i>), ICGs 8956 (<i>A.duranensis</i>), 8959 (<i>A. kempff-mercadoï</i>), 8954 (<i>A. khulmanii</i>)
IV	ICGs 8123, 8139, 8196, 8200, 8201, 8205, 8207 (<i>A. duranensis</i>)
V	ICG 8208 (<i>A. duranensis</i>)
VI	ICG 8957(<i>A. duranensis</i>)
VII	ICG 8955 (<i>A. helodes</i>)
VIII	ICG 8190 (<i>A. hoehnei</i>)
IX	ICGs 5813, 5770, 287, 3704 (<i>A. hypogaea</i>)
X	ICG 8164 (<i>A. kempff-mercadoï</i>)
XI	ICGs 8197, 8198, 8135 (<i>A. monticola</i>)
XII	ICGs 8125, 8126, 8137,8906 (<i>A. stenosperma</i>)
XIII	ICG 11548 (<i>A. valida</i>)

A. cardenasii and *A.correntina* shows that probably one of the species might have contributed to the evolution of the amphiploid species *A. monticola* or *A. hypogaea*.

The systematic studies based on numerical relationship proved to be a system for finding taxonomic relationship and for describing species characteristics. The difficulty of handling wild species for taxonomical studies is the simulation of environmental conditions close to its natural habitat for expressing their full morphological features. On the contrary from the utilization point of view an evaluation near to the experimental condition is essential. Hence, a taxonomical system which is depending on a large amount of data that are less influenced by the environment is necessary. In this study, by collating characters derived from palynological and anatomical studies with the morphological characters an effective description for the taxa could be prepared.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. A.K. Singh, Former Senior Scientist, ICRISAT, Patancheru, A. P, India, for providing the germplasm and Dr .A. Bandyopahyay, Director, NRCG, Junagadh, India for providing the facilities.

REFERENCES

- Chaturvedi, M., D. Yunus and P.K.K. Nair. 1990. Cyto palynological studies of *Arachis* (Leguminosae) cultivated and wild species and their hybrids. Grana 29(2): 109-117.
- Chandran, K. 1999. Characterization of wild *Arachis* species of the section *Arachis* assembled from primary and secondary centers of diversity. PhD thesis Saurashtra University, Rajkot, Gujarat, India. pp.124.
- Dwivedi, S.L., P.W. Amin, Rasheedunisa, S.N. Nigam, G.V. S. Nagabhushanam, V. R. Rao and R.W. Gibbons. 1986. Genetic analysis of trichome characters with resistance to Jassid (*Empoasca kerri* Pruthi) in peanut. Peanut Sci. 13: 15-18.

SYSTEMATIC STUDIES IN THE GENUS *Arachis*

- Erdtman, G. 1966. Pollen morphology and plant taxonomy- Angiosperm. pp. 162. Hafner Publishers. Co. New York.
- Godoy, R., O.D. Smith, R.A. Taber and R.E. Pettit. 1985. Anatomical traits with pod rot resistance in peanut. *Peanut Sci.* 12: 77-82.
- He, G.H., A.K. Singh and C.S. Prakash. 1997. Analysis of genetic relationship among accessions of *Arachis stenoperma* and *A. duranensis* using DNA markers. *Plant Genetic Resources Newsletter.* 111:25-28.
- Heslop-Harrison, J., Y. Heslop-Harrison and K.R. Shivanna. 1984. Evaluation of pollen quality and a further appraisal of the florochromatic (FCR) test procedure. *Theor. Appl. Genet.* 67: 367-375.
- IBPGR. 1990. Preliminary descriptors for *Arachis* International Crop Network Series.2. Proceedings of a Workshop on the Genetic Resources of Wild *Arachis* Species. International Board for Plant Genetic Resources, Rome.
- Kochert, G., T. Halward, W.D. Branch and C.E. Simpson. 1991. RFLP variability in peanut (*Arachis hypogaea* L.) cultivars and wild species. *Theor. Appl. Genet.* 81: 565-570.
- Kornerup, A. and J.H. Wanscher. 1963. *Methuen hand book of colour.* pp 252. Eyre Methuen Ltd., 11 New Fetter Lane, London.
- Lim, E.S. and J.S. Gumpil. 1983. The flowering, pollination and hybridization of groundnuts (*A. hypogaea*). *Pertanika* 7(2): 161-166.
- Lu, J. and B. Pickersgill. 1993. Isozyme variation and species relationship in peanut and its wild relatives (*Arachis* L.-Leguminosae). *Theor. Appl. genet.* 85: 550-560.
- Malik, C.P. and N. Chhabra. 1976. Hormonal regulation of pollen germination and pollen tube elongation in *A. hypogaea* Reitz. *Proceedings of Indian Acad. Sci.* 84(3): 101-108.
- Mayee, C.D. and A.P. Suryawanshi. 1995. Structural defense mechanism in groundnut to late leaf spot pathogen. *Indian phytopathol.* 8(2): 160-165.
- Nair, P.K.K. 1964. Pollen morphology *In* *Advances in palynology.* Eds. P.K.K. Nair. pp 253-271 The United Block Printers, Lucknow.
- Nair, P.K.K. 1970. Pollen morphology of Angiosperms. A historical and phylogenetic study. pp160. Vikas publishing house, Lucknow.
- Raman, V.S. 1965. Pollen size in natural and synthetic populations of certain plant species. *J. Palynol.* 1: 97-104.
- Singh, A.K., S. Sivramakrishnan, M.H. Mengesha and C.D. Ramaiah. 1991. Phylogenetic relations in section *Arachis* based on seed protein profile. *Theor. Appl. genet.* 82: 593-597.
- Sokal, R.R. and C.D. Michener. 1958. A statistical methods for evaluating systematic relationships. *Univ. Kansas Sci. Bull.* 38:1409-1438.
- Stalker, H.T. 1990. A morphological Appraisal of wild species in section *Arachis* of peanuts. *Peanut Sci.* 17(2): 117.
- Suryakumari, D., V. Seshavatharam, and U.R. Murthy. 1984. Association of Rust resistance with number of tannin sacs in groundnut. *Current Sci.* 53(11): 604-606.
- Suryakumari, D., V. Seshavatharam, and U.R. Murthy. 1989. Leaf anatomical features of some inter-specific hybrids and polyploids in the genus *Arachis* L. *J. Oilseeds Res.* 6(1): 75-84.