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A Systematic Analysis for Grouping Greek Peanut (*Arachis hypogaea* L.) Germplasm Based on Eight Important Phenotypic Traits

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Abstract: An extensive evaluation of 43 varieties from the Greek collection of groundnut was carried out during years 1986-90 in the farm of the Cotton and Industrial Plants Institute, Greece. A systematic characterization referred to eight botanical, morphological and agrophysiological traits included in the descriptor lists of IBPGR and ICRISAT, followed field evaluation. These traits were: growth habit, branching pattern, leaf colour, pod distance from the main root, synchronized pod maturity, days to emergence, days to 50% flowering and days to maturity. Principal Component Analysis (PCA) extracted two main factors representing 83% of the total variation. PC1 (interpreted as earliness factor) explained 68.4% and PC2 (interpreted as synchronized maturity factor) 14.6% of the total variance. Cluster analysis classified the assessed cultivars into distinct groups on the basis of earliness and synchronized pod maturity. The evaluation has shown that most of the Greek varieties botanically belong to the subspecies *hypogaea* and to Virginia type which is late material. Only a few varieties belong to the subspecies *fastigiata* and to Valencia or Spanish type and found to be an early genetic material. The evaluation also contributed in identifying certain varieties, such as Serraiki, Sakania Sindu and Poroia, as promising for their significant earliness, varieties Tragana, Ispaniki and Proimi Funtoti for high pod concentration and varieties Krestena, Karolina and Lakonia for highly synchronized pod maturity.

Key words: *Arachis hypogaea*, groundnut characteristics, principal components, cluster analysis

INTRODUCTION

Genus *Arachis* includes 40 to 70 species (Gregory and Gregory, 1976) that have as their main and distinctive characteristic the formation of a peg that penetrates into the soil to form an underground fruit (Ramanatha and Murty, 1994). The species differ in regard to plant habit, stem, leaf, root, fruit and seed characteristics (Banks, 1976). According to Krapovickas (1973) the cultivated species have been taxonomically classified into 2 subspecies and four botanical varieties:

- Subspecies *hypogaea* which includes the variety *hypogaea* to which the US market types Virginia and Runner belong, and the variety *hirsuta*.
- Subspecies *fastigiata* which includes the variety *fastigiata*, to which the market type Valencia belongs, and the variety *vulgaris* which includes the Spanish market type.

According to Gregory *et al*. (1951) and Gibbons *et al*. (1972) the varieties of Virginia type have a bunching or runner growth habit, while those of Valencia and Spanish type have an erect growth habit. Leaf colour is much lighter in subspecies *fastigiata* than in subspecies *hypogaea*. In crosses between the two subspecies, branching pattern of F1s is usually similar to the varieties from subspecies *hypogaea* and this trait is better described by a quantitative model than by a qualitative one (Qujada and Layrisse, 1985).

The peanut crop usually contains partly unripe pods at harvest; this is due to the continuous flowering characteristic of the species that starts 30-40 days after sowing and continues throughout the whole growing period (Gilman and Smith, 1977). For this reason synchronized maturity is a very important characteristic for the assessment of the varieties. Another characteristic, an important consideration for mechanized harvesting, is pod distance from the main root. Pods formed at a great distance from the main root lead to increased losses at harvest. Peanut crop yields have been nearly doubled with the introduction of new varieties resistant to the main diseases, but there has been no significant corresponding improvement in earliness (Knauft *et al*., 1987). Earliness is of extreme importance for Greece because the crop is harvested in the autumn and it is susceptible to humidity

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when the weather is rainy over extended periods in this season (Kotzamanidis, 1989). This problem is more common in northern Greece, particularly in the region of Serres, where the crop of the large-seeded Virginia type varieties is uncertain in some years due to unfavorable weather conditions at harvest (Kotzamanidis, 1993). Days to emergence, days to 50% flowering and days to maturity, are important characteristics for the assessment of earliness. Assaying Cuban peanut germplasm, Fundora Mayor *et al.* (2006) reported successful grouping in Cuban peanut collection, based on Principal Components Analysis and Cluster Analysis of 14 traits such us flowering pattern, growth habit, seed length and width etc. Early-maturing and large-seeded peanut varieties suitable for commercial cultivation were reported by many researchers (Upadhyaya *et al*., 1995a, b) as a result of proper peanut breeding programmes.

The aim of this study was to evaluate local *Arachis* germplasm of the Greek collection and identify varieties with earliness, high pod concentration near the main root and synchronized pod maturity or combinations of these properties. Principal component and cluster analysis were used for grouping genetic materials combining interesting characteristics. The identification of such varieties would greatly advance breeding programmes designed to solve the problems the crop faces in Greece today.

MATERIALS AND METHODS

The Greek groundnut collection, consisting of 28 local and 15 improved varieties (Kotzamanidis, 1994), was evaluated for several morphological characteristics and for earliness components (Table 1), based on the Descriptor List of IBPGR and ICRISAT (1985). Eight characters were measured, pod distance from the main root and synchronized pod maturity are not included in the Descriptor List, but were assessed in these trials for their agronomic importance. Evaluation trials took place on the farm of the Cotton and Industrial Plants Institute in the period 1986-1990.

Pod distance from the main root was scored as small (3) on Table 1 when the majority (in percentage) of pods were formed within a radius of 10 cm around the main root, medium (2) when the majority formed a radius of 10-20 cm and large (1) when they formed a radius exceeding 20 cm. Synchronized pod maturity was scored low (1) when less than 60%, medium (2) when 60-80% and high (3) when over 80% of the pods matured simultaneously (Kotzamanidis, 1994).

Characters 1-5 in Table 2 were evaluated on 5 plants randomly selected for each variety, while characters 6-8 were assessed by the average performance of all the plants of each variety, according to the rankings of the Descriptor List.

Table 1: Characters used for the description and evaluation of Peanut germplasm

Characters	Coding
1. Growth habit (Gh)	3 = Decumbent-1,4 = Decumbent-2, 5 = Decumbent-3, 6 = Erect
2. Branching pattern (Bp)	1 = Alternate, 2 = Sequential
3. Leaf colour (Lc)	1 = Yellow, 2 = Dark green
4. Pod distance from the main root (Pd)	1 = large (more than 20 cm) 2 = medium (10 to 20 cm) 3 = small (less than 10 cm)
5. Synchronized pod maturity (Sp)	1 = low (less than 60%)2 = medium (60 to 80%), 3 = high (more than 80%)6
6. Days to emergence (De)	1 = 10 2 = 12 3 = 13
7. Days to 50% flowering (Df)	1 = 24 - 30, 2 = 31 - 34, 3 = 35 - 38
8. Days to maturity (Dm)	1 = 141 - 150, 2 = 171 - 180

Table 2: Description and evaluation of the Greek collection of peanuts (characters, as described in Table 1)

	Origin	Characters							
Varieties	County or institute	Gh	Bp	Lc	Pd	Sp	De	Df	Dm
Vatikiotiki	Ilia	3	1	2	1	1	3	2	2
Dafnula	Ilia	5	1	2	2	2	3	2	2
Trifyllia	Ilia	3	1	2	1	2	3	2	2
Serraiki	Serres	6	2	1	3	3	1	1	1
S. George	Lakonia	5	1	2	2	2	3	3	2
St. John	Ilia	5	1	2	2	2	3	2	2
Epitalio	Ilia	5	1	2	2	2	2	3	2
Irea Orthia	Arkadia	5	1	2	2	2	3	2	2
Irea Erpusa	Arkadia	3	1	2	1	1	3	2	2
Krestena	Ilia	5	1	2	2	3	2	3	2
Makrisia	Ilia	5	1	2	2	3	2	3	2
Burnia	Messinia	5	1	2	2	3	2	3	2
Neapoli	Lakonia	3	1	2	2	3	2	3	2
Sekula	Ilia	3	1	2	3	3	2	3	2
Tragana	Ilia	5	1	2	3	2	3	3	2
Vrasna	Thessalo niki	5	1	2	2	2	2	3	2
Vrasna Dopia	Thessalo niki	5	1	2	2	3	2	3	2
Evia	Evia	5	1	2	1	3	3	3	2
Iraklio	Iraklio	3	1	2	1	2	3	2	2
Kalamata Orthia	Messinia	5	1	2	3	3	3	1	2
Kalamata Erpusa	Messinia	3	1	2	1	2	3	2	2
Poroia	Serres	6	2	1	2	3	1	1	1
Pyrgos	Ilia	5	1	2	2	3	3	3	2
Samos	Samos	3	1	2	1	3	3	3	2
Serraiki Dopia	Serres	6	2	1	2	3	1	1	1
Tripoli	Arkadia	4	1	2	1	3	3	2	2
Halkidiki	Halkidiki	3	1	2	2	2	3	3	2
Hania	Hania	5	1	2	2	3	2	3	2
Vergina	C.I.P.I*	5	1	2	2	2	3	2	2
Karolina	"	5	1	2	2	3	3	3	2
Sakania	"	6	2	1	3	3	1	1	1
Sindu									
Vergina 46-2	"	5	1	2	2	2	3	2	2
Vergina G-2	"	5	1	2	2	1	3	2	2
Lakonia	"	5	1	2	2	3	2	3	2
Altika Sindu	"	5	1	2	3	3	3	2	2
Vergina 67	"	5	1	2	2	2	3	2	2
Karolina 17	"	5	1	2	2	2	2	3	2
Sindos 11055	"	6	2	1	3	3	1	1	1
Florida	"	4	1	2	2	2	2	1	2
Ispaniki	"	6	2	1	3	3	1	1	1
Star Sindu	"	6	2	1	3	3	1	1	1
Makedonia	"	5	1	2	2	3	2	3	2
Proimi Funtoti	"	5	1	2	3	2	2	3	2

*Cotton and Industrial Plants Institute

The observation and evaluation trials took place on the farm of the Cotton and Industrial Plants Institute in the period 1986-1990. Seeds of each variety were sown at 20 cm distance, 6 m rows long 0.7 m apart.

Principal Component Analysis following Varimax rotation and Cluster Analysis were the multi variate analysis procedures used to explain the variation exhibited by the germplasm evaluated. All analyses were carried out using the SPSS/PC software package. Additional correlation and frequency procedures were based on Snedecor and Cochran (1980).

RESULTS

Earliness characteristics were varying in the germplasm studied (Table 2). Days to emergence ranged from 1 (10 days as in varieties Serraiki, Poroia, Ispaniki) to 3 (13 days as in varieties Dafnula, Samos, Tripoli). Days to maturity ranged from 1 (141-150 days as in varieties Sakania Sindu, Sindos 11055, Star Sindu) to 2 (171-180 days as in Iraklio, Vergina, Lakonia).

Principal Component analysis extracted 2 principal components accounting for 83% of the overall variance (Table 3). The PC1 was the most important, expressing 68.4% of the variance. PC2 expressed 14.6%. PC1 may be described as an earliness factor. Higher loadings on this factor, following Varimax rotation, included the characters: days to 50% flowering, days to maturity, branching pattern and leaf colour (0.94, 0.93, -0.93 and 0.93 respectively) (Table 4). The varieties appear in different areas on the PC1 axis (Fig. 1) according to their particular characteristics. Thus, on the negative side of the PC1 axis was plotted the group of the early varieties which belong to subspecies *fastigiata,* while the varieties of subspecies *hypogaea* appear on its positive side. The dendrogram from Cluster Analysis gave similar supportive results (Fig. 2) by grouping varieties belonging to subspecies *fastigiata* and *hypogaea* into distinct clusters. The loadings on the second principal component (PC2) included the characters: synchronized pod maturity, pod distance from the main root and plant growth habit (r = 0.78, 0.76 and 0.70, respectively) (Table 4). Therefore PC2 could be interpreted as a "synchronized maturity factor".

From Table 2, growth habit was found ranging from decumbent-1, i.e., prostrate (Vatikiotiki, Neapoli), to erect (Serraiki, Poroia, Ispaniki). Pod distance from the main root was found to be more than 20 cm (Vatikiotiki, Trifyllia, Irea Erpusa), from 10 cm to 20 cm (Dafnula, Makrisia, Makedonia) or less than 10 cm (Serraiki, Star Sindu, Proimi Funtoti), while synchronized pod maturity was less than 60% (as in varieties Vatikiotiki, Irea Erpusa, Vergina G-2), 60 to 80% (Trifyllia, Epitalio, Tragana) or more than 80%

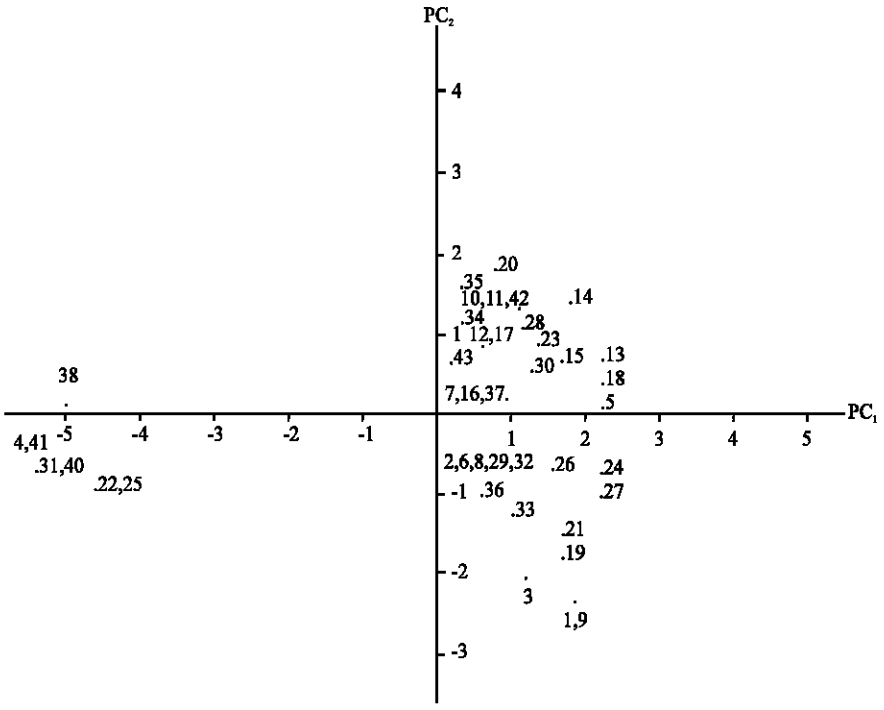

Fig.1: Projection of varieties on PC1 (earliness factor) and PC2 (synchronized maturity factor)

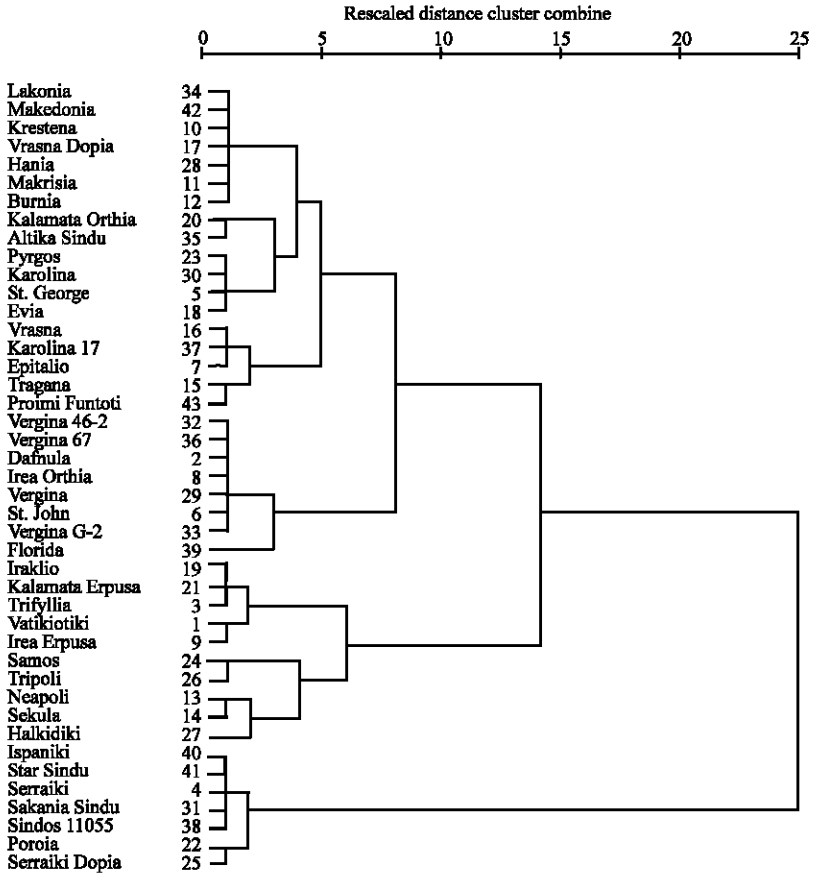

Fig. 2: Dendrogram obtained by Cluster Analysis on the initial data. Varieties belonging to the subspecies *hypogaea* and *fastigiata* appear as distinct groups

Table 3: Results of principal component analysis conducted on 43 entries of *A. hypogaea*

Characters	Communality	Factor	Eigen value	Percentage of variance	Cumulative percentage
Growth habit	0.66015	1	5.47359	68.4	68.4
Branching pattern	0.98612	2	1.16675	14.6	83.0
Leaf colour	0.98612	-	-	-	-
Pod distance from the main root	0.64365	-	-	-	-
Synchronized pod maturity	0.61628	-	-	-	-
Days to emergence	0.87182	-	-	-	-
Days to 50% flowering	0.89005	-	-	-	-
Days to maturity	0.98612	-	-	-	-

Table 4: Contribution of the various characters (factor loadings) to the variation explained by the first 2 PCS following Varimax rotation

Characters	PC1	PC2
Growth habit	-0.40124	0.70651
Branching pattern	-0.93218	0.34229
Leaf colour	0.93218	-0.34229
Pod distance from the main root	-0.23538	0.76697
Synchronized pod maturity	-0.08415	0.78051
Days to emergence	0.79146	-0.49539
Days to 50% flowering	0.94331	-0.01488
Days to maturity	0.93218	-0.34229

(Sekula, Karolina, Lakonia). On the negative side of the PC2 axis (Fig. 1) was plotted the group of varieties which are all more prostrate and with high to medium distance of pods from the main root. On the positive part, appears the group of varieties which all have more than 80% synchronized pod maturity. The prostrate varieties of Decumbent-1 type and the semi-prostrate varieties of Decumbent-2 type are clustered together in the dendrogram (Fig. 2).

The frequencies from Table 2, showed that the most frequent values for the 8 traits described in Table 1, were, respectively 5,1,2,2,2,3,3,2 representing a Decumbent-3 growth habit, a sequential branching pattern, dark green leaf colour, medium pod distance from the main root, medium synchronized pod maturity, 13 days to emergence, 35-38 days to 50% flowering and 171-180 days to maturity.

The correlations between the 8 traits (Table 5) revealed a strong relationship between almost all the traits, except days to 50% flowering with pod distance from the main root and synchronized pod maturity. Branching pattern was negatively correlated to days to

Table 5: Correlations between traits of Table 1

	Gh	Bp	Lc	Pd	Sp	De	Df	Dm
Gh	1.00							
Bp	0.59**	1.00						
Lc	-0.59**	-1.00**	1.00					
Pd	0.61**	0.46*	-0.46*	1.00				
Sp	0.38*	0.38*	-0.38*	0.35*	1.00			
De	-0.56**	-0.80**	0.80**	-0.52*	-0.50*	1.00		
Df	-0.33*	-0.71**	0.71**	-0.25	-0.01	0.37*	1.00	
Dm	-0.59**	-1.00**	1.00**	-0.46*	-0.38*	0.80**	0.71**	1.00

(*, **) Significant at the 0.05 and 0.01 levels, respectively

maturity (r = -1), leaf colour (r =-1) and days to emergence. As a consequence, days to maturity was positively correlated to leaf colour with r = 1.

DISCUSSION

From the dendrogram obtained by Cluster Analysis on the initial data, it was found that varieties belonging to the subspecies *hypogaea* and *fastigiata* appear as distinct groups. Seven subgroups were found, based on differences in earliness, maturity and branching type. Fundora Mayor *et al.* (2006), also reported successful grouping in Cuban peanut collection, with 9 distinct groups.

The factor PC1 described earliness and thus, on the negative side of the PC1 axis was plotted the group of the early varieties which belong to subspecies *fastigiata* while the varieties of subspecies *hypogaea* appear on its positive side. Subspecies *fastigiata*, may insure earliness in varieties and probably in their crosses and consequently their accessions (Upadhyaya *et al.*, 1995a). The varieties of Valencia and Spanish type have erect growth habit, sequential branching pattern, light green leaf colour and belong to subspecies *fastigiata* (Gregory *et al.*, 1951; Gibbons *et al.*, 1972). Valencia type varieties are Serraiki, Poroia and Serraiki Dopia, and Spanish type varieties are Sakania Sindu, Sindos 11055, Ispaniki and Star Sindu. Varieties with alternate branching pattern and dark green leaf colour are of Virginia type (Krapovickas, 1973). Such varieties are Vatikiotiki, Irea Erpusa, Iraklio etc. The PC2 factor consisted mainly from synchronized pod maturity, pod distance from the main root, and plant growth habit, therefore PC2 could be interpreted as a synchronized maturity factor. These characters are important for the evaluation of the varieties, since they are related to the quick and easy harvest of the crop. Varieties having erect growth habit or shorter pod distance from the main root and synchronous pod maturity are harvested without substantial losses in the field and secure good yields. In general, the Greek germplasm grouping analysis based on the 8 important traits studied here, was considered satisfactory. In similar studies, Fundora Mayor (1999) and Fundora Mayor *et al.* (2006), analysed 14 traits and described satisfactory Cuban collection peanut germplasm.

Correlations between the traits studied, could be an analysing procedure with satisfactory results in separating variety groups and subspecies. Branching pattern was negatively correlated to days to maturity, leaf colour and days to emergence, in a way that this could be a criterion for separating varieties and thus finding the most appropriate for breeding purposes. Additionally, the most frequent characteristics determined a main group of varieties that could be used in breeding programmes after proper selection.

The results have shown that the germplasm of the Greek groundnut collection is extremely variable and therefore it can be used as a starting material in breeding programmes for escaping or tolerating the adverse wet conditions at harvest in the peanut growing zone of northern Greece. The current work was successful in identifying promising early germplasm with high pod concentration and synchronized maturity, which are best suited to mechanical harvesting with minimal losses. Such varieties were Krestena and Karolina with highly synchronized pod maturity, Poroia, Sakania Sindu and Serraiki with significant earliness and varieties Tragana, Ispaniki and Proimi Funtoti for their high pod concentration. It has been generally observed in the germplasm used in this study that most early varieties usually combine the other two desired characteristics of synchronized maturity and high pod concentration; thus by selecting for earliness one could expect simultaneous progress on all desired traits (earliness, high pod concentration and synchronized maturity).

Valencia and Virginia groups were separated easily, as they belong to different subspecies. Additionally, from correlation findings, it seems that there are great differences in homogeneity between the two groups (Kotzamanidis *et al.*, 2006), as a consequence of different genetic basis between groups.

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