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Classification and Evaluation of Greek Groundnut (*Arachis hypogaea* L.) Using 17 Main Agronomic and Quality Traits

[1]S.T. Kotzamanidis, [2]N. Stavropoulos and [3]C.G. Ipsilandis
[1]N.AG.RE.F. Cereal Institute, [2]Greek Gene Bank, 57001 Thermi, Thessaloniki, Greece
[3]Department of Plant Sciences, Technological Education Institution of W. Macedonia,
Branch of Florina, Terma Kontopoulou, 53100 Florina, Greece

Abstract: Forty-three cultivars from the Greek collection of groundnut were characterized and evaluated for various agronomic and quality traits and resistance to waterlogging, during 1986-90 in the farm of the Cotton and Industrial Plants Institute. Seventeen morphological and physiological traits included in the descriptor lists of IBPGR and ICRISAT were used in total. Principal Component Analysis (PCA) extracted 5 factors representing 77.3% of the total variation. PC1 explained 35.6, PC2 14.2, PC3 13.0, PC4 8.4 and PC5 6.1% of the total variance. Cluster analysis classified the assessed cultivars into distinct cultivar-groups on the basis of pod and seed characteristics. The evaluation showed that most Greek *Arachis* cultivars belong to subspecies *hypogaea,* group Virginia. Only a few belong to subspecies *fastigiata* groups Valencia or Spanish. The experimental work succeeded in preliminary identification of certain cultivars with promising tolerance to waterlogging at harvest which are to be used either directly in the *Arachis* production zone in Northern Greece, or as breeding materials for the improvement of the species.

Key words: *Arachis hypogaea*, agronomic characteristics, multivariate analysis

INTRODUCTION

The genus *Arachis*, which includes the domesticated peanut, *A. hypogaea* L., consists of 40 to 70 species (Gregory and Gregory, 1976). They all possess a unique structure, the peg, for producing subterranean fruit. The species differ in various stem, fruit and seed characteristics (Banks, 1976). The peanut cultivars grown in Greece belong to the following 3 cultivar groups, according to systematic classification approaches given by Gregory *et al.* (1951), Bunting (1955, 1958), Krapovickas and Rigoni (1960), as combined by Gibbons *et al.* (1972).

- Virginia group, with cultivars characterised by large pods, pronounced pod beak and apparent constriction and two seeds per pod of characteristic stable colour.
- Valencia group includes cultivars with medium-sized pods, without constriction and pod beak, usually with 3 to 4 flattened seeds per pod of red colour.
- Spanish group includes cultivars with small pods, absence of pod beak, with pronounced constriction, two seeds per pod and a characteristic seed colour.

The need for a common interface for information exchange among breeders became more intensive after the establishment of international foundations for exchanging genetic materials. Additionally there was found a great gene diversity among botanical varieties in peanut (Ferguson *et al.*, 2004). In Greece there was no reference for taxonomic grouping based on description of agronomic and quality traits of landraces and cultivars (Papadopetros, 1979). Also in Greece, the crop is harvested in the autumn, which usually marks the onset of the rainfall season. The fruit is susceptible to prolonged excessive humidity in that season. Such adverse conditions are more frequent in Northern Greece where the crop of the large seeded varieties (of Virginia group) is in certain years damaged because of unfavourable weather conditions for the harvest and drying of the pods of these cultivars (Kotzamanidis, 1989).

The need for an international co-operation in utilising promising genetic materials, led us to study certain important characteristics of pods and seeds of the Greek *Arachis* germplasm and to identify cultivars belonging to different cultivar-groups which are tolerant to soil waterlogging at harvest, in order to overcome certain practical limitations of the crop in Greece. Additionally, there were studied some traits with commercial and agronomic importance.

Corresponding Author: S.T. Kotzamanidis, N.AG.RE.F. Cereal Institute, 57001 Thermi, Thessaloniki, Greece
Tel: +302310471544

MATERIALS AND METHODS

Characterisation and evaluation of a Greek groundnut collection, consisting of 43 cultivars (Kotzamanidis, 1994) was carried out during 1986-1990 in the farm of the Cotton and Industrial Plants Institute (Greece) using 17 morphological and physiological characteristics based on the Descriptor List of IBPGR and ICRISAT (1992) (Table 1). According to Gibbons *et al.* (1972) with these characteristics we can effectively classify the cultivars into the different botanical groups (i.e., cultivar-groups).

Characteristics 1-13 were measured in the laboratory on 5 samples of pods and seeds taken randomly immediately after harvest from the harvested pod lots. Shell thickness and hardness as well as taste of the seed were not included in the descriptor lists used in the study, nevertheless they were assessed using empirical and therefore subjective evaluation criteria, because they were considered important agronomic traits. More specifically, shell thickness and hardness were determined by the ease or difficulty of pod shell breaking with the fingers. Seed taste was determined by organoleptic evaluation from a 3-person panel. Characteristics 14-17 refer to observations made in the field and represent means of at least five measurements. For plant height the height of the main stem of the plant was scored at the stage of pod formation. The infestation of the cultivars by mites and leaf-eating insects was scored following visual assessment of the damage made by these pests in the varieties under study. Finally, the tolerance to waterlogging of the pods of these cultivars was assessed by measuring the percentage of decayed pods under such prolonged adverse environmental conditions at that stage. The observation and evaluation trials took place in the farm of the Cotton and Industrial Plants Institute over the period of 1986-1990. Seeds of each variety were sown at 20 cm distance, along 6 m rows long, 0.7 m apart. Correlation analysis was used to find the relation between a few interesting characters. Principal Component and Cluster Analyses were the multivariate analysis procedures used to explain the variation exhibited by the germplasm evaluated. All analyses were carried out using the SPSS/PC software package.

Table 1: Characters used for the description and evaluation of peanut material

1. Pod length (mm)	
2. Pod width (mm)	
3. Pod constriction:	0 = absent, 3 = slight, 5 = moderate, 7 = prominent, 9 = very prominent
4. Pod beak:	0 = absent, 3 = slight, 5 = moderate
5. Pod reticulation:	3 = slight, 5 = moderate, 7 = prominent
6. Shell thickness:	1 = thin, 2 = medium, 3 = thick
7. Shell hardness:	1 = low, 2 = intermediate
8. No. of seeds per pod:	1 = 2, 3 = 2-1, 6 = 3-4
9. Seed length (mm)	
10. Seed width (mm)	
11. Testa colour:	1 = light tan red, 2 = light red, 4 = red
12. Seed taste:	1 = very tasty, 2 = tasty, 3 = tasteless
13. 100-seed weight (g):	1 = 45-50, 2 = 51-55, 3 = 56-60, 4 = 61-65, 5 = 66-70, 6 = 71-75, 7 = 76-80, 8 = 81-85, 9 = 86-90, 10 = 91-95, 11 = 96-100, 12 = 101-105
14. Height of main stem (cm)	
15. Susceptibility to *Tetranychus* spp.	5 = intermediate, 7 = high
16. Susceptibility to foliage insects:	3 = low, 5 = intermediate, 7 = high
17. Tolerance to waterlogging at harvest:	3 = low, 5 = medium, 7 = high

RESULTS

Description and evaluation of the 17 characters scored in the current study appear on Table 2. Factor analysis extracted 5 principal components with Eigen values greater than 1, accounting for 77.3% of the overall variance (Table 3). From the communalities it results that higher contribution to the overall variance have the characters testa colour (0.93), pod constriction (0.91) and pod length (0.90) etc. which have the most discriminating power. Cultivars were clearly discriminated on PC1, PC2 and PC5, which may be described as classification factors. Higher loadings on the Factor 1 were given by seed length, 100-seed weight, pod length and pod beak (0.92, 0.90, 0.88 and 0.84, respectively) (Table 4). Higher loadings on the factor 2 have the testa colour and the number of seeds per pod (0.94 and 0.71, respectively) while for factor 5 the character pod constriction (0.91).

Characterisation and classification: Principal components 1, 2 and 5 (Table 4) include the more suitable characteristics for the classification of the evaluated germplasm. PC1 contains the characteristics that describe pod size (pod length and width) and pod beak, while PC2 the characteristics number of seeds/pod and testa colour and PC5 the characteristic pod constriction.

Factor 1 (PC1): Cultivars that have medium pods sized (30-36 X 12-13 mm) like Poroia, Serraiki and Serraiki Dopia of Valencia Group, are distinguished from those having small sized pods (19-27×9-13 mm) like Sakania Sindu, Ispaniki, Sindos 11055 and Star Sindu of Spanish Group. Pod beak is absent in two groups. Large pod size (40-42×15-20 mm) with slightly to moderately pronounced pod beak is characteristic of cultivars belonging to Virginia Group and like Dafnula, Epitalio and Karolina.

Factor 2 (PC2): Regarding the number of seeds per pod and testa colour, Valencia Group (e.g. Serraiki, Poroia, Serraiki Dopia) have 3-4 seeds/pod with red testa colour, while those of Spanish Group (e.g., Sakania Sindu and

Table 2: Description and evaluation of the Greek collection of Peanuts

	Characters *																
Varieties	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Vatikiotiki	39	15	7	3	5	2	1	3	18	9	2	2	9	22	7	3	3
Dafnula	42	20	9	3	5	2	2	3	20	10	2	2	11	40	5	3	7
Trifyllia	38	15	5	5	7	2	2	1	18	10	2	1	9	26	5	3	7
Serraiki	36	13	3	0	3	1	2	6	15	9	4	1	3	43	5	7	7
St. George	35	14	3	3	3	1	2	1	17	10	2	2	11	40	7	5	7
St. John	35	14	5	3	5	2	2	3	17	8	2	2	10	38	7	3	5
Epitalio	41	15	7	5	5	1	2	3	20	9	2	2	12	36	5	5	7
Irea Orthia	40	15	3	3	7	2	2	1	19	10	2	2	10	38	5	3	5
Irea Erpusa	35	14	3	3	5	1	2	1	17	8	2	2	9	20	7	3	5
Krestena	40	14	7	3	5	2	2	3	19	9	2	2	10	27	5	5	7
Makrisia	40	14	5	3	5	2	2	1	19	10	2	2	9	42	5	3	5
Burnia	42	14	3	3	5	2	2	1	20	9	2	2	8	38	5	3	7
Neapoli	40	17	5	3	5	2	2	1	19	11	2	2	9	23	5	3	7
Sekula	37	14	5	3	5	2	2	1	18	10	2	2	7	22	5	3	7
Tragana	40	14	7	3	5	2	2	3	19	9	2	2	9	40	5	3	5
Vrasna	42	17	5	3	5	2	2	1	20	12	2	2	11	42	5	3	7
Vrasna Dopia	42	14	5	3	5	2	2	1	20	10	2	2	10	30	7	3	7
Evia	39	14	3	3	5	2	2	1	19	10	2	2	10	25	7	3	5
Iraklio	42	14	5	3	5	2	2	1	20	10	2	2	9	20	5	3	7
Kalamata Orthia	38	16	5	3	5	2	2	1	18	10	2	1	10	35	5	3	7
Kalamata Erpusa	40	14	5	3	5	2	2	1	19	9	2	2	8	20	5	5	7
Poroia	30	12	3	0	3	1	2	6	13	9	4	1	1	45	5	7	5
Pyrgos	42	17	5	5	5	2	2	1	20	10	2	2	10	26	7	3	7
Samos	39	16	5	3	5	3	2	1	18	11	2	1	9	22	5	3	7
Serraiki Dopia	32	13	3	0	3	1	2	6	14	8	4	1	2	45	5	7	7
Tripoli	37	15	5	3	5	1	2	1	18	10	2	2	9	25	7	3	7
Halkidiki	35	14	3	5	7	1	2	1	17	9	2	2	10	20	7	3	7
Hania	35	14	3	0	5	2	2	1	16	9	2	2	9	38	5	3	7
Vergina	39	15	3	3	7	1	1	3	19	10	2	2	8	37	5	3	5
Karolina	40	16	5	3	5	2	2	1	19	11	2	1	9	43	5	5	7
Sakania Sindu	27	13	5	0	3	1	1	1	13	9	1	2	2	43	5	7	7
Vergina 46-2	35	15	5	3	7	1	1	1	17	9	2	1	10	27	5	3	3
Vergina g-2	37	14	5	3	5	1	1	3	18	9	2	2	10	38	7	3	3
Lakonia	39	17	5	3	5	2	2	1	19	11	2	1	10	42	5	3	7
Altika Sindu	38	15	7	5	7	2	2	3	18	8	2	1	10	40	7	3	5
Vergina 67	36	14	5	3	5	2	2	1	17	10	2	2	6	40	5	3	3
Karolina 17	34	16	5	0	3	2	2	1	16	12	2	2	10	35	5	5	7
Sindos 11055	22	12	7	0	5	1	1	3	10	9	1	3	1	45	5	7	5
Florida	33	14	5	3	5	2	2	1	16	9	2	3	4	58	5	7	7
Ispaniki	27	13	5	0	3	1	1	1	13	9	1	3	3	40	7	7	7
Star Sindu	19	9	5	0	5	1	1	3	9	9	1	3	1	45	5	7	7
Makedonia	35	14	5	0	5	2	2	1	17	9	2	2	9	42	5	3	7
Proimi Funtoti	40	16	3	3	5	2	2	1	19	9	2	2	11	43	5	3	7

* As described in Table 1

Table 3: Results of factor analysis conducted on 43 Greek *A. hypogaea* varieties using the SPSS/PC+ package, procedure factor

Character	Communality	Factor	Eigen value	% of Variance	Cumulative percentage
Pod length (mm)	0.89781	1	604.466	35.6	35.6
Pod width (mm)	0.74162	2	242.044	14.2	49.8
Pod constriction	0.91365	3	2.206	13.0	62.8
Pod beak	0.78092	4	142.438	8.4	71.2
Pod reticulation	0.49006	5	103.799	6.1	77.3
Shell thickness	0.59165				
Shell hardness	0.83580				
No. of seeds/pod	0.89975				
Seed length (mm)	0.89808				
Seed width (mm)	0.69661				
Testa colour	0.92956				
Seed taste	0.69569				
100 seed weight	0.83109				
Height of main stem	0.52173				
Suscept. to *Tetranychus*	0.66480				
Suscept. to foliage insects	0.84998				
Tolerance to waterlogging	0.89468				

Table 4: Contribution of the 17 characters (factor loadings) to the variation explained by the first 5 PCS following Varimax rotation

Characters	PC1	PC2	PC3	PC4	PC5
Pod length (mm)	0.88188	0.26237	0.07370	0.21130	0.03442
Pod width (mm)	0.70863	0.09205	0.09730	0.42094	0.21051
Pod constriction	0.13353	-0.19204	-0.08990	0.07713	0.91918
Pod beak	0.84828	-0.05534	-0.06130	-0.18781	0.13870
Pod reticulation	0.56709	-0.21125	-0.33410	-0.08619	0.06905
Shell thickness	0.52617	-0.08350	0.10580	0.52880	0.13032
Shell hardness	-0.04938	-0.01287	0.91170	0.01878	0.03915
No. of seeds/pod	-0.44121	0.71960	-0.06620	-0.29657	0.30808
Seed length (mm)	0.92024	0.11944	0.06140	0.17854	0.03637
Seed width (mm)	0.28793	-0.15917	0.14360	0.73654	0.15890
Testa colour	-0.05665	0.94230	0.05040	-0.02090	0.18828
Seed taste	-0.29570	-0.73563	0.08520	-0.19228	0.15119
100 seed weight	0.90517	-0.07463	-0.00930	0.07791	0.00597
Height of main stem	-0.59079	0.11886	0.03010	0.33244	0.21713
Suscept. to *Tetranychus*	0.27215	-0.18882	-0.07060	-0.72495	0.15663
Suscept. to foliage insects	-0.86166	0.11340	0.25860	-0.09228	0.13865
Tolerance to waterlogging	0.02649	0.05808	-0.92150	-0.19884	0.04170

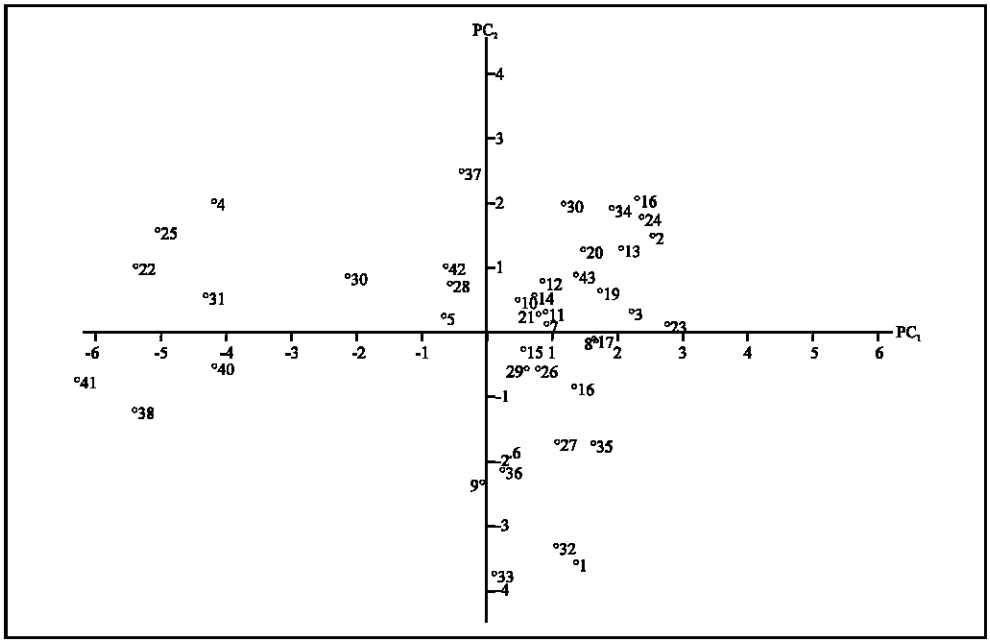

Fig. 1: Projection of varieties on PC1 and PC2

Table 5: Performance of some peanut varieties in different cultivar groups, for earliness, shell thickness and hardiness over years and the respective estimation for tolerance to waterlogging

						1986		1987		1989	
a/a	Variety	Cultivar group	Earliness	Shell thickness	Shell hardiness	Waterlogging tolerance	Rainfall (mm)	Waterlogging tolerance	Rainfall (mm)	Waterlogging tolerance	Rainfall (mm)
1	VRASNA	Virginia	Late	Medium	Intermed	High	50	High	40	High	20
2	LAKONIA	Virginia	Late	Medium	Intermed	High	50	High	40	High	29
3	KAROLINA	Virginia	Late	Medium	Intermed	High	50	High	40	High	20
4	SERRAIKI	Valencia	Early	Thin	Intermed	High	25	High	49	High	36
5	PYRGOS	Virginia	Late	Medium	Intermed	High	19	High	40	High	29
6	ISPANIKI	Spanish	Early	Thin	Low	High	25	High	49	High	8

Table 6: Correlation coefficients between the characters evaluated in the current study

	1	2	9	10	14
Pod length (mm)	1.00				
Pod width (mm)	0.71 **	1.00			
Seed length (mm)	0.98 **	0.72 **	1.00		
Seed width (mm)	0.35	0.54 **	0.35	1.00	
Height of main stem (cm)	-0.36 *	-0.19	-0.39 *	-0.06	1.00

(*) Statistically significant at P<0.05 and (**) p<0.01

Ispaniki) have usually only 2 seeds/pod with light tan red testa colour.

Factor 5 (PC5): As regards pod constriction, Valencia Group cultivars (e.g., Serraiki, Serraiki Dopia and Poroia are characterised by the absence of pod constriction, while those of Spanish Group cultivars show either moderate (e.g., Sakania Sindu, Ispaniki, Star Sindu) or prominent constriction (e.g., Sindos 11055). Virginia Group cultivars have either slight (e.g., St. George, Burnia, Chania), moderate (e.g. , St John, Neapoli, Sekula), prominent (e.g. Epitalio, Krestena, Tragana) or very prominent pod constriction (e.g. Dafnula).

From the scattergram (Fig. 1) for the assessment of classification (PC1, PC2) it is obvious that the cultivars with similar characteristics are grouped together. Also, the dendrogram from cluster analysis gave similar results (Fig. 2), grouping cultivars of the Valencia, Virginia and Spanish Groups in distinct clusters.

Tolerance to waterlogging: From Table 4 it is apparent that PC3 is a factor which represents the tolerance of varieties to soil moisture content at harvest since the characters tolerance to waterlogging and shell hardness have the highest loading on this factor (r = -0.92 and 0.91, respectively).

From the scattergram of Fig. 3 showing the distribution of cultivars along the PC2 and PC3 axes, it is obvious that the cultivars with low shell hardness and low tolerance to waterlogging at harvest appear as a distinct group. Such cultivars are Vatikiotiki (1), Vergina 46-2 (32) and Vergina G-2 (33). Also on PC3, cultivars with very similar characteristics are grouped together, so the first

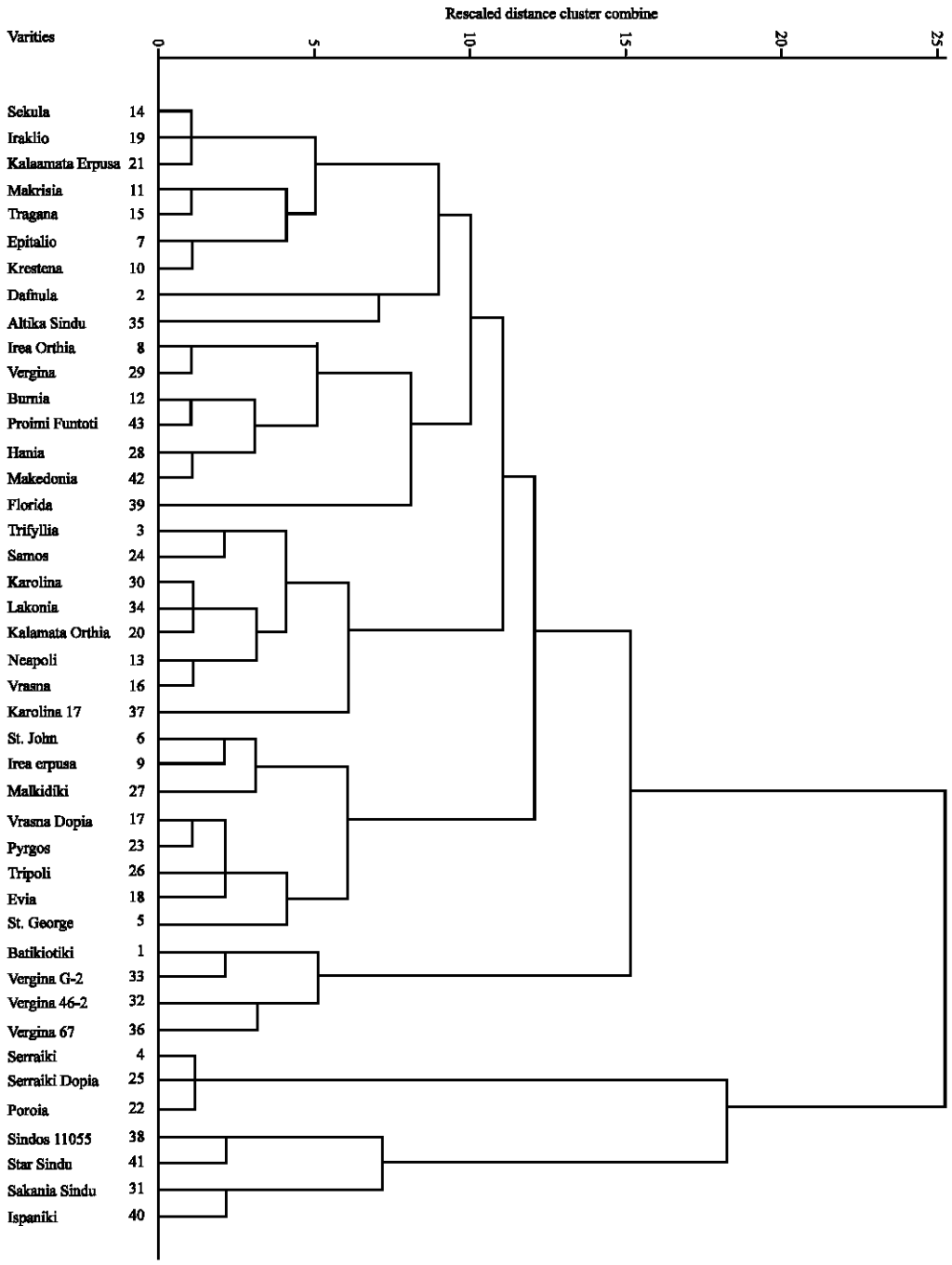

Fig. 2: Dendrogram obtained by cluster analysis on the initial data. Varieties belonging to the subspecies *hypogaea* and *fastigiata* appear as distinct groups

group contains cultivars with low shell hardness and high to medium tolerance to waterlogging. Such cultivars are Ispaniki (40), Star Sindu (41), Sindos 11055 (38) and Sakania Sindu (31). In the second group all the cultivars showed intermediate shell hardness and high to medium tolerance to waterlogging at harvest. Such cultivars are Serraiki (4), Poroia (22) and Serraiki Dopia (25). The above groups are also observed as distinct clusters in the dendrogram (Fig. 2).

An example of the performance of a number of varieties from different cultivar groups, with different

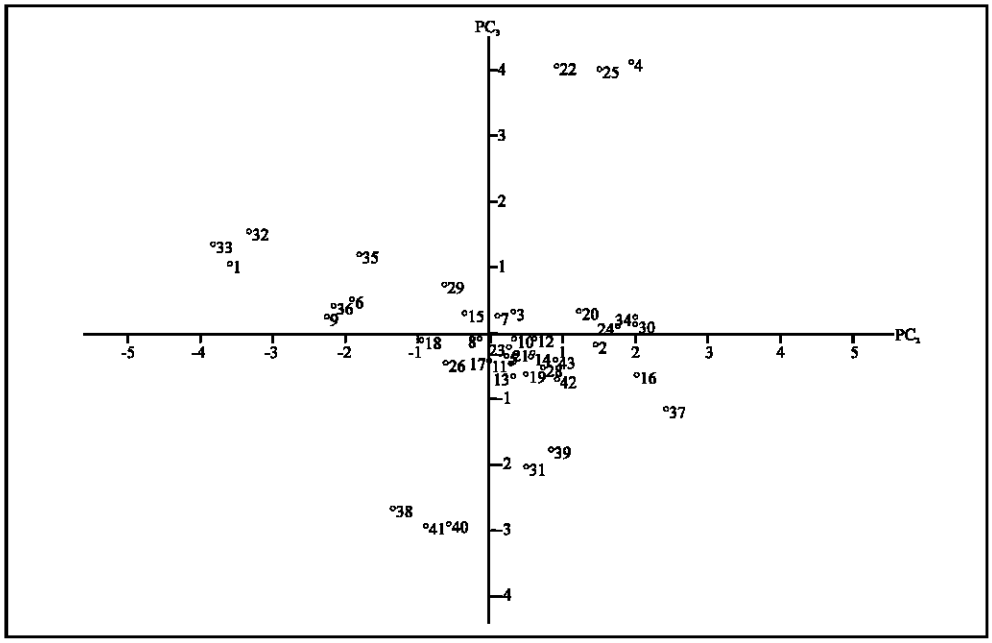

Fig. 3: Projection of varieties on PC2 and PC3

earliness, shell thickness and hardness, for this character over the years, is presented in Table 5.

Finally, correlation analysis showed significant and positive relations among five main characteristics, with r-values between 0.54 and 0.98 (Table 6). Seed length was found strongly correlated to pod length (r = 0.98).

DISCUSSION

The multivariate analysis performed using 17 main agronomic and quality traits, revealed that most of the varieties studied belong to subspecies *hypogaea* group Virginia and only a few belong to subspecies *fastigiata* groups Valencia or Spanish (similar to Fundora Mayor *et al.*, 2006). Also, this procedure resulted to a successful grouping of varieties according to their characteristics, in order to preserve and utilize for breeding purposes peanut genetic materials of Greece. The need for an international co-operation in utilising promising genetic materials, led us to this study aiming to identify cultivars belonging to different cultivar-groups which are tolerant to soil waterlogging at harvest, in order to overcome certain practical limitations of the crop in Greece.

The characteristics that refer to pods and seeds of peanut are related to industrial uses based on the consumers preferences. Large-seeded (with large pods) varieties are better preferred for consumed directly by humans and thus varieties that belong to type Virginia became more interesting (Kotzamanidis, 1994). Such Greek varieties are Vrasna, Pyrgos, Karolina and Dafnoula. But cultivars with very prominent pod constriction, like Dafnula, are not favoured because their pods frequently break in two parts at harvest and processing, reducing pod uniformity and quality and thus yield.

Shell thickness and hardness are also important traits for industrial treatment of peanuts and field conditions with high humidity may cause severe damages to seeds (Kotzamanidis, 1994). Cluster analysis was successful in grouping Valencia and Virginia Groups in distinct clusters and in identifying some cultivars with promising tolerance to waterlogging at harvest. The evaluation identified many cultivars (e.g., Lakonia and Vrasna of Virginia Group, Serraiki and Serraiki Dopia of Valencia Group, Sakania Sindu and Star Sindu of Spanish Group) with promising tolerance to waterlogging. These cultivars may be used as a promising breeding material for the transfer of this tolerance to modern cultivars. As regards specifically the effect of the environment on the expression of tolerance to waterlogging, it was observed that, within the limits of the range of the rainfalls occurring 5-10 days prior to harvest date (8-50 mm), the varieties retained their score for this character over the years of the study. However, earlier evidence from year's 1985 trials (personal unpublished data) showed that, in extreme waterlogged conditions (129 mm rainfall near harvest) even resistant varieties suffered significant losses. Therefore, our data serve as indicators for preliminary identification of promising varieties (with

medium to high resistance or tolerance), which must be further evaluated in specific trials over locations and years, under accurately controlled waterlogged conditions. In this way, we can find a solution for the unfavourable conditions of Northern Greece.

Seed taste interests those that grow the cultivar for direct consumption, to have the best organoleptic quality (Kotzamanidis, 1994). Of the large-seeded Virginia Group cultivars most are tasty, some are very tasty such as Karolina, Lakonia and Samos but one, Florida, is tasteless. The cultivars of Valencia Group are all very tasty, in contrast to the Spanish Group, where most cultivars have tasteless seeds (Sindos 11055, Ispaniki, Star Sindu) and only one cultivar (Sakania Sindu) is tasty.

Plant height and foliage are important traits for utilizing the whole plant in feeding farm animals. Finally the recorded reactions of the cultivars to mite infections and their susceptibility to foliage insects, gives an indication of the resistance of these cultivars to these pests.

Regarding correlations, it was found that pod and seed size were positive and significantly correlated to each other and this was in agreement with other researchers (Shakudo and Kawabata, 1965; Coffelt and Hammons, 1974; Varisai-Muhamad *et al*., 1975; Soomro and Larik, 1981; Godoy, 1982; Dwivedi *et al*., 1989; Fundora Mayor *et al*., 2006). These results suggest that the combination of some favourable characters may become useful for breeding purposes.

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