# EVOLUTIONARY STUDIES ON THE CULTIVATED DIPLOID POTATOES - *Solanum stenotomum* Juz. et Buk., *S. goniocalyx* Juz. et Buk. and *S. phureja* Juz. et Buk.

by

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## Summary

The whole variability of the cultivated diploid potatoes in the International Potato Centre gene bank was studied both morphologically and biochemically to detect any discontinuities existing in the variation pattern. This information, together with the eco-geographical distribution data, was then used to support a taxonomic classification and to postulate an evolutionary scheme for the cultivated diploids.

Over six hundred distinct native cultivars were observed in the field and out of these, 327 were analysed morphologically using 124 characters with the following numerical techniques : principal coordinate analysis, average linkage clustering and 'REGROUP' (a method that forms groups by maximising the within-group similarity). These analyses and other sorting techniques such as MST, single linkage clustering, nearest neighbours list, etc., were tested using known hybrid populations; and it was shown that these numerical techniques were sensitive enough to provide meaningful results in the study of the diploid cultivars.

These findings indicate a slight difference from previous classification of this material, in placing it as one species, S. stenotomum, divided into three distinct morpho-ecogeographical subspecies - subsp. stenotomum, subsp. goniocalyx and subsp. phureja. However, in the present study some definite boundaries within the three taxa could also be distinguished.

A chromatographic study of the leaf phenolic compounds and an electrophoretic study of the soluble tuber proteins qualified the results obtained from the morphological studies.

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# 1. INTRODUCTION

Potatoes are the main staple crop of the Andean Indians and have been so since very ancient times. They are widely cultivated throughout the Andes, above the 2000m mark, from Venezuela to northern Argentina and are also grown at lower altitudes in southern Chile on the mainland and on the Island of Chiloe and elsewhere. In the Andes they exist in a polyploid series, ranging from diploid (2n = 24) to pentaploid (2n = 60).

Previous works on the taxonomy and evolution of cultivated potatoes have indicated the close relationship between all the different ploidy levels and between these and many of the wild species (Hawkes, 1962, 1972; Cribb, 1972; Huaman, 1975; Jackson, 1975; Schmiediche, 1977).

An astonishing wealth of variation has been brought about during long years of cultivation, through the processes of mutation, hybridization, introgression, unreduced gamete formation and natural and artificial selection. This vast amount of diversity is well represented in the Potato Gene Bank at the International Potato Centre (CIP) in Lima, Peru. The species composition of the collection is shown in the table below (Table 1.1).

Considering the large amount of materials available for breeding, it is surprising that only a very few clones have been used up to now. This is mainly due to the lack of knowledge of the

collections. For example, the few clones that have been known to be resistant to various diseases and pests, and to possess frost resistance have been used extensively for various breeding programmes at CIP, whilst most of the others have remained unused.

| Species | 2n | No. of accessions | Percent |
|---|---|---|---|
| S. stenotomum | 24 | 659 | 8.6 |
| S. goniocalyx | 24 | 181 | 2.3 |
| S. phureja | 24 | 70 | 0.9 |
| S. x ajanhuiri | 24 | 65 | 0.8 |
| Diploid total | | 975 | 12.6 |
| S. x chaucha | 36 | 585 | 7.6 |
| S. x juzepczukii | 36 | 200 | 2.6 |
| Triploid total | | 785 | 10.2 |
| S. tuberosum | | | |
| spp. andigena | 48 | 5606 | 72.8 |
| spp. tuberosum | 48 | 117 | 1.5 |
| Tetraploid total | | 5723 | 74.3 |
| S. x curtilobum | 60 | 222 | 2.9 |
| Total | | 7705 | 100.0 |

TABLE 1.1: Composition of cultivated potatoes identified at CIP up to 1978.

At the moment, screening for specific genes is very much hindered by the large number of accessions in the collection. However, many of these accessions are duplicates and even more may be grouped into "complexes" of closely related forms. For example, Ochoa (1975) studying the triploid, S. x chaucha identified only 30 morphotypes out of 540 accessions observed. Jackson (1975) in a study on the same material detected 20 morphotypes from 114 accessions. Huaman (1975) studying the diploid, S. x ajanhuiri observed only two major morphotypes, "Ajawiri" and "Yari" with very narrow variability within each morphotype. Schmiedicha (1977), working with the bitter potatoes, detected 19 phenotypes from 137 accessions of S. x juzepczukii and two morphotypes from 143 accessions of S. x curtilobum.

Work is now in progress at CIP to reduce the size of the collection through the elimination of duplicates. This will certainly facilitate systematic screening work in the future and even promote detailed genetic study on the combining ability between the different sub-populations.

The importance of the diploids in the evolution of the cultivated potatoes has already been emphasised by various authors (Hawkes, 1962, 1972; Ugent, 1970) and is summarised in Fig. 1.1. Hence an understanding of the genetic nature of the diploids should bring about a clearer picture of the evolution of the cultivated potatoes as a whole and their progenitors may be postulated more decisively. The taxonomy of species at the other ploidy levels may be understood better through a greater understanding of the diploids.

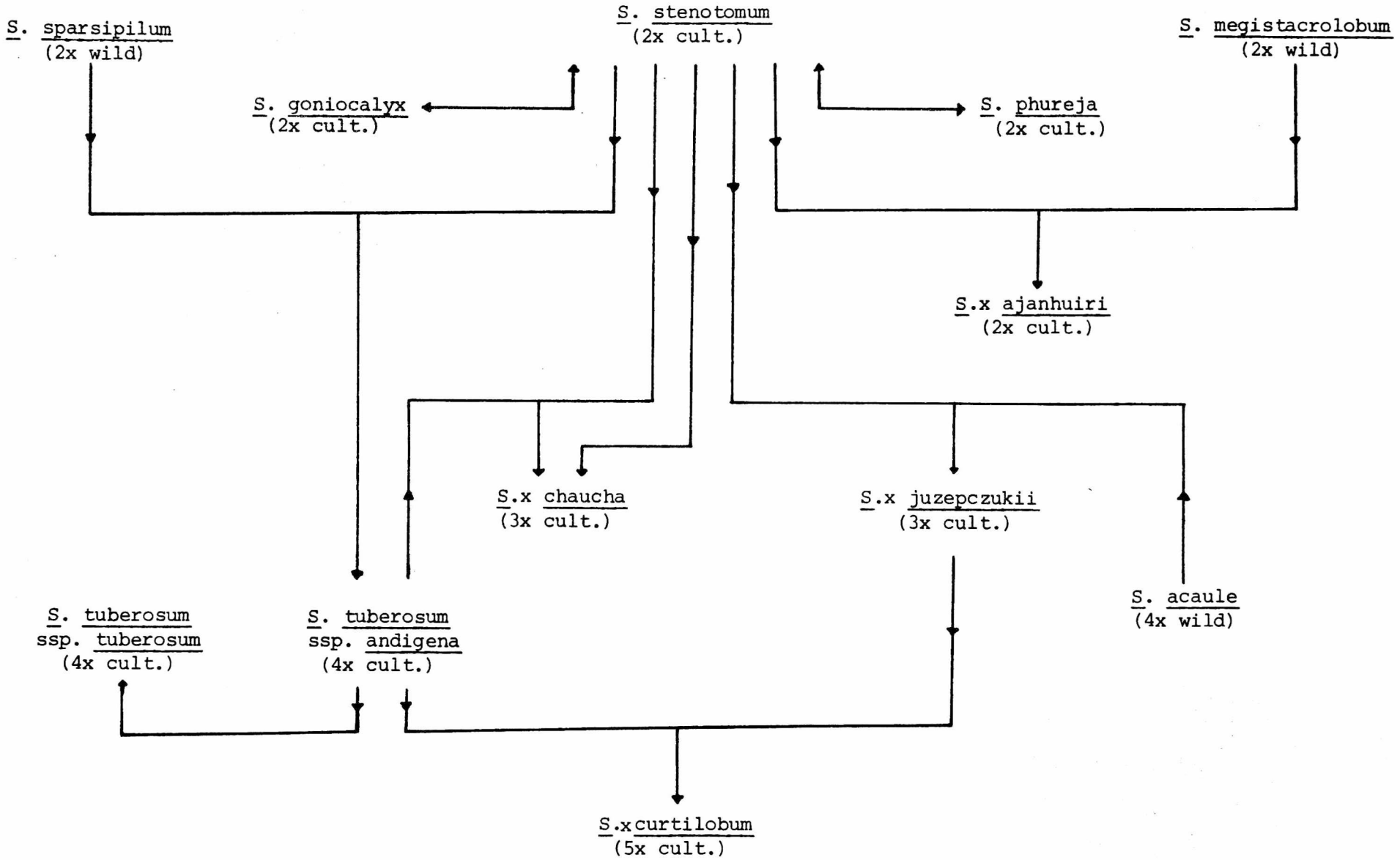



Fig. 1.1 Evolutionary relationships of Cultivated Potatoes

Attempts to classify the cultivated diploids have met with some difficulties in the past (Juzepczuk and Bukasov, 1929; Bukasov, 1930; Bukasov in Vavilov, 1937; Hawkes, 1944, 1956, 1963; Dodds in Correll, 1962). The most recent classification by Hawkes (1978) is the division of the whole diversity of diploids into four species, namely S. stenotomum, S. goniocalyx, S. phureja and S. x ajanhuiri. S. x ajanhuiri has been shown to be a hybrid between the southern forms of S. stenotomum, around the Lake Titicaca basin to Potosi in Bolivia, with a wild species, S. megistracrolobum (Huaman, 1975). However, the nature and inter-relationships of the other three species remains unclear. There is a great range of morphological variation existing among them, and diagnostic characters of one species overlap with those of another. No definite boundary can so far be drawn between the three species, and disagreement among the potato taxonomists on how to classify them is therefore unavoidable.

It was decided in the first and second Exploration and Taxonomy Planning Conferences in 1973 and 1976 at CIP to make a detailed taxonomic study on this material. Previous experience by most potato taxonomists has shown the drawbacks in using a limited number of morphological characters to classify them. It was therefore decided to make use of the maximum number of taxonomic characters possible, both morphological and biochemical. these data could then be objectively subjected to various numerical taxonomic analyses to look for clusters of cultivars which might or might not correspond with the species boundaries as at present understood.

It was hoped that this present study, carried out on a more complete collection ( >1000 accessions) and in a place closest to their natural environments (at Huancayo, Peru, 3300m above sea-level), might bring to light some of the taxonomic relationships between the cultivated diploids and therefore provide the basis for a more useful classification.

# 2. TAXONOMY OF THE CULTIVATED POTATOES

## 2.1. General

Cultivated potatoes were once collectively known as S. tuberosum L. until the publication of the stimulating work by Juzepczuk and Bukasov in 1929. These authors saw the existence of a wide range of morphotypes in the Andes and on the basis of this variation they considered it possible to define seven diploid, six triploid, two tetraploid and one pentaploid species, each with a very narrow species definition. Their work was strongly supported by the discovery of a polyploid series in cultivated potatoes ranging from diploid to pentaploid (Rybin, 1930). More collections were made by other investigators and more variation was encountered. This led to further naming as a species, variety or form of almost every single morphotype that differed significantly from the existing narrowly described species (Bukasov, 1937; Hawkes, 1944). At this stage, there were some 32 named cultivated species (their names are given below in the summary of Hawkes' 1956 Revision on tuber-bearing Solanums). The classification became so complex, since in many cases the "species" were based on one or only a very few related clones. Thus every new collection needed to be given a new Linnean name and the concept of classification was brought into disrepute.

In 1956, Hawkes made a major revision of the whole tuber-bearing Solanum classification in which the narrow species definition was replaced by a broader species concept. Under this scheme groups

of similar microspecies were put together to form wider and more polymorphic species. This was thought to be necessary especially after an extensive hybridization study had been made.

A summary of the revision with the synonyms is as shown below:

1. S. ajanhuiri Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 605, 1929).

2. S. goniocalyx Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 605-06, 1929).

   S. yaberi Hawkes (Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 129, 144, pro parte).

3. S. phureja Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 604-05, 1929).

   S. ascasabii Hawkes (Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 130, 1944).

   S. boyacense Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 609, 1929).

   S. cardenasii Hawkes (Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 129-130, 1944).

   S. kesselbrenneri Juz. et Buk. (in Vavilov, Theor. Bases Plant Breed., 3, 18, 1937; nomen nudum.).

   S. rybinii Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 606, 1929).

4. S. stenotomum Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 604, 1929).

   S. churuspi Hawkes (Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 129, 1944).

S. yabari Hawkes (Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 129, 1944; pro parte).

5. S. x chaucha Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 609, 1929).

S. chocclo Juz. et Buk. (in Vavilov, Theor. Bases Plant Breed., 3, 18, 1937, nomen nudum).

S. coeruleiflorum Hawkes (Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 131, 1944).

S. mamilliferum Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 609, 1929).

S. tenuifilamentum Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 603, 1929).

6. S. x juzepczukii Buk. (Proc. U.S.S.R. Congr. Genet., 3, 603-04, 1929).

7. S. tuberosum L. (Sp. Pl. I, 185, 1753).

S. andigena Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 609-10, 1929).

S. chiloense (A.DC.) Berth. (Ann. Sci. Agron., Paris, 28, 179, 1911).

S. cultum (A.D.C.) Berth. (Ann. Sci. Agron., Paris, 28, 179, 1911).

S. esculentum Neck. (Delic. Gallo-Belg. 1, 119, 1768).

S. herrerae Juz. (Bull. Acad. Sci. U.R.S.S., 2, 310-11, 1937).

S. leptostigma Juz. (Bull. Acad. Sci. U.R.S.S., 2, 309-10, 1937).

S. molinae Juz. (Bull. Acad. Sci. U.R.S.S., 2, 308-09, 1937).

S. sabinii (A.D.C.) Berth. (Ann. Sci. Agron., Paris, 28, 179, 1911; pro parte).

S. sinense Blanco (Fl. Filip, ed. I, 137, 1837).

S. subandigena Hawkes (Imp. Bur. Plant Breed. and Genet., Cambridge, 128, 1944).

(i) subsp. tuberosum

(ii) subsp. andigena (Juz. et Buk.) Hawkes

8. S. x curtilobum Juz. et Buk. (Proc. U.S.S.R. Congr. Genet., 3, 609, 1929).

Later, in 1963, Hawkes made a second revision. The major modification was the inclusion of the former S. goniocalyx as a subspecies of S. stenotomum. Also, S. caniarense Juz. et Buk. (in Vavilov, Theor. Bases Pl. Breed., 3, 17, 1937; nomen nudum) was inserted as a synonym of S. phureja, and S. maglia Schlechtd. subsp. meridionale Bitt. (in Fedde, Report, 12, 453, 1913) as a synonym of S. tuberosum. S. tuberosum ssp. andigena Juz. et Buk. was defined as comprising of S. andigena Juz. et Buk., S. apurimancense Vargas (Papas Sudperuanas, 2, 58-59, 1956) and S. subandigena Hawkes.

Due to the incomplete agreement with Hawkes' classification by some potato taxonomists, an alternative system was put forward by Dodds (in Correll, 1962). He based his classification heavily on his study of the genetic system of cultivated diploids which he demonstrated as sharing many loci in common (Dodds and Paxman, 1962). He then proceeded to include all the species under one single taxon, S. tuberosum L., except for the hybridogenic S. x juzepczukii and S. x curtilobum. He then divided S. tuberosum according to the ploidy level and formed "groups" in accordance with the International Code of Nomenclature for Cultivated Plants. Dodds' classification is summarised in Table 2.1.

TABLE 2.1: Schematic arrangement of the Dodds classification of cultivated potatoes (taken from Dodds, in Correll, 1962)

| Species | Ploidy | Group | Main Distribution | Origin | Remarks |
|---|---|---|---|---|---|
| S. tuberosum | 2x | Stenotomum | 1 Central Peru to Bolivia | from unknown wild diploid species | Includes Subgroup Goniocalyx |
| | 2x | Phureja | 2 Venezuela to northern Peru | | Includes Subgroup Amarilla |
| | 3x | Chaucha | 3 Central Peru to Bolivia | From crosses of 1 and by 4 | Mixed with 1 and 4 in field |
| | 4x | Andigena | 4 Venezuela to northern Argentina | Doubling of chromosome numbers of 1 and 2 | |
| | 4x | Tuberosum | 5 Europe and N. America and Chile | Selection from 4 | |
| S. x juzepczukii | 3x | | 6 Central Peru to Bolivia | From crosses between 1 and S. acaule | Few and unimportant. Usually mixed with 1 and 4 |
| S. x curtilobum | 5x | | 7 Central Peru to Bolivia | Crosses between 4 and 6 | Few and unimportant. Usually mixed with 1, 4 and 6. |

It is clear that the scheme is essentially similar to that of Hawkes with each Group being roughly equivalent to Hawkes' species. The difference is the species concept used which is itself a very controversial topic.

A critical point is that Dodds kept the hybridogenic taxa, namely S. x juzepczukii and S. x curtilobum as good species. However, recently Jackson (1975) showed that S. x chaucha (according to Hawkes' classification) is a hybrid by nature from crosses between the tetraploids and the diploids. Also, it was shown by Huaman (1975) that S. x ajanhuiri is a hybrid between the southern form of S. stenotomum and a wild species, S. megistracrolobum and also from the resultant backcrosses to S. stenotomum. The origin of S. x juzepczukii was confirmed to be from crosses between a cultivated diploid and the wild frost-resistant species, S. acaule. S. x curtilobum was postulated as having been formed from a cross of S. x juzepczukii (with unreduced gametes) with S. tuberosum subsp. andigena (Hawkes, 1962; Schmeidiché, 1977). Therefore, for Dodds' classification to be consistent part of Group stenotomum (ajanhuiri) should be promoted to species level as S. x ajanhuiri.

## 2.2. Taxonomy of the Cultivated Diploids

Among cultivated potatoes, the diploids are the most difficult to classify. This is because of the immense amount of variation which occurs in them. In 1929, Juzepczuk and Bukasov

described six distinct diploid species. They were S. ajanhuiri, S. goniocalyx, S. phureja, S. rybinii, S. boyacense and S. stenotomum; Bukasov in 1937 added three more, S. kesselbrenneri, S. caniarense and S. riobambense. Later in 1944, Hawkes classifying the British Empire Potato Collection, named four more, S. yabari, S. ascasabii, S. cardenasii and S. churuspi but reduced S. boyacense to a form of S. rybinii.

The main weakness of these descriptions is that they were too narrowly defined and no provision was made to accommodate other variants as they were discovered. This scheme worked well enough when only a limited number of collections were available for study but in a situation like this, the danger of describing an intermediate form as a new species was unavoidable. Another point that has to be considered is the high phenotypic plasticity of potato species.

The type descriptions, translated into English, of the diploids are given in Appendix I. They were kindly provided by Professor Hawkes.

Apart from naming four new species, Hawkes (1944) working with a large living collection found it necessary and convenient to group them further into varieties and forms according to the leaf dissection, calyx length and dissection, corolla shape, colour and size, anther and filament size and style length. This is especially true for S. stenotomum.

It is worth noting that Hawkes' 1944 materials lacked collections from the Central Peruvian Andes, which would undoubtedly have provided much more variation, which could then have been classified in the same way.

A summary of the varieties and forms of the diploids is given in Appendix II.

Hawkes in his revision of the tuber-bearing Solanums (1956) described the three revised species as follows:-

1. S. goniocalyx Juz. et Buk.

A northern derivative of S. stenotomum with large white or pink flowers and ribbed calyx base. Tubers with bright yellow flesh. Forms with pinkish lilac flowers occur both in S. stenotomum and S. goniocalyx and were formerly grouped by me as a distinct species S. yabari. In view of the fact that this colour has now been found to be due only to a single gene difference (Dodds and Long, 1955) the species S. yabari cannot be maintained as distinct. It is possible also that S. goniocalyx may also be shown to be an extreme variant of S. stenotomum, but since the evidence available so far is not very conclusive it seems better to retain it for the present. Distribution: Central Peru, dept. Junin. 2n = 24.

2. S. phureja Juz. et Buk.

Distinguished by the sparsely pubescent leaf, which is shining in the living state, and rather irregular calyx with lanceolate lobes. Tubers yield in 3-4 months under short day conditions and

possess no dormancy period. This very widespread and highly variable species was formerly separated into a number of smaller units. These have been found to hybridize without lack of vigour or fertility in the $F_2$ generation under experimental conditions and hence cannot be considered as distinct. The absence of tuber dormancy indicates that it has become specially adapted to regions that are free from long periods of drought or frost. Distribution: Venezuela, Colombia, Ecuador, Peru and North Bolivia. Wet mountain slopes at lower altitudes than the other cultivated species so far described. 2n = 24.

3. S. stenotomum Juz. et Buk.

Distinguished from S. phureja by the more densely pubescent leaf which is not shining in the living state; tubers produced in 5-6 months or longer and with definite dormancy period. Calyx generally irregular with lanceolate lobes as in S. phureja. A very variable species which is probably ancestral to all the other cultivated potatoes. These have been produced from it either by hybridization (S. x chaucha, S. x curtilobum, S. x juzepczukii, S. ajanhuiri) by auto- or allopolyploidy (S. tuberosum), or by evolutionary divergence at the same level of ploidy (S. goniocalyx, S. phureja). Forms with pinkish-lilac corollas from S. Peru which were formerly placed with S. yabari and S. churuspi (the latter with very short corolla lobes) have now been united with S. stenotomum. Distribution: South Peru to Central Bolivia at very high altitudes. Some forms are frost resistant. 2n = 24.

The findings on S. x ajanhuiri (Hueman, 1975) provide a new outlook on the nature of the diploid population. S. x ajanhuiri is widely grown in the Lake Titicaca Region and South to Potosi in Bolivia mainly because of its frost resistance and good cooking quality. In view of its intensive cultivation in certain areas it is surprising to find that it possesses a very narrow variation. Only two major morphotypes, "Ajawiri" and "Yari" with very little variability within each morphotype were present. They are morphologically quite distinct from other potatoes, especially the "Yari". It may be due to these two factors, their distinctness and intensive cultivation that they have generally been retained as a species right after the description by Juzepczuk and Bukasov in 1929. It seems quite likely that their definite but restricted distribution has played a very important role in drawing the attention of many potato taxonomists toward them.

It now seems clear that many of the forms, varieties and species described in earlier classifications of the diploids, S. stenotomum, S. goniocalyx and S. phureja, mentioned above, should be re-evaluated. This is especially so now that a more complete collection from the whole range of their distribution is available for study.

## 3. GEOGRAPHICAL DISTRIBUTION OF CULTIVATED POTATO SPECIES IN SOUTH AMERICA

### 3.1. General distribution of cultivated potatoes

Of all the cultivated potatoes, the tetraploid, S. tuberosum ssp. andigena is the most widely grown and distributed. It is found from Venezuela in the north to northern Argentina in the South. However, in the low altitude temperate region of southern Chile on the mainland and on the Island of Chiloe and nearby islands it is replaced by the typical subspecies of tuberosum.

The diploids are also very common in the Andes and each species is grown in a well-defined geographic region. Thus, S. stenotomum extends from the central Peruvian departments of Huancavelica and Junin, southwards through Apurimac, Cuzco and Puno, into the Bolivian departments of La Paz, Cochabamba, Oruro and Potosi. However, its greatest concentration of diversity seems to be in southern Peru (Cuzco and Puno departments) and northern Bolivia (La Paz department). On the other hand, S. goniocalyx has its maximum variability in the Central Peruvian highlands with a very popular form called "Papa Amarilla" widely grown from northern Peru down to Cuzco in the south. S. phureja, a non-dormant species, is the only diploid species in Venezuela, Colombia and Ecuador, extending southwards through Peru into northern Bolivia (departments of La Paz and Cochabamba). However, it seems that this species may have two major centres of diversity. The first centre is in Colombia and Ecuador, whilst the other is the lower eastern slope of the Andes in Puno and northern Bolivia.

The hybridogenic S. x ajanhuiri, which is frost resistant, is adapted to the cold altiplano from Lake Titicaca to Oruro and Potosí. The other two hybrid bitter potatoes, S. x juzepczukii and S. x curtilobum, all share a similar cultivation zone. All three may be seen as a perfect example of hybrids adapting themselves to marginal environments through the influx of genes from other species that are hardier than the original cultivated parent species.

The spread of the surprisingly highly polymorphic triploid, S. x chaucha is extensive. It has its greatest concentration in the Central Peruvian highlands and spreads down into Bolivia. The similar pattern of distribution between several morphotypes of this species with that of "Papa Amarilla" will be discussed in Sect. 3.4.

## 3.2. Distribution of morphotypes of Cultivated Diploids by political boundary

The distribution of the CIP morphotypes in the present study is summarised in Table 3.1. It should be noted that if the same clone was collected in more than one political department it was counted separately for each department in which it occurred. It should be noted here that S. phureja from Venezuela, Colombia and Ecuador was poorly represented in the CIP collections available for study.

It appears that there is a bi-regional distribution, with concentration of diversity in the departments of Ancash, Huanuco, Pasco, and Junin, in the north to centre, and Cuzco down into Puno and La Paz in the south. However, this may possibly be due to the result of more intensive collection in these two regions. If not, this is an important fact that should be appreciated in the study of the evolution of cultivated potatoes.

| Political Departments (by country) | No. of Morphotypes |
|---|---|
| Colombia | |
| Nariño | 6 |
| Peru | |
| Piaura | 5 |
| Lambayeque | 1 |
| Amazonas | 4 |
| Cajamarca | 12 |
| La Libertad | 10 |
| Ancash | 46 |
| Huánuco | 93 |
| Pasco | 70 |
| Junín | 85 |
| Lima | 15 |
| Huancavelica | 29 |
| Ayacucho | 21 |
| Apurímac | 21 |
| Cuzco | 70 |
| Arequipa | 1 |
| Puno | 60 |
| Bolivia | |
| La Paz | 32 |
| Oruro | 7 |
| Potosí | 8 |
| Cochabamba | 1 |

TABLE 3.1: Distribution of diploid cultivated morphotypes in the CIP collections arranged by political departments.




Map 3.1 Political map of Peru.

## 3.3. Distribution of Single Clones

It can be postulated from the provenance data[1] that each individual clone is only cultivated in a very small geographic territory. Most clones are often confined to their own valley or close neighbouring townships.

However, some of the clones are more widespread and these show some definite patterns of distribution that divide the whole distribution range into five more or less separate regions.

These regions are:-

(1) the Bolivia, Puno and Cuzco complex; with major concentration in Bolivia and Puno.

(2) the Puno, Cuzco, Apurímac and Ayacucho complex; with major concentration in Cuzco and Apurímac,

(3) the Huancavelica, southern Junín and south-eastern Lima complex,

(4) the northern Junín, Cerro de Pasco, Huánuco, north-eastern Lima and Ancash complex; with major concentration from northern Junín to Huánuco,

(5) the northern Peru, Ecuador and Colombia complex.

## 3.4. Distribution of a widely cultivated clone - "Papa Amarilla"

The distribution of "Papa Amarilla", the type of *S. goniocalyx*, and some other related clones is of special interest.

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[1] a list of material with provenance data is available for consultation if required.

Map 3.2 shows the distribution of "Papa Amarilla", a single clone. It is cultivated from Cajamarca southwards to Cuzco. Its original home can be postulated as the central Peruvian highlands because it is referred to as "Limeña" (meaning "of Lima") by some of the farmers in Cajamarca and "Lima Runtus" (meaning "Lima egg", "egg" may refer to the resemblance of the deep yellow flesh to that of egg yolk) by some Cuzco farmers.

A very similar pattern of distribution was also detected for "Huayro" and the "Shuitus" of S. x chaucha (Ochoa, 1975; Jackson, 1975). In addition, "Huayro" and "Papa Amarilla" both have good quality tubers with high dry matter content and deep yellow flesh colour and other morphological similarities. This may have led Ochoa (1975) to postulate the role of S. goniocalyx in the evolution of "Huayro" and "Puca Muru Rucma".

This brings one to the point of trying to assess the relative importance between natural and human selection in cultivated potatoes. In cultivation, "Papa Amarilla" does not seem to have any better agronomic characteristic than other clones. The growth is vigorous enough but the clone is very susceptible to virus infection and many other diseases. It is fairly clear from observations in the field that the wide distribution of this clone is not its adaptability to the natural environment but rather its market value. This potato has its special place in all the Peruvian markets and is used in special traditional dishes. Thus, the market price is always higher than others and the same holds for "Huayro".




Map 3.2 The geographical distribution of Visual Groups (VGs) 6, 7, 8 and 9.

At the other extreme, S. x ajanhuiri, S. x juzepczukii, S. x curtilobum and some forms of S. stenotomum and S. tuberosum ssp. andigena are of importance because of their special adaptive quality to the harsh cold environment with frequent frosts in the high Andes of Peru and Bolivia, and especially the altiplano around the Lake Titicaca basin.

In between these two extremes lie most of the clones of which we have very little knowledge. Many of them have very good cooking quality by Peruvian standards also. The question is why do they still remain so narrowly distributed? Can there be other selective forces than the two mentioned above? Is it likely that these clones have such a narrow agronomic adaptibility? Or rather, is it the conservativeness of the farmers which preserves each of them in a very limited geographical range?

# 4. NUMERICAL TAXONOMIC STUDY

## 4.1. Introduction

### 4.1.1. Cluster analysis

Numerical Taxonomy is defined by Sneath and Sokal (1973) as the grouping by numerical methods of taxonomic units into taxa on the basis of their character states. The methods of grouping can be briefly generalised as follows:- Firstly, a set of multivariate data in the form of a matrix of Operative Taxonomic Units (O.T.U.s) by variables is assembled. Then the resemblance between all possible pairs of OTUs is calculated using a chosen mathematical function, collectively known as similarity coefficient (here, to include both the similarity and distance coefficients). A half-matrix of size $\frac{n(n-1)}{2}$ along the diagonal is formed. It is generally known as similarity matrix. Finally, the similarity matrix is subjected to a sorting procedure which summarises the total variation of the original data matrix into groups of most similar OTUs.

The end result of any numerical taxonomic study depends on the options that were imposed at each stage of the analysis. By subjecting the same set of data to different analyses it is very likely that different results will be obtained, except perhaps for very clear-cut data. The result also depends on the characters used. Different character sets used will give rise to different results, unless the character sets are correlated for the same material. All these points will be discussed below.

Starting with the sampling of material, the inclusion or the exclusion of some OTUs will interfere with the resulting clustering. For example, the clustering of two morphologically distinct putative parents of certain hybrid swarms together with the supposed hybrid swarms, may fail to show the difference between the two taxa because there are many intermediate forms that tend to fill the "gap" in between these two and thus link them together as one variable taxon. However, most often nothing can be done about this because the detection of the putative parents, if they exist at all, is part and parcel of the study itself. In this situation, ordination, which is another type of multivariate analysis that can handle less well structured data better and therefore is useful for within-groups study, is often preferred. This will be discussed further later. Also, in a study of a closely related group an inclusion of a few very dissimilar individuals may drastically affect the sorting result of the group as a whole. Since most often so little is known about the nature of the population under study the sampling process may then be the most unpredictable part of any study.

After deciding on the material we proceed to make a survey of the characters that can be useful. The number of characters required to give a stable result depends on the nature of the material under study. A group with well structured data may need relatively fewer characters to achieve a stable classification than another with more disorderly and overlapping sort of data. However, there is no fixed rule on the number of characters to be used but rather it should be tested out empirically by comparing the stability of the classifications produced using different character sets of the same material and also

using different analyses. Sneath and Sokal (1973) gave a very thorough account on this topic. They recommend the use of as many characters as possible which should be unit characters, and, if possible, weighted equally. The use of dependent characters should be avoided because this will indirectly weight the same genetic factor more than once.

Upon deciding on the characters to be used they have to be coded. Coding of characters should be done with maximum biological sense because the character state is the starting point of all numerical calculation. First of all characters can be categorised into four types. They are (1) binary, (2) nominal, (3) ordinal and (4) meristic and continuous.

Coding of the binary character is straightforward, by alotting 0 for absence and 1 for presence. The nominal character such as flower colours, is the most difficult to handle. Usually, after the number of character states have been decided it is coded with the best biological logic possible. An alternate method is to split out the different character states into different binary characters. This however gives rise to extra weighting of the character depending on the number of character states. This is unwanted. For the ordinal character, the number of states should be decided from a preliminary study and then each state is assigned to an appropriate number in an order according to a logical gradient of the character. This will thus reflect the relationship between the different states.

Meristic characters such as leaflet number and continuous characters are counted and measured respectively.

Before the data are to be used for the estimation of resemblance between OTUs they may have to be standardized in some cases. For example, plant height will inevitably mask out node-length if they are not brought down to a common base for comparison. The three common methods for standardizing continuous data are by mean score, by variance and by range. This may be applied to ordinal data also but with some reservation because of the likely non-linearity of the ordinal data. Normally, one encounters mixed-mode data of all types in a study. They may then have to be converted into a single mode either as binary or continuous. Examples on the methods of transformations are shown in the Users Guide to CLUSTAN 1A (1978). Usually, these will result in a great loss of information. Fortunately, some similarity coefficients were invented to take in mixed-mode data. The computer classification package-CLASP incorporates the process of standardization and the use of mixed-mode data into the computation of the similarity coefficient (this will be discussed in detail in Sect. 5.4). Talkington (1967) proposed another form of this sort of similarity coefficient.

Quite often, the data may be strongly skewed. In this case, before any standardization they may have to be first transformed to give a more normal distribution. Logarithmic and square root transformations are commonly used. However, transformation should be performed with reservation because usually we have so very little knowledge about the "biological sense" of the transformed data.

The use of ratios to correct for "size" and "density" factors as character may be adapted. This technique is especially useful when shape is of more importance than size. Also, in cases when samples (OTUs) were drawn from diverse environments where the development of the plants was affected by the differences in environment, a ratio rather than actual measurements can then be very useful as a form of standardization. However, in a closely related population, grown under "uniform" environment size differences may be treated as an intrinsic factor which is therefore important in the process of classification. On such occasions, ratios may have to be avoided. Furthermore, ratios often lead to highly skewed distributions which are not desirable, as noted above. If this is the case, it is more advisable to apply some ordination methods when the "size" factor and other interrelated characters will be isolated out as different principal components and therefore redundant.

After the data have been "polished" they can then be used to estimate the resemblance between the OTUs by applying one of the many mathematical functions. There are many different coefficients to choose from depending on the nature of the study and the structure of the data. Generally, they can be roughly classified into four main types:-

(1) Association coefficients

(2) Distance coefficients

(3) Correlation coefficients

(4) Probabilistic coefficients.

Association coefficients point to the total similarity between the two OTUs studied. They are available in a wide variety of forms to handle both binary and nominal types of data. For binary data, the Simple Matching Coefficient (S.M.C.) and the Jaccard's coefficient are the most commonly used. The difference between the two is that Jaccard's coefficient does not take a double absence of a character into consideration. Relating to these two there is a whole family of derivatives. Many of them were invented for some specific studies only. For nominal data, the same association coefficients are usually used but here a considerable amount of information may be lost if no allowance is made to account for the fact that a match in a five-state character might be less likely to occur than in a two-state character.

Distance coefficients can be subdivided into two main types. They are the Euclidean distances and other distances. Among them Squared Euclidean distance is the most widely used both for meristic and continuous, and ordinal data types. It is in many ways easier to visualise than other coefficients but is affected by occasional large readings in a data set. Other distances include the Manhatten or City-block metric and many variants of it like the Canberra metric and the "Bray and Curtis" coefficient. The Canberra metrix has the advantage of not being affected by certain unusually large readings in the data and is therefore useful to discriminate proportional differences between individuals but not absolute differences.

Correlation coefficients are also used to measure resemblance

both for binary, ordinal and meristic and continuous data. For binary data, there are " Yule", Pearson and McConnanghy coefficients and the "mean square contingency" (M.S.C.). The product-moment correlation coefficient (r) is used for ordinal amd meristic and continuous data. Since it is able to measure shape differences only but not size it may then be useful only when shape is considered to be relatively more important than size.

Probabilistic similarity coefficients take into account the frequency of the character states occurring and then use this information to estimate the similarity between OTUs. There is a lot of controversy about the weighting of "rare" character states, and several suggestions have been made for giving greater weight to these.

The resultant similarity matrix is usually too big to be handled by visual sorting. Therefore, it is often subjected to some sorting procedures, to look for clusters. There are many sorting procedures available. Sneath and Sokal (1973) gave a very thorough coverage on this topic in their chapter on "A taxonomy of clustering methods". They identify eight aspects of clustering methods. They are:-

(1) Agglomerative versus Divisive methods

(2) Hierarchic versus Non-hierarchic methods

(3) Non-overlapping versus Overlapping methods

(4) Sequential versus Simultaneous methods

(5) Local versus global criteria

(6) Direct versus Iterative solutions

(7) Weighted versus Unweighted clustering

(8) Nonadaptive versus Adaptive clustering.

In biological clustering, the most popular methods are those of Sneath and Sokal's "sequential, agglomerative, Hierarchic, non-overlapping clustering methods". All these methods start off by grouping the most similar OTUs into a pair (or pairs). Then the remaining individuals and the pair (or pairs) will be grouped according to the criterion of the particular sorting procedure used. This cycle is repeated until all the individuals are accounted for and the end result is usually presented as a dendrogram.

Some of the most common procedures are:-

(1) Single linkage or Nearest-neighbour clustering.

This method fuses by joining the two most similar individuals. This can be between an individual with another individual, an individual with another individual belonging to a cluster or between two individuals of two different clusters. It has the tendency to link many individuals together into a chain like cluster and is compatible with all forms of similarity coefficients.

(2) Complete linkage or Furthest-neighbour clustering.

This method is opposite to that of single linkage clustering. It fuses when the similarity between an individual and the least similar OTU of a cluster to that individual is greatest or when the similarity between the two least similar OTUs of each cluster is greatest. It forms tight clusters and can also be used with all forms

of similarity coefficients.

(3) Average linkage clustering.

This method is intermediate between the two above. A cluster is formed on the basis of the average of all the similarity coefficients for pairs of individuals, one from each cluster. It is known as the unweighted pair-group method using arithmetic averages (UPGMA) by Sneath and Sokal (1973). It is also compatible with all forms of similarity measures.

(4) Centroid sorting.

Clustering is based on the coordinates of the centroids when considered in multidimensional space. Any two clusters fuse when their centroids are the most similar. It is known as weighted pair-group centroid method (WPGMC) by Sneath and Sokal (1973). It is only compatible with distance, size difference and shape difference measures and is also liable to form chaining clusters.

(5) Median sorting (Gower's method).

It is only compatible with distance measures. Clustering is based on the distance between the centroid of the group to be fused to the midpoint of the line joining the centroids of the two formerly fused groups. This method therefore prevents the domination of the classification by large groups.

(6) Ward's method (Error sum of squares).

It is again only compatible with distance measures. Fusion between two clusters takes place when the error sum of square increases at the least amount.

(7) Lance-Williams Flexible Method

Lance and Williams (1966) suggested a relationship with four variables so that by varying these four variables different sorting procedures are carried out.

It can be seen that most of the similarity measures and clustering procedures were defined from intuitive reasoning. The validity of any of these methods can therefore best be verified using a "known" data set.

4.1.2. Ordination

In taxonomy, ordination is an equal alternative to cluster analysis for the analysis of multidimensional data. It includes a series of related techniques that seeks to summarise multivariate information into a more interpretable and presentable form. These techniques are generally recommended for data that are not so well structured where variables of different individuals tend to overlap in a complex manner e.g. hybrid swarm, intraspecific population, etc.

Ordination has been used for several purposes in taxonomic study. However, it does not create any classification as such, as in cluster analysis. It only shows the relationships between individuals or groups of individuals when presented in a scatter diagram. Some of the most common uses are:-

(1) to summarise the multidimensional data by reducing them into fewer new dimensions;

(2) to represent the individuals in a set of new summarised coordinates. These when plotted out as a scatter diagram may reveal the relationships between the individuals.

(3) Sometimes, they may be used to detect the relative discriminating power of each variable and therefore serve as a means to reduce the number of variables in further study. This will greatly reduce the time and cost spent.

Ordination can be performed on the variables (R-type) or on the objects (Q-type). In R-type analysis, covariance matrix is used to find new variable dimensions whereas in Q-type, resemblance matrix between the individuals is used to look for possible relationships between them.

Principal components analysis (PCA) which often operates on the correlation matrix between the variables is a commonly used R-type ordination. It extracts orthogonal independent dimensions called principal axes which are the linear combinations of the original variables that successively account for the major independent patterns of variation in the sample. Since the principal axes are independent of each other and therefore there is no redundancy, fewer dimensions are enough to account for most of the information content in the original data. Depending on the structure of the data very often the

first few principal axes will account for a high percentage of the total variance of the original data. If the variance accounted for is high ( >50%) by the first two or three axes a presentation of the individuals on scatter diagrams between any of the two axes or three-dimensional plot between all the three axes will reveal some taxonomic relationships between the individuals. However, this method tends to show the general relationship between groups but not individuals within the same cluster. In view of this ordination and cluster analysis may be seen as a complementary to each other because cluster analysis tends to be more sensitive within the cluster level.

In addition, we can gain some insight into the nature of the original data by observing the factor loadings of the variables on the principal axes. As Blackith and Reyment (1971) postulated the first component as a "size" component if most of the variables load highly in a single direction. From this type of interpretation "character-complexes" may be formulated.

Since the principal axes are the summary of the original data, the component scores of the first few principal axes (assuming that the variance accounted for is high) will represent most of the information content in the original data. A cluster analysis performed on these component scores will therefore greatly reduce the data matrix size, without much loss of information.

A common Q-type analysis is the Principal coordinate analysis (PCO). This analysis was formulated by Gower (1966) out of dissatisfaction with the common misuse of some forms of data in correlation functions e.g. nominal type. By working on the objects instead of the variables, similarity or distance coefficients can then be used directly, therefore taking care of mixed-mode data. It extracts a series of principal axes as in PCA and the result can be presented and interpreted as in PCA.

A lesser use R-type of analysis is Factor analysis. It has a great variety of forms but they all serve to resolve the inter-correlations among variables into their underlying common factor. Like PCA, covariance matrix is used but the diagonal of the matrix instead of 1 i.e. total correlation is replaced by the communalities, the percentage of variation due to the common factors.

The result of any of the ordinations as mentioned above can be presented in two or three dimensions as scatter diagrams or "pin and ball" diagram respectively. It should be pointed out that the cluster of points for each set of plot is subjected to a certain degree of distortion. In cases when a cluster of points tends to stand out all the time from different sets of plot then the genuineness of the cluster may be assumed.

Another technique is to superimpose on the scatter diagram

the analysis of Minimum Spanning tree (MST). This method seeks the minimum path length to connect all the n individuals with (n-1) edges based on the similarity coefficients. If there is a crisscrossing of edges from one cluster to another then these clusters are likely to be distorted.

## 4.2. Statistical computer packages used

### 4.2.1. DATAVET

This package was used to verify any punching mistake in the data. Since it performs a "range" test any punching mistake committed within the range is not recognised by this test. This should be appreciated because it is very common to mispunch a number with two figures the other way round. For example, if the range is from 10 to 30 a mispunch of 12 as 21 will pass undetected. Also, the common error in punching 6 as 9 and the other way round is unavoidable.

The data on the whole were very accurately punched. Less than 20 mistakes were committed for all the data punched.

### 4.2.2. SPSS (Statistical Packages for Social Sciences)

This package was written specially for the analysis of social sciences data. Since the analysis of social sciences data

involves a great deal of data manipulation the package thus provides a wide range of procedures just to do this. First of all, it allows for a very flexible data input and then provides plenty of facilities for data transformation and recoding, and file manipulation. In addition, the procedure on Factor Analysis provides a wide range of methods for factoring.

### 4.2.3. CLUSTAN

This package was specially written to do cluster analysis by D. Wishart. It has 40 similarity coefficient options and nine sorting procedures to choose from. The nine sorting procedures are:-

(1) Single linkage (Nearest neighbour)

(2) Complete linkage (Furthest neighbour)

(3) Average linkage (Unweighted pair-group average)

(4) Centroid sorting (Weighted pair-group centroid)

(5) Median sorting (Gower's method)

(6) Ward's method (Error sum of square)

(7) Lance-Williams Flexible Beta method

(8) McQuitty's similarity analysis

(9) Mode analysis.

In addition, PCA and k-linkage lists are available. Also, the similarity coefficient can be preformed on the factor scores from a selected number of principal component axes instead of the data matrix.

The overall limitation of CLUSTAN 1A implemented on the ICL 1906A computer at the University of Birmingham Computer Centre is for not more than 200 individuals in a job. For example, a job on PCA with 160 cases and 99 variables required around 15 minutes to complete!

The newer versions, CLUSTAN 1B and CLUSTAN 1C provide room for up to 999 cases and 200 continuous variables and 400 binary variables. They also include many more procedures like "RELOCATE", "DIVIDE", "KDEND", "DNDRITE" and other facilities. Unfortunately, CLUSTAN 1C is just in the process of implementation at the time of writing and 1B is only available at the University of Manchester Regional Computer Centre and could not be adapted in time for use at Birmingham.

### 4.2.4. CLASP

This package was developed at the Statistics Department of Rothamsted Experimental Station by G. J. S. Ross, F. B. Lauckner and Diana Hawkins. It is designed to handle larger data sets, which their general purpose statistical package, "GENSTAT" could not possibly manage.

The main features are:-

(1) A simple user's language

(2) Flexible input instructions and data manipulation

(3) Mixed data types and missing values accepted

(4) Clustering procedures (a) Single linkage

(b) Complete linkage

(c) Average linkage

(d) Centroid sorting

(e) Median method.

(5) Principal coordinate analysis

(6) Minimum spanning tree (MST)

(7) Data plotted on coordinate axes

(8) Key-forming aids

(9) Identification systems

(10) Fast processing of large sets of data.

The similarity coefficient used has the advantage of being able to handle all types of variables at any one time. It is calculated as follows:-

Similarity between units I and J = $S_{IJ} = \frac{\text{Total score}}{\text{Total weight}}$

where scores and weights are as follows:

| | Score | Weight |
|---|---|---|
| Binary character | | |
| either value unknown | 0 | 0 |
| both values 0 | 0 | 0 |
| values differ | 0 | 1 |
| both values 1 | 1 | 1 |
| Nominal character | | |
| values agree | 1 | 1 |
| values differ | 0 | 1 |

| | | Score | weight |
|---|---|---|---|
| Ordinal, Meristic and continuous | | | |
| | $1 - \frac{\text{Abs. diff.}}{\text{range}}$ | | 1 |
| OR | $1 - \frac{(\text{Diff.}^2)}{\text{range}^2}$ | | 1 |

It will be noted that when all the characters used are of binary type the similarity coefficient is essentially Jaccard's coefficient.

An interesting directive, "REGROUP" forms groups with maximum within-group similarity by reallocating individuals from group to group until no further changes in the average similarity is detected. Another procedure, "KEY" used in conjunction with "REGROUP" serves to construct a key for those groups formed.

Since PCO does not provide the factor loading, CLASP has a directive to calculate a pseudo-F ratio that relates the contribution of each variable to the different vectors. If the data are only of meristic or continuous type a list of regression coefficients is calculated for each variable. These regression coefficients are equivalent to the principal component loading in PCA and the principal coordinate scores become principal component scores.

The PCO method used is iterative multiplication and scaling, and continuous correction to preserve orthogonality.

## 4.3. Strategy of the Analysis

It will be noticed by now that there are very many methods that can be used to analyse a set of data. Depending on the problem under study and therefore the data structure, some methods were said to be more useful than others for taxonomic purposes. The most common recommendation is the use of clustering or ordination. As was noted in Sect. 4.1.1., clustering is more suitable for more or less defined data but when the data are of the poorly correlated type ordination is believed to be better. Bryant and Atchley (1975), and Atchley and Bryant (1975) actually went to the extent of dividing them into within-groups and among-groups methods. Now, the question is, which method should one adopt for use in the present work.

Wishart (1975) suggested the comparison of the analytical results between those methods that tend to give tight "minimum variance" clusters e.g. "RELOCATE" (CLUSTAN) or "REGROUP" (CLASP) and Ward's method, with those that give more natural clusters from "MODE", "KDEND" and Single linkage clustering. He went on to suggest two schemes, one for large populations and the other for sizes of less than 150 individuals to achieve this.

Most often the resulting classification from an analysis is compared with that of the existing accepted classification. This works well when the two classifications coincide but when they do not no conclusion can then be reached. There is no way to support either of them since numerical taxonomic methods are completely neutral.

A scheme was tried out here to test the various methods of analysis. This scheme was based on the genetical fact that segregation of a cross is often limited to within the possible recombination between the two parents (Anderson, 1949). These progenies are usually intermediate between the two parents. In potatoes, this phenomenon applies and in several natural crosses the putative parents could even be postulated and were later proved to be correct e.g. S. x ajanhuiri (Huaman, 1975); S. x juzepczukii and S. x curtilobum (Hawkes, 1962; Schmiedicha, 1977); and others. Furthermore, from field observations families of crosses can usually be identified because of their overall resemblance within each family. Thus, data from a set of known hybrid families can be used to test out these analytical methods. If members of the same family or from families with a common parent tend to cluster together then it can be concluded that the analysis works. This will test in a single run all the different factors that affect the results, i.e. the validity of the coding, the characters used, the similarity coefficient acquired, the sorting procedure employed etc. However, since many clones of the cultivated diploids may be somehow or another related to one another we should therefore expect a certain amount of discrepancy.

## 4.4. Testing the numerical analysis using a series of hybrids

### 4.4.1. Material and methods

The sixteen families used were shown in Table 4.1. These crosses were kindly provided by Professor C. Ochoa.

| Family | Pedigree | Species* | Germination per 100 seeds | No. of plants for analysis |
|---|---|---|---|---|
| FAM-01 | OCH 5496 x 702151 | s x s | 89 | 41 |
| FAM-02 | H/J 351 x HJT 5626 | s x s | 94 | 41 |
| FAM-03 | H/J 501 x OCH 5316 | s x s | 81 | 42 |
| FAM-04 | OCH 6134 x OCH 6401 | g x g | 74 | 37 |
| FAM-05 | HJT 5448 x HJT 5718 | g x g | 53 | 38 |
| FAM-06 | 702151 x 700042 | s x g | 92 | 42 |
| FAM-07 | HJT 5457 x OCH 6401 | s x g | 87 | 40 |
| FAM-08 | OCH 5546 x CUP 140 | g x s | 52 | 40 |
| FAM-09 | OCH 5422 x HJT 6010 | p x s | 44 | 42 |
| FAM-10 | H/J 660 x 700341 | p x s | 77 | 40 |
| FAM-11 | HJT 5457 x H/J 352 | s x p | 62 | 40 |
| FAM-12 | CUP 140 x OCH 5422 | s x p | 61 | 36 |
| FAM-13 | OCH 5758 x OCH 5422 | g x p | 50 | 38 |
| FAM-14 | HJT 5493 x 700936 | g x p | 56 | 39 |
| FAM-15 | OCH 5422 x OCH 6426 | p x g | 40 | 40 |
| FAM-16 | H/J 352 x OCH 6324 | p x g | 88 | 42 |

TABLE 4.1: The sixteen families used to test the statistical analyses.

*key s = *S. stenotomum*

g = *S. goniocalyx*

p = *S. phureja*

One hundred seeds per family were treated with 1000 ppm of Gibberellic acid for 24 hrs. before they were sown in separate seed trays in the greenhouse at La Molina, Lima, near sea level. The number of seedlings obtained for each family was shown in Table 4.1. Forty-two seedlings selected randomly from each family were transplanted into 15 cm pots. They were raised in the greenhouse during the southern winter in 1977. Flower and tuber data were taken in this season.

In the following southern winter in 1978, they were grown in the field at "El Asesor", Lima, also near sea level, in a completely randomised block design (RCBD). They were planted to six blocks with 16 plots each. Each plot had seven clones of three plants each of a family. This would have eliminated some of the variations due to the environment. Leaf, stem and plant habit data and some of the flower data were taken during this season.

During the course of the two plantings several plants were killed by diseases or eliminated as the result of virus infection. The number of plants which remained for each family was shown in Table 4.1. It was not possible to include the flower data in the analysis because many of the clones failed to flower.

### 4.4.2. Characters used

As was mentioned in Sect. 4.1.1., the maximum number of

characters should be used to obtain a "stable" classification. Furthermore, the characters chosen should be represented from every part of the plant. This may be thought of as the conversion of physical form into numerical data.

It is frequent for a clone to possess a combination of some diagnostic characters from another "species" or even two. Fig. 4.1. is a good example showing a plant with typical leaf and plant type of S. phureja but the flower is typical of S. stenotomum.

The following characters were used:-

TUBER CHARACTERS:

| | | | |
|---|---|---|---|
| 1. | Number of very small tubers (M)* | | |
| 2. | Number of small tubers (M) | | |
| 3. | Number of medium tubers (M) | | |
| 4. | Number of big tubers (M) | | |
| 5. | Number of soft tubers (M) | | |
| 6. | Number of non-dormant tubers (M) | | |
| 7. | Degree of tuber dormancy (O) | 0 | dormant |
| | | 1 | fairly dormant |
| | | 2 | weakly dormant |
| | | 3 | non-dormant |
| 8. | Shape of tuber (N) | 1 | obliquely compressed from both apexes |
| | | 2 | Normal - from round to cylindrical |
| | | 3 | fusiform |
| | | 4 | pyriform |
| | | 5 | falcate |
| 9. | Cross-section of tuber (O) | 1 | round |
| | | 2 | slightly flattened |
| | | 3 | flattened |

10. Primary tuber skin colour - the colour that is underneath the other if there is one (N)

1. yellow
2. red
3. purple-red
4. red-purple
5. purple
6. black

11. Intensity of the primary tuber skin colour (O)

1. light
2. medium
3. intense

12. Secondary tuber skin colour (N)

0. none
1. light red
2. red
3. light purple
4. purple
5. black

13. Distribution type of secondary tuber skin colour (N)

1. scattered - when the secondary colour is distributed at random in one or more areas around the tuber
2. stippled - when the surface of the tuber is more or less uniformly covered with spots.
3. splashed - when the secondary colour is confined to areas around the eyes.
4. spectacled - when the primary colour is confined to areas around the eyes and the remainder of the tuber is of the secondary colour.

14. Depth of tuber eyes (O)

1. shallow
2. medium
3. deep

15. Distribution of tuber eyes (B)

1. predominantly apical
2. evenly distributed

16. Number of eyes per tuber (O)

1. very few
2. few
3. some
4. many

17. Length of tuber eye-brow (O)
    1 short
    2 medium
    3 long

18. Shape of area behind the tuber eye-brow (N)
    1 bulging uniformly
    2 slightly bulging uniformly
    3 flat
    4 slightly bulging skewly toward the eye
    5 bulging skewly toward the eye

19. Tuber skin type (N)
    1 smooth
    2 tiny indentations
    3 rough (flaky)
    4 netted
    5 heavily netted

20. Number of tuber lenticels (O)
    1 few
    2 some
    3 many

21. Primary tuber flesh colour (N)
    1 white
    2 yellow-white
    3 light yellow
    4 yellow
    5 dark yellow

22. Secondary tuber flesh colour (N)
    0 none
    1 yellow
    2 light red
    3 red
    4 red purple
    5 light purple
    6 purple

23. Distribution of secondary tuber flesh colour (N)
    0 none
    1 vascular ring
    2 part of medulla
    3 vascular ring and medulla

24. Length of tuber (cm) (Nu)

25. Width of tuber (cm) (Nu)

26. Location of pigment in tuber skin (N)
    0 none
    1 cork
    2 cork and hypodermis
    3 hypodermis

27. Colour of sprout (N)

0 white
1 light red
2 red
3 brown
4 light purple
5 purple
6 deep purple

28. Distribution of the sprout pigment (N)

0 none
1 at the apex
2 at the base
3 spotted uniformly
4 unevenly diffused
5 completely pigmented

29. Vigour of sprout (O)

1 weak
2 fair
3 strong
4 very strong

PLANT HABIT CHARACTERS AND FRESH LEAF CHARACTERS

30. Plant vigour (O)

1 weak
2 fair
3 vigorous

31. Plant height (cm) (Nu)

32. Number of shoots (O)

1 few
2 some
3 many

33. Length of stem internodes (O)

1 short
2 short and medium
3 medium
4 medium and long
5 long

34. Diameter of stem (O)

1 thin
2 medium
3 thick

35. Shape of stem (O)

1 round
2 round and angular
3 angular

36. Position of stem wing (O)

1 extended over ¼ of the stem circumference
2 extended from ¼ to ½ of the stem circumference
3 extended from ½ or more of the stem circumference.

| | | |
|---|---|---|
| 37. Width of stem wing (O) | 0 | none |
| | 1 | narrow |
| | 2 | medium |
| | 3 | wide |
| 38. Shape of stem wing (N) | 0 | none |
| | 1 | flat |
| | 2 | semi-wavy |
| | 3 | wavy |
| 39. Colour of stem (N) | 1 | green |
| | 2 | brown |
| | 3 | red |
| | 4 | purple-red |
| | 5 | red-purple |
| | 6 | light purple |
| | 7 | purple |
| | 8 | black purple |
| 40. Intensity of stem pigment (O) | 0 | none |
| | 1 | light |
| | 2 | moderate |
| | 3 | intense |
| 41. Distribution of stem pigment (N) | 0 | green |
| | 1 | diffused stripe |
| | 2 | defined spot |
| | 3 | completely pigmented |
| 42. Colour of apical shoot (N) | 1 | yellow green |
| | 2 | yellow purple |
| | 3 | dark purple |
| 43. Colour of mature leaf (O) | 1 | yellow-green |
| | 2 | green |
| | 3 | dark dull green |
| 44. Degree of leaf arching (O) | 0 | straight |
| | 1 | slightly arched |
| | 2 | arched |
| 45. Degree of leaflet arch (O) | 1 | curved down |
| | 2 | straight |
| | 3 | curved up |
| 46. Angle of terminal leaflet to the rachis (O) | | |
| | 1 | pointed up |
| | 2 | in the same line |
| | 3 | pointed down |
| 47. Plane of the leaf blade (O) | 1 | leaflets pointed down |
| | 2 | leaflets horizontal |
| | 3 | leaflets pointed up |

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48. Plane of individual primary lateral leaflet (O)

1 the edges pointed down
2 in the same plane
3 the edges pointed up

49. Depth of primary leaflet vein (O)

0 shallow
1 medium
2 deep

50. Glossiness of the primary leaflet (B)

0 dull
1 glossy

51. Type of primary leaflet margin (B)

1 smooth
2 wavy

52. Size of pseudostipulate leaf (O)

1 small
2 medium
3 large

53. Curvature of pseudostipulate leaf (O)

1 straight
2 moderately curved
3 strongly curved

54. Pubescence of upper surface of primary leaflet (O)

1 sparse
2 moderate
3 dense

55. Pubescence of lower surface of primary leaflet (O)

1 sparse
2 moderate
3 dense

56. Pubescence of primary leaflet margin (O)

1 sparse
2 moderate
3 dense

57. Pubescence of rachis groove (O)

1 sparse
2 moderate
3 dense

58. Pigmentation of upper surface of leaf rachis (N)

0 none
1 yellowish
2 brown
3 red
4 red-purple
5 purple

59. Intensity of the pigmentation in character (58) (O)

0 none
1 light
2 moderate
3 dense

60. Pigmentation of the nodal area of leaf rachis (N)

0 none
1 yellowish
2 brown
3 red
4 red-purple
5 purple

61. Intensity of pigmentation in character (60) (O)

0 none
1 light
2 moderate
3 dense

62. Pigmentation of the midrib of the terminal leaflet (O)

0 none
1 ¼ length
2 ½ length
3 ¾ length
4 whole length

63. Pigmentation of the lower surfaces of terminal leaflet lamina (O)

0 none
1 light
2 moderate
3 dense

64. Involution of terminal leaflet (O)

0 none
1 slight
2 strong

LEAF HERBARIUM CHARACTERS

65. Length of leaf (cm) (Nu)

66. Width of leaf (cm) (Nu)

67. Distance from the base to the widest part of the leaf (cm) (Nu)

68. Length of petiole (cm) (Nu)

69. Number of primary lateral leaflets (M)

70. Number of secondary lateral leaflets (M)

71. Number of tertiary lateral leaflets (M)

72. Number of acroscopic leaflets (M)

73. Number of basiscopic leaflets (M)

74. Number of semibasiscopic leaflets (M)

75. Number of secondary and tertiary leaflets on terminal petiolule (M)

76. Openess of leaf (O)
1 closed
2 intermediate
3 open

77. Pattern of the terminal and the first pair of lateral leaflets (O)
1 closed
2 intermediate
3 open

78. The pair of primary leaflets where the leaf is widest (O)
1 first pair
2 between first and second pair
3 second pair
4 between second and third pair
5 third pair

79. Angle of insertion of the second pair of primary laterals (O)
1 narrow (less than60°)
2 intermediate (ca. 60-90°)
3 wide (ca. 90°)

80. Type of apex of the terminal leaflet (O)
1 acuminate
2 acute
3 obtuse

81. Type of terminal base (O)
1 cordate
2 truncate
3 obtuse
4 cuneate

82. Type of apex of the first lateral leaflet (O)
1 acuminate
2 acute
3 obtuse

83. Type of base of the first lateral leaflet (O)
1 cordate
2 truncate
3 obtuse

84. Symmetry of the base of the first lateral leaflet (O)

1 top half longer
2 same
3 bottom half longer

85. Curvature of the first lateral leaflet toward the terminal leaflet (O)

1 straight
2 slightly curved
3 curved

86. Length of terminal petiolule (cm) (Nu)

87. Length of terminal leaflet lamina (cm) (Nu)

88. Width of terminal leaflet (cm) (Nu)

89. Distance from base to the widest part of the terminal leaflet (cm) (Nu)

90. Length of the first lateral leaflet petiolule (cm) (Nu)

91. Length of the first lateral leaflet lamina (cm) (Nu)

92. Width of the first lateral leaflet lamina (cm) (Nu)

93. Distance from the base to the widest part of the first lateral leaflet (cm) (Nu)

94. Distance of the rachis between the first and second pair of lateral leaflets (cm) (Nu)

95. Type of attachment of the secondary lateral leaflet (N)

1 both sides decurrent
2 apical side free
3 both sides free

96. Length of the biggest secondary lateral leaflet (cm) (Nu)

97. Width of the biggest secondary lateral leaflet (cm) (Nu)

98. Distance from the base to the widest part of the biggest secondary lateral leaflet (cm) (Nu)

99. Length of the longest petiolule (cm) (Nu)

*key B - binary form
N - nominal form
O - ordinal form
M - meristic form
Nu - continuous form



Fig. 4.1 A clone showing the typical leaf and plant type of S. phureja and the typical flower of S. stenotomum.

### 4.4.3. Logic in the coding of Characters

In any study, the use of meristic and continuous types of characters will logically carry the maximum amount of information. However, because of the time factor involved in the measurement very often a compromise to code them into ordinal type may be necessary. Also, coding is inevitably required for nominal type of characters. During coding care must be taken to prevent any serious loss of information.

The coding of the characters in this study was based on a preliminary survey of the variability of these characters from the hundred clones designated as different species and "hybrids" between them in the winter of 1977 in "El Asesor" . The genetic factors that control the characters were considered wherever available. Since very little is known about the genetics of most of the characters, coding was based as far as possible on biological " sense".

The inclusion of some of the characters which at first sight might seem to be doubtful is justified as follows. The recording of the tuber number may be justifiable because they were grown under well controlled environment in the greenhouse and harvesting was done over a sieve, thus miscounts due to losses were negligible.

For tuber shape, the round to cylindrical forms were grouped as a single class because their sizes were measured numerically in characters (24) and (25). One should be aware of the fact that it is

frequent to get a range of forms from round to somewhat cylindrical even from a single plant.

Coding the pigmentation may be the most difficult of all. The interaction of the various pigments, their intensity, the amount of illumination and the age of the part of the plant easily confuses ones visual judgement. A standard colour chart is difficult to use and the most practical method may be the use of fresh petal preparation when flowers are scored that comprises the whole range of colour. This is in a way a colour chart.

The genetics of pigmentation in potato is fairly well understood (Howard, 1970). Different anthocyanidins were shown to be the product of different genes and/or interaction of genes and the intensity of all the pigmentations was attributed to a gene, Ac, where the recessive homozygous ac ac gives the deeper tone for all the pigments. Pigmentation can then be divided into two separate characters, one dealing with the type of pigment and the other the intensity. This therefore represents an interesting case of coding in accordance to the genetic make-up of the character. However, in several cases because of practical constraints this scheme was not followed.

No attempt was made to use ratio to correct "size" factor because size differences may be treated as an intrinsic part of the total variation. Of course its use would have been tried if time had permitted.

## 4.4.4. Results and discussion

### 4.4.4.1. Analysis of individual families separately

The means and standard deviations of all the characters for each of the families are given in Appendix III . They serve to indicate the amount of variability that existed between the different families. Medium, mode, kurtosis, skewness, range, minimum and maximum were determined also but they are not presented here.

The result of the PCO analysis is summarised in Table 4.2 as the first ten latent roots (eigenvalues) and the cumulative percentage of variance accounted for at each vector. The first ten component scores of each individual of all the families are given in Appendix IV . The latent roots were very consistent for all the sixteen families. The percentage of variance accounted for by each vector was very low. The first ten vectors in all cases accounted for only about 50% of the total variance. The trace (sum of all the latent roots) ranged from 15.008 to 17.368 only in all the sixteen families. This indicates the presence of very little variability within the family.

In view of this the presentation of the individuals in two-dimensional scatter diagrams should be interpreted with reservation (Fig. 4.2). It may have been subjected to much distortion. A good cluster in a plot between the first and the second vectors may be quite far apart in other pairs of plots. For example, the first and second vector plot of FAM-05 showed two defined or even three clusters (Fig. 4.2)

TABLE: 4.2 : Values of the first ten latent roots, the trace and the accumulative percentage of variance.

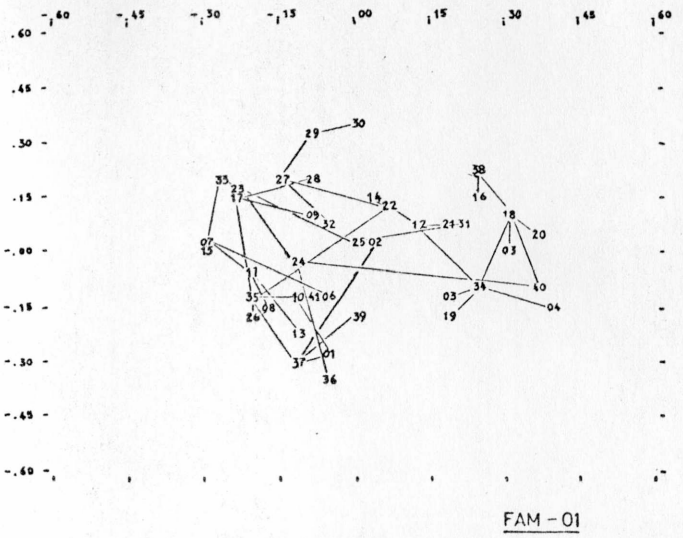
| Vectors / Families | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Trace (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FAM-01 | 1.576[a] | 1.118 | 1.050 | 0.905 | 0.770 | 0.738 | 0.719 | 0.672 | 0.640 | 0.552 | 17.253 |
| | 9.1[b] | 15.6 | 21.7 | 26.9 | 31.4 | 35.7 | 39.9 | 43.8 | 47.5 | 50.7 | 100.0 |
| FAM-02 | 1.164 | 1.123 | 0.952 | 0.933 | 0.845 | 0.847 | 0.700 | 0.685 | 0.642 | 0.583 | 17.166 |
| | 6.8 | 13.3 | 18.9 | 24.3 | 29.2 | 34.2 | 38.2 | 42.2 | 46.0 | 49.4 | 100.0 |
| FAM-03 | 1.428 | 0.992 | 0.822 | 0.756 | 0.701 | 0.664 | 0.616 | 0.573 | 0.542 | 0.537 | 15.145 |
| | 9.4 | 16.0 | 21.4 | 26.4 | 31.0 | 35.4 | 39.5 | 43.3 | 46.8 | 50.4 | 100.0 |
| FAM-04* | - | - | - | - | - | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - |
| FAM-05 | 1.722 | 1.237 | 0.982 | 0.847 | 0.671 | 0.724 | 0.654 | 0.620 | 0.560 | 0.551 | 15.606 |
| | 11.0 | 19.0 | 25.3 | 30.7 | 35.0 | 39.6 | 43.8 | 47.8 | 51.4 | 54.9 | 100.0 |
| FAM-06 | 1.287 | 1.110 | 1.027 | 0.885 | 0.838 | 0.796 | 0.757 | 0.623 | 0.570 | 0.582 | 16.552 |
| | 7.8 | 14.5 | 20.7 | 26.0 | 31.1 | 35.9 | 40.5 | 44.2 | 47.7 | 51.2 | 100.0 |
| FAM-07 | 1.349 | 1.117 | 0.938 | 0.813 | 0.787 | 0.688 | 0.727 | 0.627 | 0.576 | 0.533 | 16.057 |
| | 8.4 | 15.4 | 21.1 | 26.3 | 31.2 | 35.4 | 40.0 | 43.9 | 47.5 | 50.8 | 100.0 |
| FAM-08 | 1.452 | 1.102 | 0.967 | 0.842 | 0.805 | 0.688 | 0.712 | 0.649 | 0.577 | 0.558 | 16.378 |
| | 8.9 | 15.6 | 21.5 | 26.6 | 31.5 | 35.7 | 40.1 | 44.1 | 47.6 | 51.0 | 100.0 |
| FAM-09 | 1.331 | 1.164 | 0.987 | 0.856 | 0.856 | 0.782 | 0.691 | 0.644 | 0.613 | 0.573 | 16.768 |
| | 7.9 | 14.9 | 20.8 | 25.9 | 31.0 | 35.6 | 39.8 | 43.6 | 47.2 | 50.7 | 100.0 |
| FAM-10 | 1.684 | 1.010 | 0.972 | 0.832 | 0.751 | 0.673 | 0.660 | 0.613 | 0.577 | 0.524 | 15.538 |
| | 10.8 | 17.3 | 23.6 | 29.0 | 33.8 | 38.1 | 42.4 | 46.3 | 50.0 | 53.4 | 100.0 |
| FAM-11 | 1.197 | 1.061 | 0.940 | 0.779 | 0.792 | 0.683 | 0.663 | 0.646 | 0.624 | 0.627 | 16.614 |
| | 7.2 | 13.6 | 19.2 | 23.9 | 28.7 | 32.8 | 36.8 | 40.7 | 44.4 | 48.2 | 100.0 |
| FAM-12 | 1.259 | 1.066 | 0.903 | 0.838 | 0.734 | 0.806 | 0.657 | 0.618 | 0.580 | 0.549 | 15.008 |
| | 8.4 | 15.5 | 21.5 | 27.1 | 32.0 | 37.3 | 41.7 | 45.8 | 49.7 | 53.4 | 100.0 |
| FAM-13 | 1.649 | 1.205 | 0.957 | 0.906 | 0.751 | 0.736 | 0.673 | 0.636 | 0.594 | 0.569 | 15.720 |
| | 10.5 | 18.2 | 24.2 | 30.3 | 34.8 | 39.5 | 43.7 | 47.8 | 51.6 | 55.2 | 100.0 |
| FAM-14 | 1.365 | 1.196 | 0.942 | 0.994 | 0.877 | 0.672 | 0.638 | 0.621 | 0.572 | 0.537 | 16.117 |
| | 8.5 | 15.9 | 21.7 | 27.9 | 33.3 | 37.5 | 41.5 | 45.3 | 48.9 | 52.2 | 100.0 |
| FAM-15 | 1.612 | 1.330 | 1.162 | 0.844 | 0.791 | 0.713 | 0.663 | 0.633 | 0.587 | 0.553 | 17.368 |
| | 9.3 | 16.9 | 23.6 | 28.5 | 33.0 | 37.1 | 410 | 44.6 | 48.0 | 51.2 | 100.0 |
| FAM-16 | 1.212 | 1.060 | 0.959 | 0.816 | 0.787 | 0.703 | 0.631 | 0.663 | 0.581 | 0.574 | 16.459 |
| | 7.4 | 13.8 | 19.6 | 24.6 | 29.4 | 33.6 | 37.5 | 41.5 | 45.0 | 48.5 | 100.0 |

* this part of the computer printout was missing.

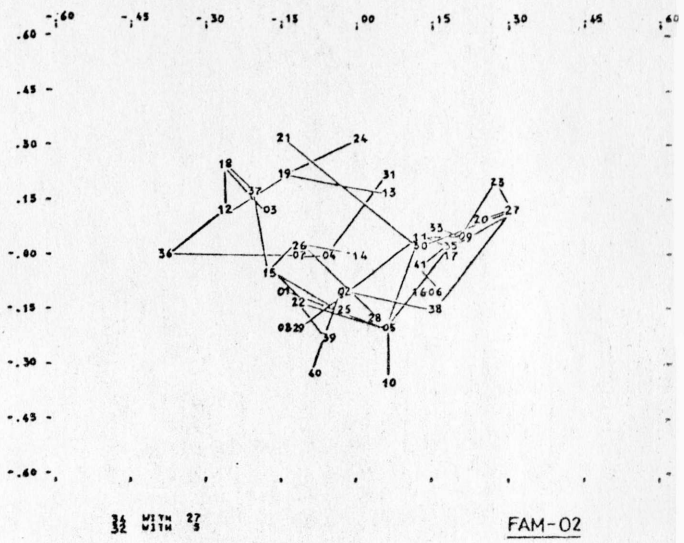
a latent root

b percentage of total variance.

Fig. 4.2 Scatter diagrams of PCO analysis between vector 1 (across the page) and vector 2 (down the page) of the sixteen families analysed separately, with the MST superimposed on them.

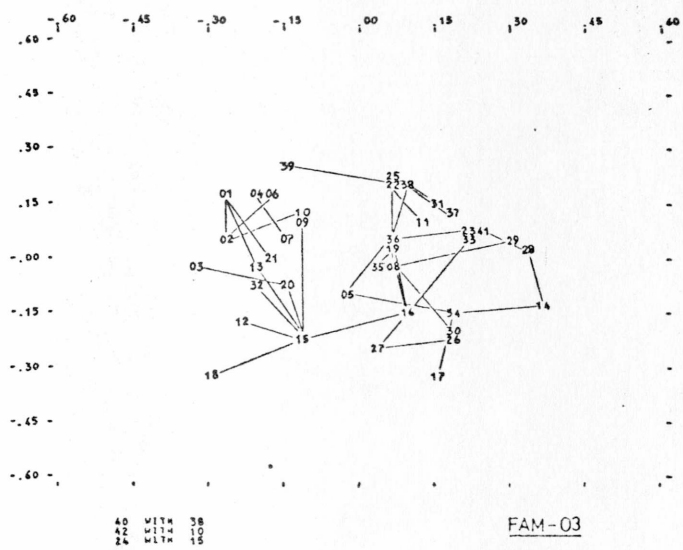


FAM - 01



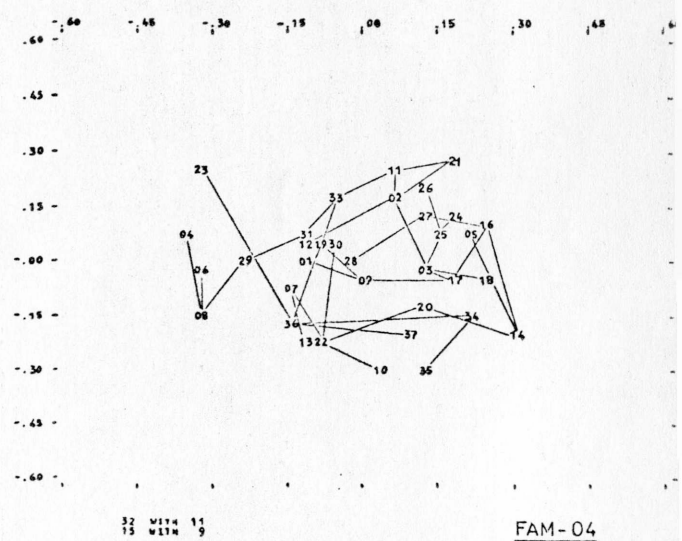
34 WITH 27
32 WITH 9

FAM - 02



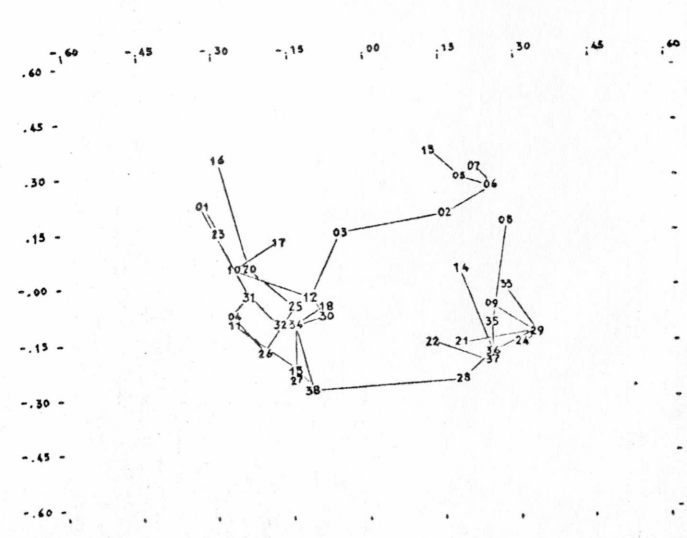
40 WITH 38
42 WITH 10
24 WITH 15

FAM - 03



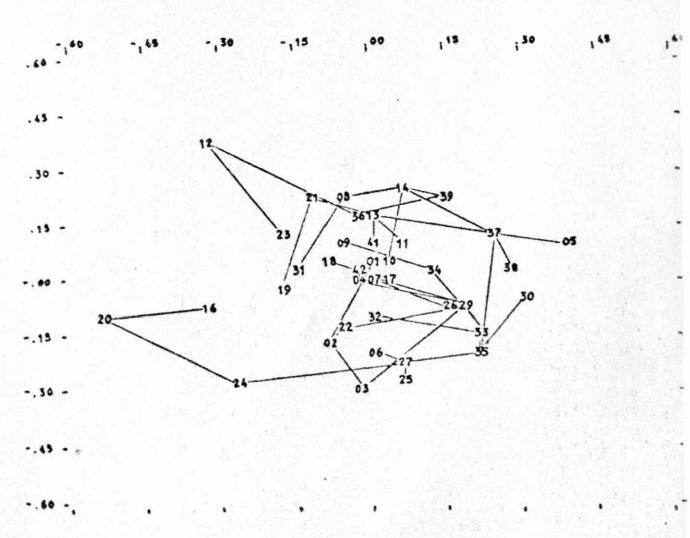
32 WITH 11
15 WITH 9

FAM - 04



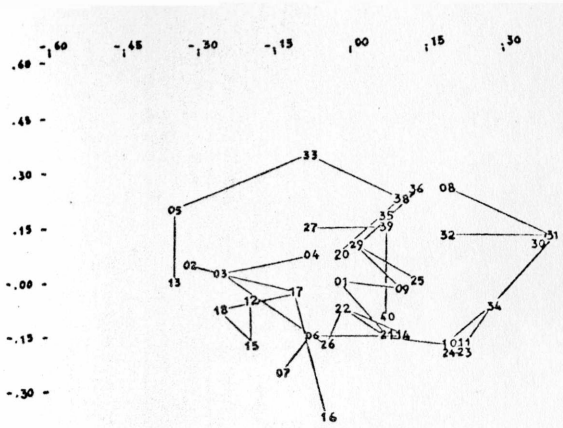
19 WITH 14

FAM - 05



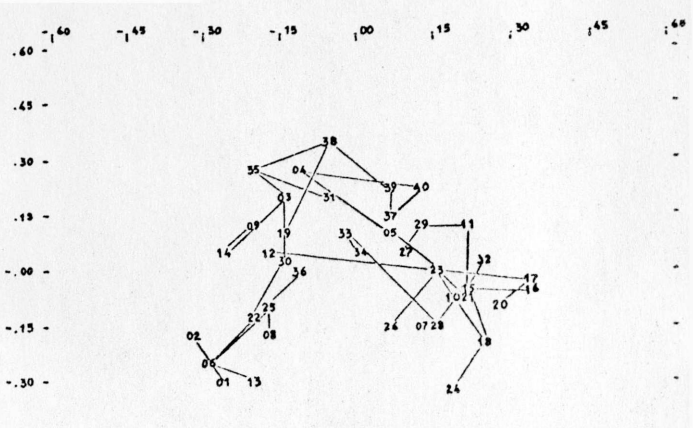
40 WITH 13
13 WITH 1
13 WITH 5

FAM - 06

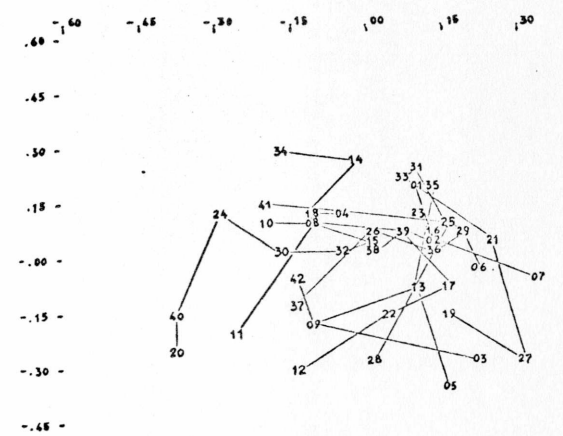


37 WITH 33
18 WITH 17
28 WITH 21

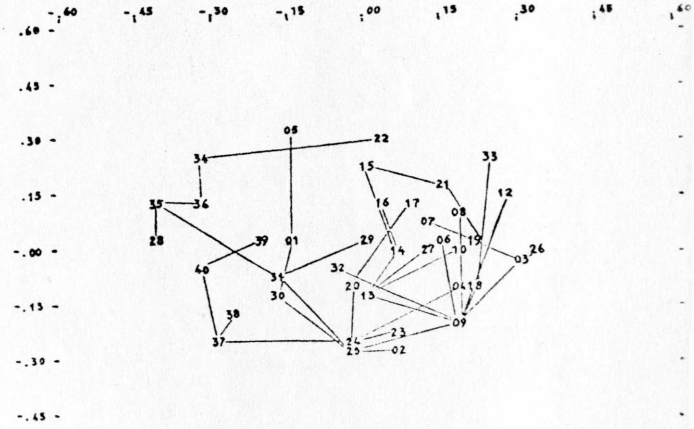
FAM-07



FAM-08

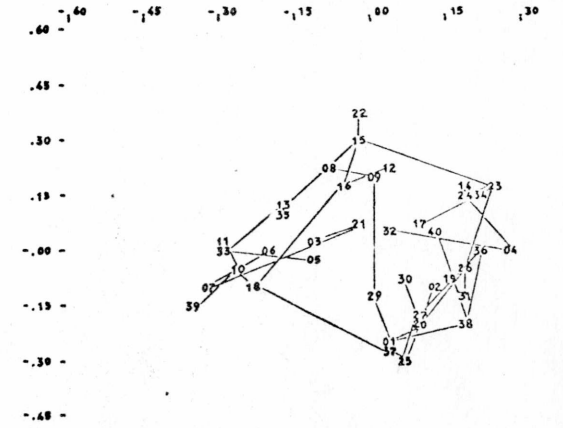


FAM-09



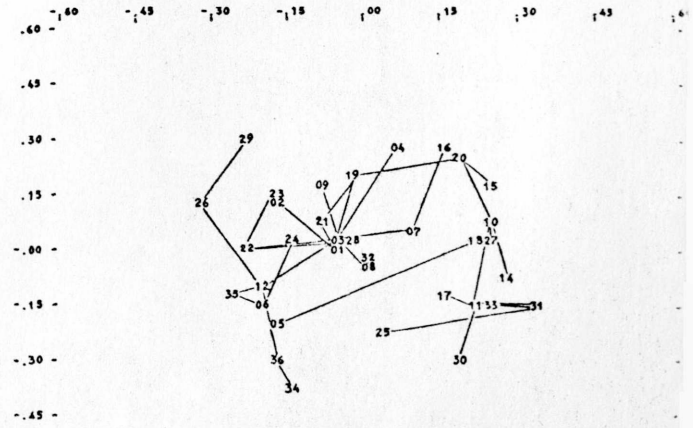
11 WITH 9

FAM-10



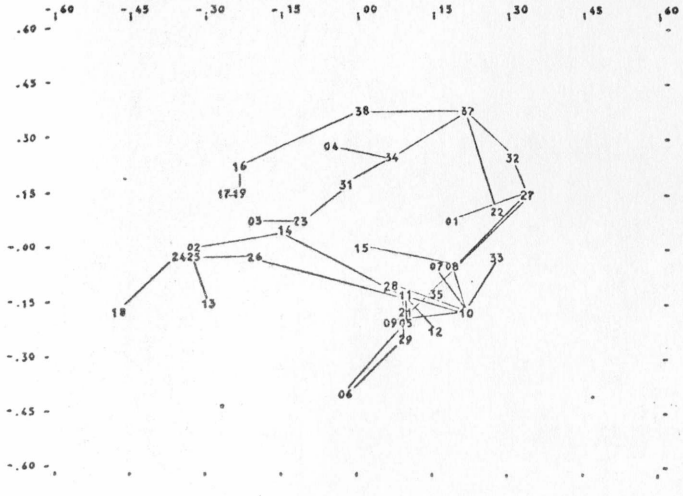
28 WITH 1

FAM-11



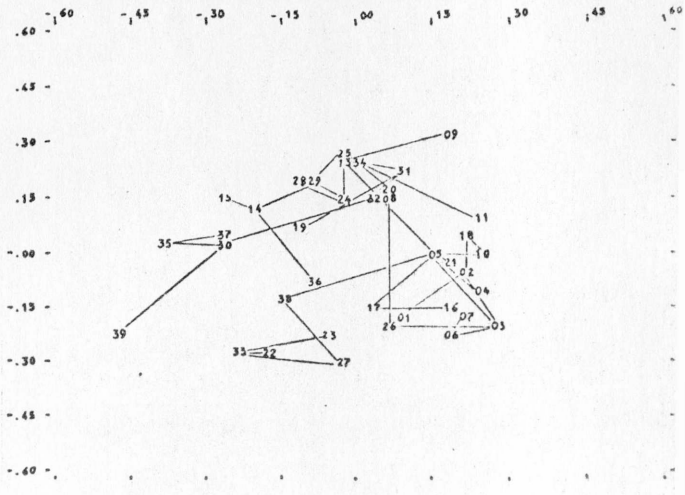
13 WITH 7

FAM-12



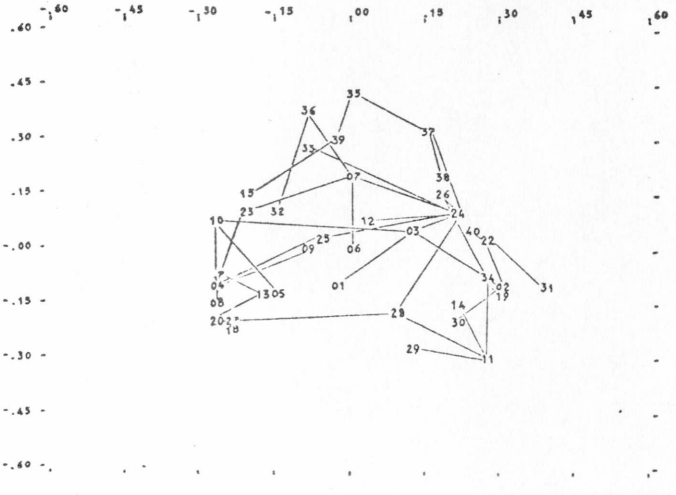
36 WITH 8
20 WITH 19
30 WITH 11

FAM-13



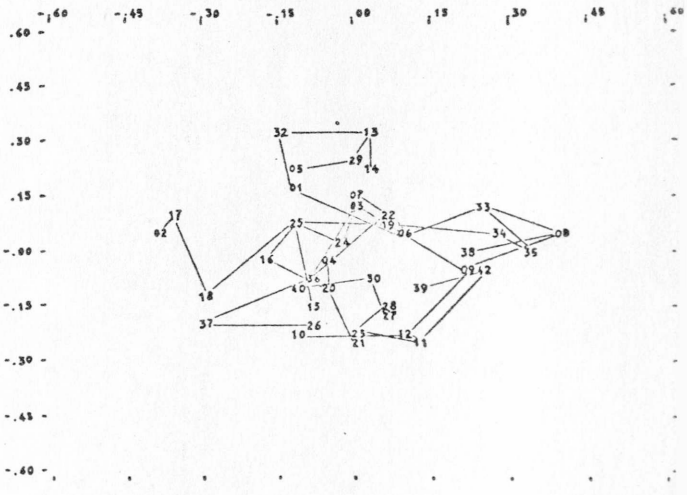
12 WITH 31

FAM-14



21 WITH 8
16 WITH 13

FAM-15



31 WITH 3
41 WITH 3

FAM-16

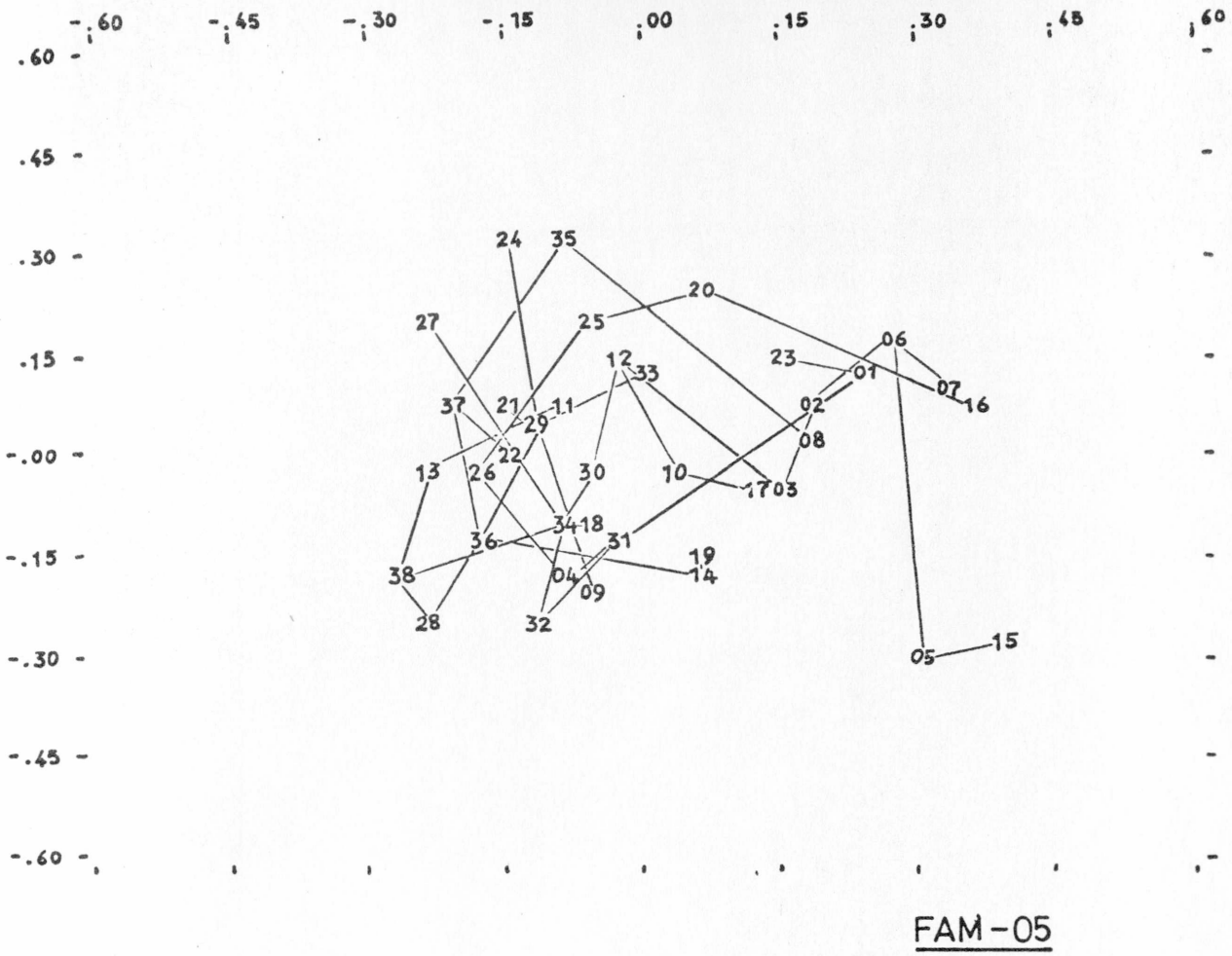



Fig. 4.3 Scatter diagram of PCO analysis between vector 2(across the page) and vector 3(down the page) of FAM-05, with the MST superimposed on it.

but the plot between vector 2 and vector 3 did not show any clustering at all (Fig. 4.3).

By superimposing the MST on to the PCO two-dimensional scatter diagram, it can be shown quite clearly that the scatter plots were distorted (Fig. 4.2). This is so for almost all the families studied except for FAM-03 and FAM-05. The edges of the spanning tree crisscrossed from one sector of the diagram to another and even between what seemed to be two well defined clusters e.g. FAM-08, FAM-11 and FAM-13.

The total length of the edges of the MST is shown in Table 4.3. It ranges from 65.76 (FAM-15) to 71.27 (FAM-03). Again the result did not show any significant difference between the families.

The results of "REGROUP" analysis which seeks to maximise the within-group similarity are presented in Table 4.4.

The five nearest neighbours of all the individuals of each family are given in Appendix V.

The dendrograms produced by single linkage clustering of each family are not shown here. There was no clustering in all the sixteen cases and all the individuals were linked up at only a few levels of similarity, ranging from an average of 60 to 75%. They showed strong "chaining" effect.

The dendrograms produced by the average linkage analysis

TABLE 4.3: Summary of MST analysis

| FAMILY | TOTAL LENGTH | No. OF VERTICES | AVERAGE LENGTH |
|---|---|---|---|
| FAM-01 | 2702.8 | 41 | 65.92 |
| FAM-02 | 2693.4 | 41 | 65.69 |
| FAM-03 | 2993.5 | 42 | 71.27 |
| FAM-04 | 2502.0 | 37 | 67.62 |
| FAM-05 | 2580.3 | 38 | 67.90 |
| FAM-06 | 2884.4 | 42 | 68.68 |
| FAM-07 | 2698.5 | 40 | 67.46 |
| FAM-08 | 2671.9 | 40 | 66.80 |
| FAM-09 | 2834.7 | 42 | 67.49 |
| FAM-10 | 2787.5 | 40 | 69.69 |
| FAM-11 | 2646.5 | 40 | 66.16 |
| FAM-12 | 2372.0 | 36 | 65.89 |
| FAM-13 | 2556.3 | 38 | 67.27 |
| FAM-14 | 2621.0 | 39 | 67.21 |
| FAM-15 | 2630.4 | 40 | 65.76 |
| FAM-16 | 2860.3 | 42 | 68.10 |

TABLE 4.4 : The results of "REGROUP" analysis where the within-group similarities were maximised.

FAM-01

| Groups | Individuals | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 24 | 36 | 37 | 39 | | | | | |
| 2 | 23 | 27 | 28 | 29 | 30 | 32 | 33 | | | |
| 3 | 4 | 5 | 12 | 16 | 18 | 21 | 34 | 38 | 40 | |
| 4 | 19 | 20 | | | | | | | | |
| 5 | 6 | 7 | 15 | 41 | | | | | | |
| 6 | 2 | 3 | 25 | 31 | | | | | | |
| 7 | 9 | 10 | 11 | 13 | | | | | | |
| 8 | 8 | 14 | 17 | 22 | 26 | 35 | | | | |

FAM-02

| Groups | Individuals | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 13 | 21 | 24 | 31 | | | |
| 2 | 2 | 22 | 28 | 32 | 38 | 39 | 40 |
| 3 | 10 | 14 | 16 | 30 | | | |
| 4 | 12 | 15 | 18 | 19 | 26 | 36 | 37 |
| 5 | 6 | 9 | 11 | 17 | 33 | 35 | 41 |
| 6 | 4 | 7 | | | | | |
| 7 | 1 | 3 | 5 | 8 | 25 | 29 | |
| 8 | 20 | 23 | 27 | 34 | | | |

FAM-03

| Groups | Individuals | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19 | 35 | 36 | 40 | | | | | | |
| 2 | 14 | 26 | 28 | 29 | 33 | 41 | | | | |
| 3 | 11 | 22 | 23 | 25 | 31 | 37 | | | | |
| 4 | 1 | 2 | 3 | 4 | 6 | 7 | 9 | 10 | 20 | 42 |
| 5 | 21 | 38 | 39 | | | | | | | |
| 6 | 12 | 13 | 15 | 18 | 24 | 32 | | | | |
| 7 | 5 | 8 | 16 | 17 | 27 | 30 | 34 | | | |

FAM-04

Group

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 34 | 35 | 36 | 37 | | | |
| 2 | 1 | 9 | 15 | 19 | 28 | | |
| 3 | 3 | 5 | 14 | 16 | 17 | 18 | 20 |
| 4 | 7 | 10 | 13 | 22 | 30 | | |
| 5 | 21 | 32 | | | | | |
| 6 | 4 | 6 | 8 | 23 | 29 | | |
| 7 | 2 | 11 | 12 | 31 | 33 | | |
| 8 | 24 | 25 | 26 | 27 | | | |

FAM-05

Group

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 5 | 6 | 7 | 8 | 15 |
| 2 | 14 | 16 | 19 | | | |
| 3 | 11 | 13 | 38 | | | |
| 4 | 3 | 12 | 17 | 18 | 30 | 34 |
| 5 | 9 | 28 | 29 | 33 | 36 | 37 |
| 6 | 1 | 4 | 10 | 23 | 31 | 32 |
| 7 | 21 | 22 | 24 | 35 | | |
| 8 | 20 | 25 | 26 | 27 | | |

FAM-06

Group

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 6 | 22 | 24 | 28 | 32 | |
| 2 | 1 | 4 | 10 | 15 | 17 | 19 | 40 |
| 3 | 3 | 25 | 27 | 30 | 35 | | |
| 4 | 12 | 18 | 23 | 36 | 39 | 42 | |
| 5 | 16 | 20 | | | | | |
| 6 | 13 | 21 | 41 | | | | |
| 7 | 8 | 31 | | | | | |
| 8 | 5 | 11 | 14 | 37 | 38 | | |
| 9 | 7 | 9 | 26 | 29 | 33 | 34 | |

FAM-07

| Group | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 13 | 33 | 37 | | | | |
| 2 | 20 | 38 | | | | | | |
| 3 | 16 | 19 | | | | | | |
| 4 | 9 | 17 | 18 | 26 | 27 | 29 | | |
| 5 | 1 | 2 | 3 | 4 | 6 | 7 | 12 | 15 |
| 6 | 10 | 14 | 25 | 34 | | | | |
| 7 | 8 | 30 | 31 | 32 | 36 | | | |
| 8 | 11 | 23 | 24 | 28 | | | | |
| 9 | 21 | 22 | 35 | 39 | 40 | | | |

FAM-08

| Group | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 8 | 19 | | | | | |
| 2 | 4 | 5 | 37 | 38 | 39 | 40 | |
| 3 | 1 | 2 | 6 | 13 | 22 | | |
| 4 | 25 | 36 | | | | | |
| 5 | 3 | 12 | 14 | 30 | | | |
| 6 | 10 | 11 | 15 | 16 | 27 | 29 | 32 |
| 7 | 7 | 17 | 21 | 23 | 26 | | |
| 8 | 18 | 20 | 24 | 28 | | | |
| 9 | 9 | 31 | 33 | 34 | 35 | | |

FAM-09

| Group | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 4 | 21 | 31 | 33 | 35 | 38 |
| 2 | 1 | 2 | 7 | 17 | 39 | |
| 3 | 23 | 24 | 30 | 32 | | |
| 4 | 3 | 5 | 19 | 27 | 28 | |
| 5 | 9 | 12 | 13 | 22 | 42 | |
| 6 | 6 | 25 | 29 | | | |
| 7 | 8 | 10 | 14 | 18 | 34 | 41 |
| 8 | 11 | 20 | 40 | | | |
| 9 | 15 | 16 | 26 | 36 | 37 | |

FAM-10

| Group | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 16 | 18 | 22 | 26 | 33 | |
| 2 | 37 | 38 | 40 | | | | |
| 3 | 7 | 10 | 17 | 20 | | | |
| 4 | 1 | 5 | 28 | 30 | 34 | 35 | 36 |
| 5 | 15 | 19 | 21 | 27 | | | |
| 6 | 4 | 6 | 8 | 12 | | | |
| 7 | 2 | 9 | 11 | 13 | 23 | 24 | 25 |
| 8 | 14 | 29 | 31 | 32 | 39 | | |

FAM-11

| Group | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 6 | 7 | 10 | 11 | 18 | 33 | 39 |
| 2 | 1 | 25 | 27 | 37 | | | |
| 3 | 36 | 38 | 40 | | | | |
| 4 | 13 | 15 | 16 | 22 | 35 | | |
| 5 | 3 | 5 | 21 | | | | |
| 6 | 17 | 28 | 29 | 30 | | | |
| 7 | 2 | 19 | 20 | 31 | | | |
| 8 | 8 | 9 | 12 | | | | |
| 9 | 4 | 14 | 23 | 24 | 26 | 32 | 34 |

FAM-12

| Group | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 8 | 18 | 27 | 28 | 32 | |
| 2 | 3 | 7 | 13 | 16 | 19 | |
| 3 | 15 | 20 | | | | |
| 4 | 4 | 9 | | | | |
| 5 | 1 | 2 | 21 | | | |
| 6 | 22 | 23 | 26 | 29 | | |
| 7 | 10 | 11 | 14 | 17 | 31 | 33 |
| 8 | 5 | 6 | 12 | 24 | 35 | |
| 9 | 25 | 30 | 34 | 36 | | |

FAM-13

| Group | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 7 | 8 | 27 | 32 | | |
| 2 | 16 | 17 | 19 | | | | |
| 3 | 30 | 35 | 36 | | | | |
| 4 | 5 | 6 | 11 | 20 | 29 | | |
| 5 | 9 | 10 | 12 | 21 | 22 | 28 | 33 |
| 6 | 2 | 3 | 14 | 23 | | | |
| 7 | 13 | 18 | 24 | 25 | 26 | | |
| 8 | 4 | 15 | 31 | 34 | 37 | 38 | |

FAM-14

| Group | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 14 | 15 | 19 | 24 | 28 | 29 | 36 |
| 2 | 22 | 23 | 33 | | | | |
| 3 | 4 | 5 | 8 | 16 | | | |
| 4 | 1 | 2 | 3 | 6 | 7 | 26 | |
| 5 | 30 | 32 | 35 | 37 | 39 | | |
| 6 | 20 | 25 | | | | | |
| 7 | 9 | 11 | 13 | 31 | 34 | | |
| 8 | 10 | 12 | 17 | 18 | 21 | | |
| 9 | 27 | 38 | | | | | |

FAM-15

| Group | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 12 | 15 | 33 | 35 | 37 | 38 | 39 |
| 2 | 2 | 3 | 22 | 24 | 40 | | |
| 3 | 19 | 26 | | | | | |
| 4 | 13 | 16 | 17 | 18 | 20 | 27 | |
| 5 | 4 | 5 | 8 | 9 | 10 | | |
| 6 | 1 | 21 | 23 | 25 | | | |
| 7 | 11 | 14 | 28 | 29 | 34 | | |
| 8 | 6 | 7 | 32 | 36 | | | |
| 9 | 30 | 31 | | | | | |

FAM-16

Group

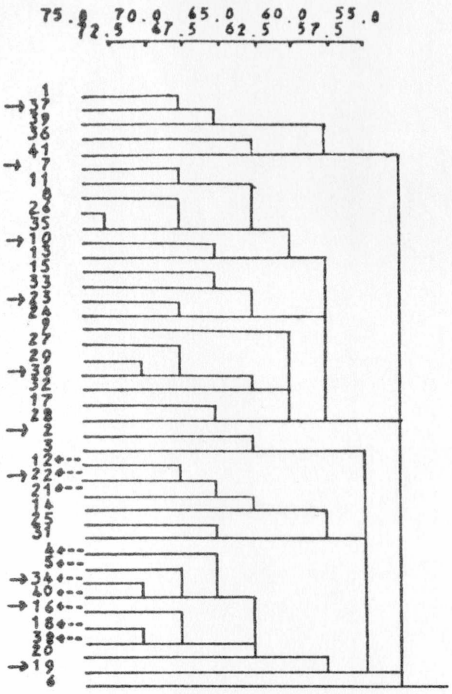
| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 26 | 36 | 37 | | | |
| 2 | 2 | 15 | 17 | 18 | 20 | 21 |
| 3 | 27 | 30 | 40 | 41 | | |
| 4 | 10 | 11 | 23 | 28 | 39 | 42 |
| 5 | 3 | 4 | 6 | 33 | 34 | 35 |
| 6 | 1 | 7 | 13 | 14 | 32 | |
| 7 | 5 | 22 | 29 | 31 | | |
| 8 | 8 | 9 | 12 | 38 | | |
| 9 | 16 | 19 | 24 | 25 | | |

are shown in Fig. 4.4. Two types of dendrogram were observed. Firstly, there were those that did not have any defined clusters at all. The typical dendrogram of this type is that of FAM-06, FAM-07 and to a lesser extent FAM-16. Here, the initial clusters could be formed at quite a high level of similarity, but in the next cycle of clustering they often joined at a relatively lower level and this gave rise to small clusters of a few individuals each. The other had more defined clusters. Dendrograms of FAM-03, FAM-05, FAM-10, and FAM-14 are of this type. In between these two extremes were various intermediate forms with more or less regular sized clusters.

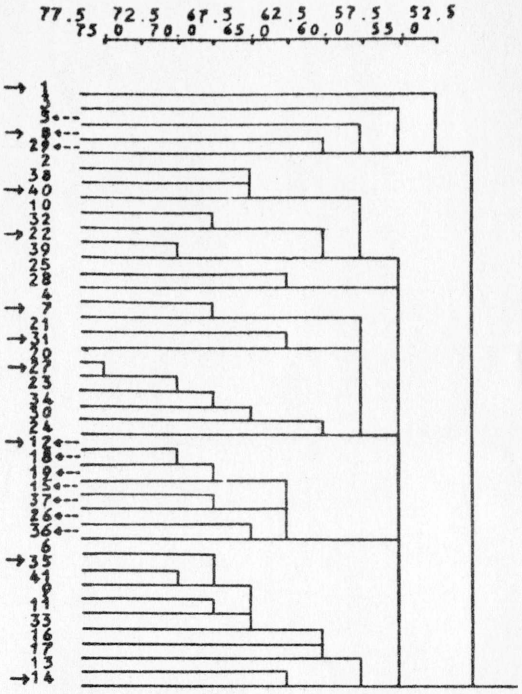
The result obtained from average linkage analysis coincides well with that obtained from "REGROUP" (the superimposed working diagrams are not presented here). Those that had well-defined clusters from the cluster analysis have quite a good fit with the groups produced by "REGROUP". Examples are FAM-03, FAM-05 and FAM-10. On the other hand, in those that had no clear clusters the fit is poor e.g. FAM-06 and FAM-07. On the whole, the results from these two analyses corresponded fairly well. This was not so for the single linkage analysis.

The average linkage analysis was also consistent with that of the PCO analysis in the creation of clusters. Members of a cluster in the average linkage analysis also stood out fairly regularly as groups or as clusters (when the groups were defined) in the scatter diagrams (Fig. 4.2 and Fig. 4.4).

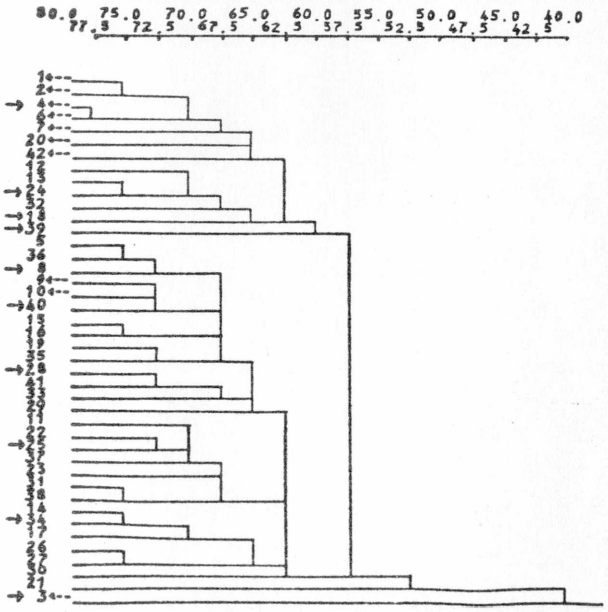
Fig. 4.4 Dendrograms of average linkage clustering of the sixteen families analysed separately.



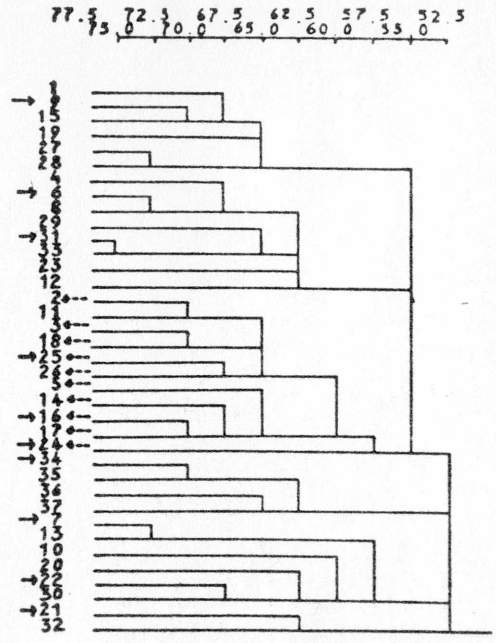

FAM-01



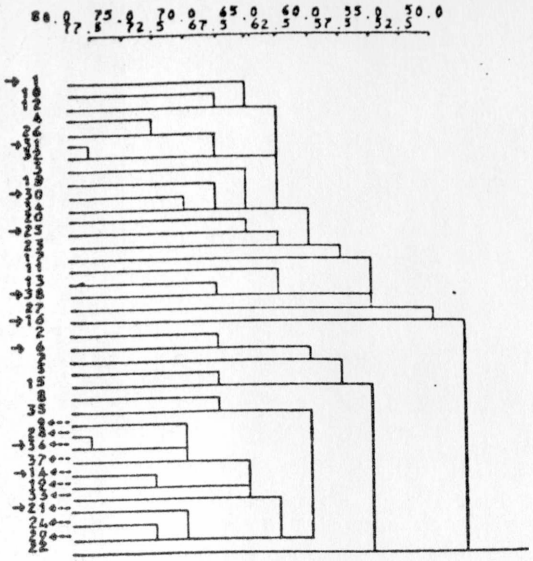

FAM-02



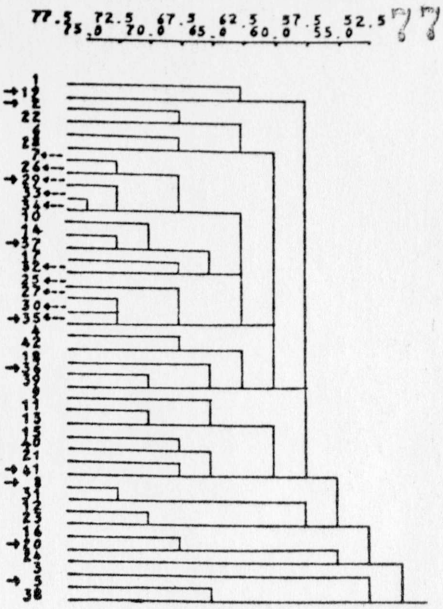

FAM-03



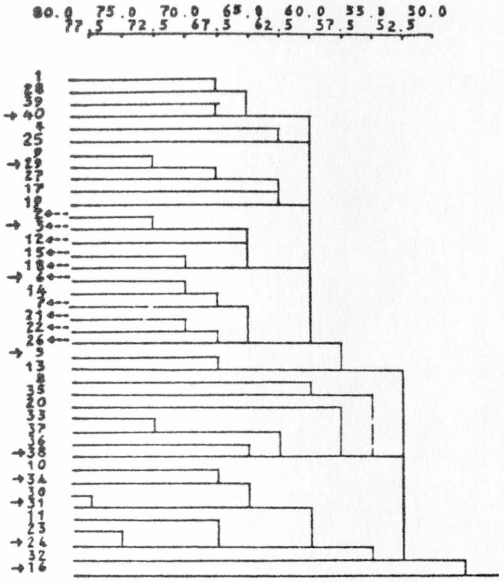

FAM-04



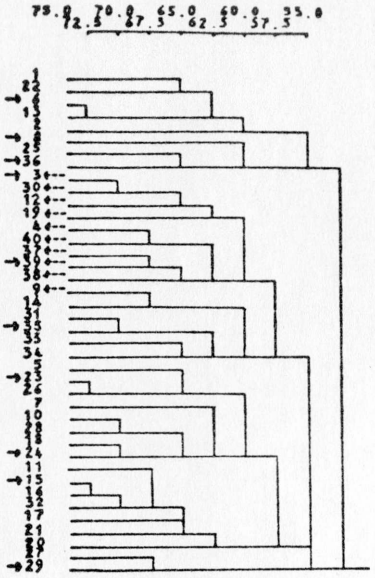
FAM-05



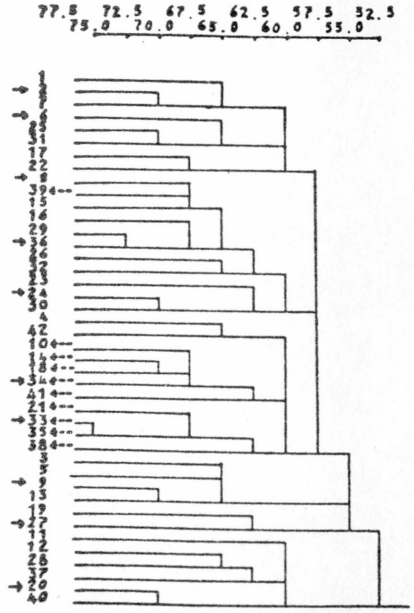
FAM-06



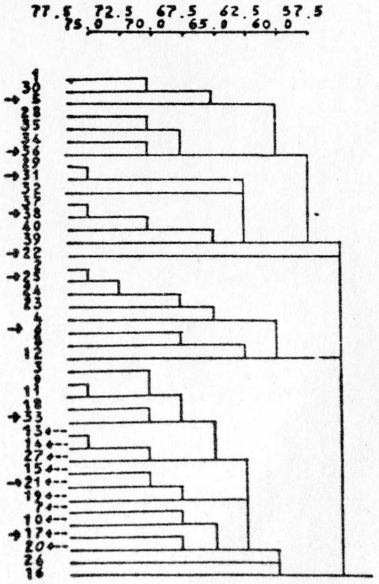
FAM-07



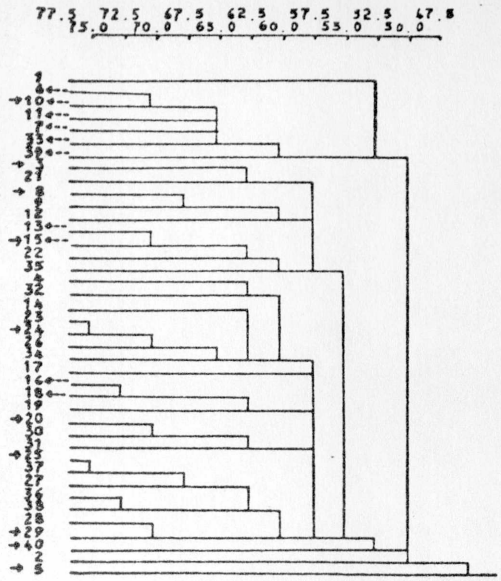
FAM-08



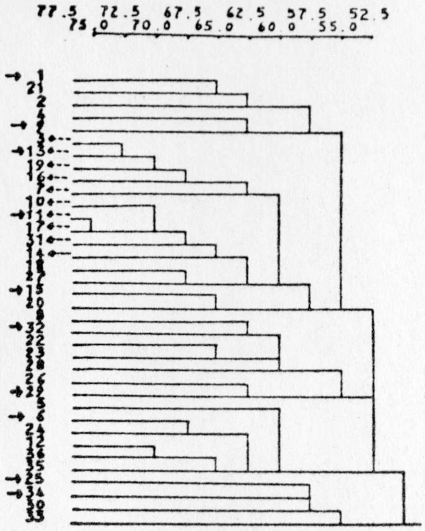
FAM-09



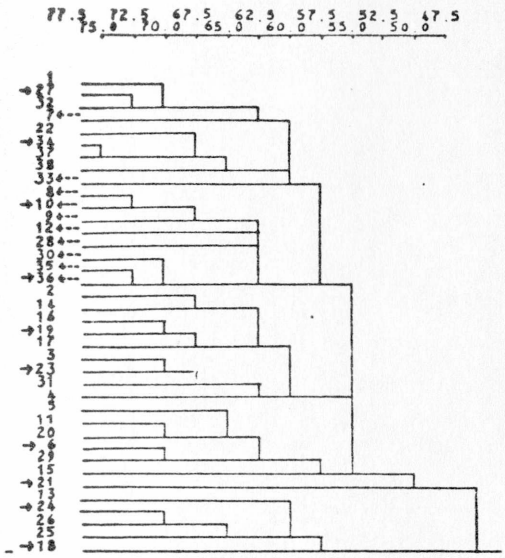
FAM-10



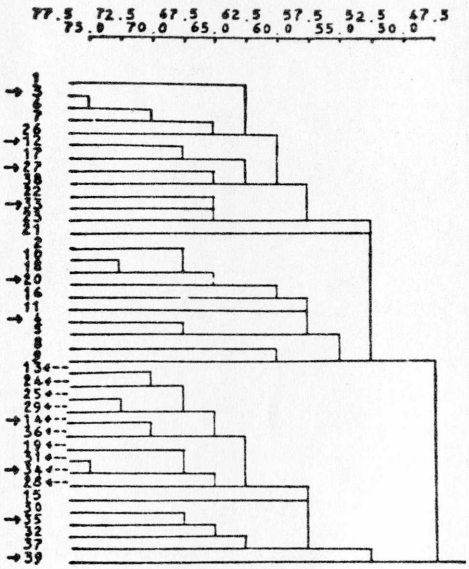

FAM-11



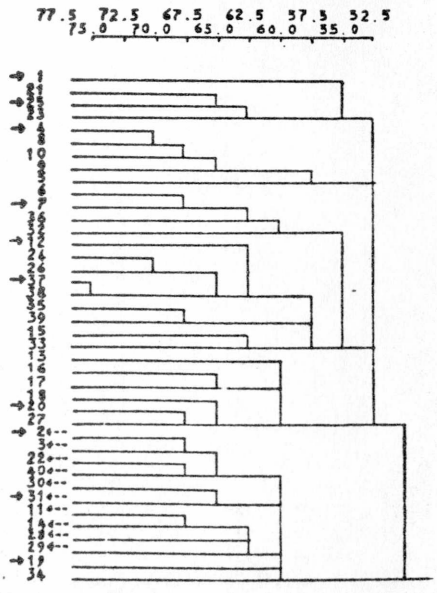

FAM-12



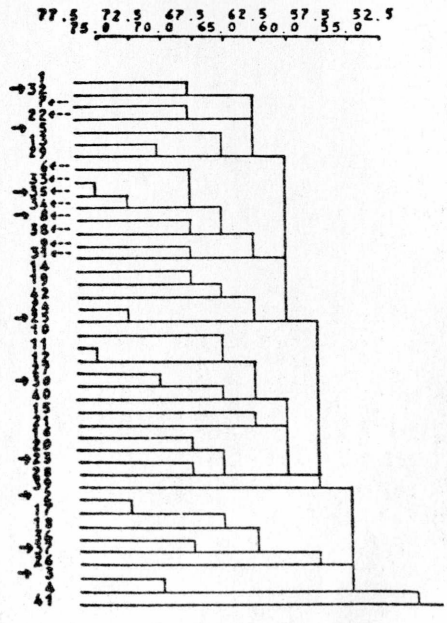

FAM-13




FAM-14




FAM-15




FAM-16

The three methods, namely, PCO, average linkage analysis and "REGROUP", together with the MST superimposed onto the PCO scatter diagram can therefore be used in the search for a more "natural" classification.

PCO is often used in the search for clusters. Usually well defined taxa will stand out quite clearly as clusters of points separated by empty spaces in between. However, when the data are not clear cut no definite clusters will be formed. In this situation, it seemed that it might be possible to divide the scatter of points into sectors of the total distribution as the analysis indicated. This will be tested and discussed further in the next section, where all the hybrids will be analysed together.

It is rather surprising to see that clusters did form in some families (c.f. FAM-03, FAM-05 and FAM-10) even though they were all single crosses. Were these clusters 'natural' or were they the artifacts of the analytical methods? Considering the number of characters used (99 characters) there may be indication of 'real' clusters. This will be discussed further in the next section. If the clusters formed were genuine they may be attributed to the segregation of 'blocks' of linked genes. In the field FAM-05 clearly produced two types of individuals, one that was extremely vigorous and the other weak.

FAM-06, 702151 x 700042 and FAM-07, HJT 5457 x OCH 6401 were both from crosses between typical S. stenotomum and typical

S. goniocalyx, "Papa Amarilla" in the first cross. There was no clustering in either case. Can this be explained as a cross between two good species, thus giving rise to a single homogeneous $F_1$ population? All the other crosses may be between the different natural "hybrid" forms, because the progenies were segregating already, even though they were undoubtedly all $F_1$ generations.

The contribution of the characters to the different vectors of the PCO analysis can be interpreted from the pseudo-F values calculated using procedure "RELATE". The pseudo-F values are not to be compared with those of the standard statistical F-value table to indicate any significant contribution but instead the rule of thumb is to consider any value greater than ten as an indication of having some significant contribution (Dr. G. J. S. Ross, personal communication).

Those values greater than ten are presented in Appendix VI . Most of the characters did not load well (i.e. did not contribute significantly) in all the first ten vectors presented except for the following characters. They were shape of tuber (8), length of tuber (24), plant height (31), diameter of stem (34), intensity of stem pigmentation (40), glossiness of primary leaflet (50), intensity of pigmentation of the upper surface of the rachis (59), intensity of nodal pigmentation of leaf (61), length of leaf (65), width of leaf (66), distance from the base to the widest part of leaf (67), number of secondary lateral leaflets (70), number of tertiary lateral leaflets (71), number of acroscopic leaflets (72), number of basiscopic leaflets (73), number of secondary lateral leaflets on the terminal petiolule (75), length of terminal petiolule (86), length of

terminal lamina (87), width of terminal lamina (88), distance from base to the widest part of the terminal leaflet (89), length of the first petiolule (90), length of the first latéral lamina (91), width of the first lateral lamina (92), distance from the base to the widest part of the first lateral lamina (93), distance of the rachis between the first and second pair of lateral leaflets (94), length of the largest secondary leaflet (96), width of the largest secondary leaflet (97), distance from base to the widest part of the secondary leaflet (98) and length of the longest petiolule (99).

This indicates the poor discriminating value of most of the characters used. This may be due to the poor correlation between most of these characters. It is also noted that most of those values that were greater than ten were meristic and continuous characters and they tended to accumulate in the first five vectors. This may appear to be the functioning of the "size" factor and "density" factor. Examples of this type of relationship are that between character numbers (91), (92), (93) and (94) and that between character numbers (96), (97), (98) and (99). Also, the "loadings" of each axis were different for different families. This indicates that the relative importance of a character was different for different families and therefore underlines the necessity of employing all possible characters available.

### 4.4.4.2. Analysis of the sixteen hybrid families together

#### 4.4.4.2.1. Materials

A complete analysis of all the individuals of the sixteen families together will have a matrix of 638 x 99 which is far too big for CLASP or CLUSTAN 1A to handle. It was therefore decided to sample some individuals from each family to be analysed further together.

Two samples were taken. One was composed of the ten "more alike" individuals from each family (SAMPLE-I) and the other was the ten "more different" individuals (SAMPLE-II). The similarity and dissimilarity of these individuals were judged arbitrarily by taking the results of the PCO analysis, MST, "REGROUP", average linkage analysis, single linkage analysis and the nearest neighbours list into consideration. They were shown in Fig. 4.2 and Fig. 4.4 by an arrow (⟶) for the "more alike" individuals and a broken arrow (---→) for the "more different" individuals.

There were 160 individuals altogether for each sample. The individuals selected are shown in Table 4.5.

SAMPLE I ("More alike")

| | CLONES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| FAM-01 | 4 | 5 | 12 | 16 | 18 | 21 | 22 | 34 | 38 | 40 |
| FAM-02 | 5 | 8 | 12 | 15 | 18 | 19 | 26 | 29 | 36 | 37 |
| FAM-03 | 1 | 2 | 3 | 4 | 6 | 7 | 9 | 10 | 20 | 42 |
| FAM-04 | 2 | 3 | 5 | 14 | 16 | 17 | 18 | 24 | 25 | 26 |
| FAM-05 | 9 | 14 | 19 | 21 | 24 | 28 | 29 | 33 | 36 | 37 |
| FAM-06 | 7 | 25 | 26 | 27 | 29 | 30 | 32 | 33 | 34 | 35 |
| FAM-07 | 2 | 3 | 6 | 7 | 12 | 15 | 18 | 21 | 22 | 26 |
| FAM-08 | 3 | 4 | 9 | 12 | 19 | 30 | 37 | 38 | 39 | 40 |
| FAM-09 | 10 | 14 | 18 | 21 | 33 | 34 | 35 | 38 | 39 | 41 |
| FAM-10 | 7 | 10 | 13 | 14 | 15 | 17 | 19 | 20 | 21 | 27 |
| FAM-11 | 6 | 7 | 10 | 11 | 13 | 15 | 16 | 18 | 33 | 39 |
| FAM-12 | 3 | 7 | 10 | 11 | 13 | 14 | 16 | 17 | 19 | 31 |
| FAM-13 | 7 | 8 | 9 | 10 | 12 | 28 | 30 | 33 | 35 | 36 |
| FAM-14 | 13 | 14 | 19 | 24 | 25 | 28 | 29 | 31 | 34 | 36 |
| FAM-15 | 2 | 3 | 11 | 14 | 22 | 28 | 29 | 30 | 31 | 40 |
| FAM-16 | 6 | 7 | 8 | 9 | 22 | 31 | 33 | 34 | 35 | 38 |

SAMPLE II ("More different")

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| FAM-01 | 2 | 7 | 10 | 16 | 19 | 22 | 23 | 30 | 34 | 37 |
| FAM-02 | 1 | 7 | 8 | 12 | 14 | 22 | 27 | 31 | 35 | 40 |
| FAM-03 | 3 | 4 | 8 | 18 | 24 | 25 | 28 | 34 | 39 | 40 |
| FAM-04 | 6 | 7 | 9 | 16 | 21 | 22 | 24 | 25 | 31 | 34 |
| FAM-05 | 1 | 6 | 14 | 16 | 21 | 25 | 30 | 31 | 36 | 38 |
| FAM-06 | 2 | 5 | 8 | 19 | 20 | 29 | 35 | 36 | 37 | 41 |
| FAM-07 | 3 | 5 | 6 | 16 | 24 | 29 | 31 | 34 | 38 | 40 |
| FAM-08 | 3 | 6 | 8 | 15 | 23 | 24 | 29 | 35 | 36 | 39 |
| FAM-09 | 2 | 6 | 8 | 9 | 20 | 24 | 27 | 33 | 34 | 36 |
| FAM-10 | 5 | 6 | 17 | 21 | 22 | 25 | 31 | 33 | 36 | 38 |
| FAM-11 | 3 | 5 | 8 | 10 | 15 | 20 | 24 | 25 | 29 | 40 |
| FAM-12 | 1 | 6 | 9 | 11 | 13 | 15 | 25 | 29 | 32 | 34 |
| FAM-13 | 6 | 10 | 18 | 19 | 21 | 23 | 24 | 27 | 34 | 36 |
| FAM-14 | 3 | 4 | 12 | 14 | 20 | 27 | 33 | 34 | 35 | 39 |
| FAM-15 | 1 | 2 | 4 | 7 | 12 | 19 | 20 | 25 | 31 | 37 |
| FAM-16 | 2 | 3 | 5 | 8 | 23 | 25 | 30 | 32 | 35 | 37 |

TABLE 4.5: Clones of SAMPLE I and SAMPLE II.

4.4.4.2.2. Numerical analysis

Both samples were subjected to a complete analysis using CLASP as in the previous section, using the standard similarity coefficient in CLASP. This included PCO, MST, single linkage clustering, average linkage clustering, nearest neighbours list, "REGROUP" and "RELATE". In addition, another set of analyses was done by converting all the characters into continuous type and then using Euclidean distance to measure the resemblance. Principal component analysis and clustering using Euclidean distance and Ward's sorting technique were done also using CLUSTAN 1A. Since PCA was carried out using mixed-mode data (i.e. including nominal data type) the result obtained should be at the most used for comparison with the other analyses only and not for drawing a conclusion by itself.

Analyses were also done using the tuber characters, plant habit, stem and fresh leaf characters, and leaf herbarium characters separately to test the stability of the results and to see how they related to the full analysis.

4.4.4.2.3. Results and discussion

Nearest neighbours list

Normally, the nearest neighbours list provides us with a list of the immediate neighbours of an individual in the order of their similarities. However, in this particular study, since there

were ten individuals to a family therefore with a nearest neighbours list of the first eight closest neighbours a sample of 80 neighbours was available for counting for each family. These 80 neighbours of each family can thus be categorised according to their families as shown in Table 4.6 to show the degree of similarity between the studied family with the other families. This may in a way show the degree of relationship between the different families.

No attempt was made to test the number of nearest neighbours required in order to arrive at a stable relationship. Here, eight were chosen for convenience in the counting of individuals in the computer printout for this list.

The results in Table 4.6 (a) and (b) were very similar to each other and this is the same for Table 4.6(c) and (d). These showed that the conversion of all the characters into continuous type and then the application of Euclidean distance did not change the results significantly.

In SAMPLE-I (Table 4.6(a) and (b)), members of a family were always more similar to each other than those of another family. FAM-01 appeared to have a reasonable similarity with FAM-06, and the reciprocal was also true. This may indicate some relationship between these two families. Other paired relationships were FAM-02 and FAM-16, FAM-08 and FAM-13, and FAM-10 and FAM-11.

TABLE 4.6: Summary of the number of individuals from different families that formed the eight most similar individuals to each of the ten individuals of the studied family.

(a) SAMPLE-I - using mixed-mode data and standard similarity coefficient

| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 53 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 2 | 1 | 33 | 0 | 2 | 7 | 0 | 1 | 4 | 0 | 1 | 4 | 1 | 2 | 2 | 3 | 19 |
| 3 | 1 | 0 | 69 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 1 |
| 4 | 0 | 0 | 0 | 58 | 6 | 0 | 0 | 4 | 0 | 1 | 0 | 1 | 6 | 2 | 2 | 0 |
| 5 | 0 | 0 | 0 | 6 | 65 | 2 | 1 | 3 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 6 | 20 | 0 | 0 | 0 | 1 | 58 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 4 | 1 | 0 | 1 | 1 | 3 | 54 | 4 | 0 | 4 | 1 | 2 | 4 | 1 | 0 | 0 |
| 8 | 0 | 1 | 0 | 10 | 3 | 1 | 3 | 29 | 0 | 2 | 1 | 1 | 27 | 1 | 0 | 1 |
| 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 60 | 0 | 0 | 8 | 1 | 0 | 9 | 1 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 57 | 12 | 3 | 3 | 1 | 1 | 0 |
| 11 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 17 | 43 | 9 | 0 | 0 | 2 | 2 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 1 | 4 | 59 | 1 | 0 | 7 | 1 |
| 13 | 1 | 0 | 0 | 4 | 5 | 0 | 4 | 22 | 1 | 5 | 0 | 1 | 35 | 0 | 1 | 1 |
| 14 | 0 | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 3 | 63 | 1 | 0 |
| 15 | 1 | 6 | 1 | 2 | 0 | 0 | 1 | 0 | 8 | 0 | 0 | 9 | 2 | 0 | 44 | 6 |
| 16 | 0 | 9 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 3 | 1 | 4 | 0 | 2 | 57 |

(b) SAMPLE-I - data converted to continuous type and using Euclidean distance

| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 50 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| 2 | 1 | 41 | 0 | 1 | 6 | 1 | 1 | 2 | 0 | 4 | 4 | 0 | 3 | 1 | 0 | 15 |
| 3 | 0 | 0 | 72 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 0 |
| 4 | 0 | 0 | 0 | 56 | 6 | 0 | 2 | 6 | 0 | 1 | 0 | 1 | 5 | 1 | 2 | 0 |
| 5 | 0 | 0 | 0 | 6 | 65 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 6 | 13 | 0 | 0 | 0 | 5 | 60 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 2 | 0 | 0 | 0 | 5 | 4 | 52 | 6 | 0 | 5 | 2 | 0 | 4 | 0 | 0 | 0 |
| 8 | 1 | 0 | 0 | 7 | 3 | 0 | 6 | 30 | 0 | 3 | 0 | 5 | 24 | 1 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 51 | 0 | 0 | 8 | 2 | 0 | 17 | 1 |
| 10 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 58 | 11 | 1 | 2 | 4 | 0 | 0 |
| 11 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 20 | 43 | 10 | 0 | 0 | 1 | 1 |
| 12 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 6 | 1 | 2 | 58 | 2 | 0 | 7 | 0 |
| 13 | 2 | 0 | 0 | 1 | 5 | 1 | 5 | 18 | 2 | 4 | 0 | 2 | 35 | 1 | 3 | 1 |
| 14 | 0 | 1 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 6 | 0 | 0 | 2 | 64 | 1 | 0 |
| 15 | 0 | 3 | 1 | 0 | 0 | 0 | 1 | 0 | 9 | 0 | 1 | 10 | 1 | 0 | 51 | 3 |
| 16 | 0 | 11 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 3 | 2 | 1 | 4 | 55 |

(c) SAMPLE-II - using mixed-mode data and standard similarity coefficient

| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 18 | 7 | 5 | 1 | 6 | 16 | 1 | 0 | 1 | 7 | 10 | 2 | 1 | 1 | 4 | 0 |
| 2 | 7 | 8 | 4 | 0 | 14 | 2 | 2 | 2 | 0 | 3 | 10 | 4 | 6 | 6 | 1 | 11 |
| 3 | 0 | 2 | 39 | 1 | 4 | 0 | 8 | 7 | 0 | 13 | 5 | 0 | 1 | 3 | 3 | 4 |
| 4 | 1 | 1 | 3 | 27 | 4 | 1 | 4 | 15 | 0 | 2 | 0 | 1 | 7 | 4 | 10 | 0 |
| 5 | 5 | 10 | 2 | 2 | 30 | 2 | 4 | 3 | 0 | 4 | 3 | 2 | 5 | 5 | 1 | 2 |
| 6 | 10 | 0 | 1 | 0 | 2 | 33 | 8 | 3 | 0 | 5 | 8 | 4 | 2 | 1 | 2 | 1 |
| 7 | 4 | 2 | 1 | 4 | 7 | 6 | 20 | 4 | 1 | 5 | 6 | 4 | 5 | 1 | 9 | 1 |
| 8 | 0 | 4 | 3 | 6 | 2 | 3 | 6 | 18 | 1 | 2 | 4 | 10 | 11 | 2 | 7 | 1 |
| 9 | 1 | 2 | 0 | 1 | 4 | 0 | 1 | 2 | 40 | 2 | 1 | 11 | 8 | 2 | 4 | 1 |
| 10 | 3 | 3 | 12 | 1 | 6 | 4 | 4 | 2 | 0 | 26 | 7 | 6 | 1 | 1 | 1 | 3 |
| 11 | 8 | 7 | 11 | 0 | 1 | 4 | 2 | 3 | 0 | 14 | 18 | 2 | 3 | 1 | 3 | 3 |
| 12 | 2 | 2 | 3 | 3 | 4 | 5 | 2 | 10 | 5 | 6 | 3 | 20 | 7 | 1 | 5 | 2 |
| 13 | 3 | 1 | 0 | 5 | 6 | 2 | 0 | 9 | 4 | 1 | 4 | 6 | 23 | 7 | 9 | 0 |
| 14 | 6 | 11 | 3 | 2 | 10 | 3 | 1 | 2 | 1 | 3 | 1 | 2 | 9 | 19 | 1 | 6 |
| 15 | 3 | 2 | 6 | 0 | 2 | 3 | 10 | 6 | 3 | 4 | 4 | 4 | 9 | 2 | 18 | 4 |
| 16 | 0 | 14 | 4 | 0 | 0 | 2 | 0 | 1 | 0 | 7 | 3 | 2 | 1 | 6 | 4 | 36 |

(d) SAMPLE-II - data converted to continuous type and using Euclidean distance.

| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 8 | 3 | 0 | 7 | 13 | 2 | 1 | 0 | 9 | 14 | 5 | 1 | 3 | 1 | 1 |
| 2 | 7 | 5 | 4 | 0 | 16 | 2 | 3 | 1 | 0 | 5 | 12 | 2 | 5 | 4 | 1 | 13 |
| 3 | 2 | 3 | 39 | 2 | 2 | 0 | 4 | 1 | 0 | 8 | 6 | 4 | 2 | 1 | 3 | 3 |
| 4 | 2 | 0 | 0 | 24 | 4 | 3 | 3 | 15 | 2 | 2 | 0 | 6 | 7 | 4 | 8 | 0 |
| 5 | 6 | 10 | 3 | 0 | 28 | 1 | 3 | 2 | 0 | 2 | 4 | 3 | 8 | 6 | 1 | 3 |
| 6 | 12 | 2 | 0 | 2 | 2 | 28 | 5 | 4 | 0 | 3 | 6 | 7 | 6 | 3 | 0 | 0 |
| 7 | 3 | 2 | 5 | 1 | 1 | 5 | 28 | 5 | 0 | 5 | 7 | 7 | 7 | 1 | 3 | 0 |
| 8 | 0 | 1 | 1 | 11 | 0 | 1 | 8 | 24 | 1 | 4 | 2 | 11 | 8 | 3 | 4 | 1 |
| 9 | 2 | 3 | 0 | 3 | 1 | 1 | 1 | 2 | 36 | 0 | 1 | 11 | 9 | 2 | 8 | 0 |
| 10 | 5 | 4 | 8 | 2 | 2 | 3 | 3 | 2 | 0 | 28 | 11 | 7 | 2 | 0 | 2 | 1 |
| 11 | 11 | 12 | 8 | 0 | 2 | 3 | 5 | 2 | 1 | 11 | 17 | 2 | 0 | 2 | 1 | 3 |
| 12 | 4 | 1 | 2 | 7 | 2 | 5 | 6 | 8 | 5 | 7 | 2 | 14 | 10 | 1 | 0 | 6 |
| 13 | 0 | 1 | 1 | 6 | 9 | 10 | 2 | 11 | 5 | 0 | 1 | 3 | 21 | 6 | 4 | 0 |
| 14 | 1 | 12 | 2 | 2 | 11 | 3 | 1 | 2 | 1 | 2 | 3 | 1 | 10 | 24 | 2 | 3 |
| 15 | 3 | 1 | 7 | 7 | 4 | 1 | 5 | 4 | 5 | 5 | 1 | 8 | 9 | 3 | 15 | 2 |
| 16 | 3 | 20 | 4 | 0 | 2 | 0 | 0 | 1 | 3 | 2 | 3 | 1 | 1 | 5 | 2 | 33 |

However, in SAMPLE-II (Table 4.6(c) and (d)) the number of coincidences between members of the same family was relatively small and in two cases, FAM-01 and FAM-02 it was even less than that from another family. The range of occurrence with other families became very wide. In most cases, a family had its members showing similarity to most other families. All these may be an indication of the close relationship between all the parents and therefore the diploid population. However, the relationship between FAM-01 and FAM-06 (plus the reciprocal) and FAM-16 and FAM-02 (but not so much the reciprocal) still showed up. In addition, several not so definite groupings were formed. They were between FAM-01, FAM-06 and FAM-11; between FAM-02, FAM-05, FAM-11 and FAM-16; between FAM-03 and FAM-10; between FAM-04, FAM-08 and FAM-15; between FAM-05 and FAM-02; between FAM-08, FAM-04, FAM-12 and FAM-13; between FAM-09 and FAM-12; between FAM-10, FAM-03 and FAM-11; between FAM-11, FAM-01, FAM-02, FAM-03 and FAM-10; between FAM-12, FAM-08 and FAM-13; between FAM-13 and FAM-08; FAM-14, FAM-02, FAM-05 and FAM-13; and between FAM-15 and FAM-07.

The result to a certain extent conveys some idea of genetic relationships between the different families. For example, FAM-01 and FAM-06 both have a parent in common, 702151, and showed considerable overlap of similar morphotypes (Table 4.6 (a) and (b)). This is also true to a lesser extent for FAM-09, FAM-12, FAM-13 and FAM-15 where the common parent was OCH 5422. However, this is not so for FAM-04 and FAM-07, FAM-07 and FAM-11, and FAM-08 and FAM-12 where the common parents were OCH 6401, HJT 5457 and CUP 140 respectively. The discrepancy may be due to the nature of the parents used, whether

they are a more or less distinct type and therefore more homozygous, or natural "hybrids" which then show segregation due to parental heterozygosity.

The result of this grouping technique may provide us with a reasonable "natural" relationship between families when the number of nearest neighbours used is big enough, because it is based on the direct similarity between individuals. In this way it is related to single linkage clustering and MST.

"REGROUP" (A technique that maximises the within-group similarity)

The results are presented below in Table 4.7.

TABLE 4.7: Results of the "REGROUP" analysis.

SAMPLE-I: - using mixed-mode data and standard similarity coefficient.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 | - | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| | | 71 | | | | | | | | | |
| Group 2 | - | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| | | 102 | 103 | 108 | 121 | | | | | | |
| Group 3 | - | 75 | 101 | 104 | 105 | 107 | 109 | 110 | 111 | 112 | 113 |
| | | 114 | 115 | 116 | 117 | 118 | 119 | 120 | | | |
| Group 4 | - | 13 | 14 | 15 | 16 | 17 | 19 | 20 | 106 | 146 | 151 |
| | | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | | |
| Group 5 | - | 23 | 73 | 74 | 76 | 122 | 123 | 124 | 125 | 127 | 131 |
| | | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 152 |
| Group 6 | - | 11 | 12 | 18 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| | | 48 | 49 | 50 | | | | | | | |
| Group 7 | - | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| | | 72 | 77 | 78 | 79 | 80 | 126 | 128 | 129 | 130 | |
| Group 8 | - | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| Group 9 | - | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
| | | 141 | 142 | 143 | 144 | 145 | 147 | 148 | 149 | 150 | |
| Group 10 | - | 21 | 22 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |

SAMPLE-I - data converted to continuous type and using Euclidean distance.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 - | 75 | 101 | 104 | 105 | 107 | 109 | 110 | 111 | 112 | 113 |
| | 114 | 115 | 116 | 117 | 118 | 119 | 120 | | | |
| Group 2 - | 12 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| | 50 | | | | | | | | | |
| Group 3 - | 25 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 |
| | 140 | | | | | | | | | |
| Group 4 - | 11 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 106 |
| | 151 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | |
| Group 5 - | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| Group 6 - | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| | 71 | 73 | 74 | 76 | 122 | 123 | 124 | 125 | 127 | 152 |
| Group 7 - | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| | 72 | 77 | 78 | 79 | 80 | 121 | 126 | 128 | 129 | 130 |
| Group 8 - | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| Group 9 - | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
| | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 |
| Group 10 - | 21 | 22 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |

SAMPLE-II - using mixed-mode data and standard similarity coefficient.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 - | 2 | 3 | 14 | 44 | 92 | 93 | 101 | 102 | 103 | 105 |
| | 107 | 109 | 110 | 145 | 155 | | | | | |
| Group 2 - | 24 | 55 | 61 | 63 | 64 | 70 | 80 | 94 | 95 | 98 |
| Group 3 - | 33 | 34 | 35 | 37 | 38 | 40 | 46 | 71 | 78 | 79 |
| | 113 | 121 | 122 | 130 | 134 | 141 | 144 | 148 | | |
| Group 4 - | 31 | 32 | 36 | 39 | 75 | 76 | 123 | 131 | 132 | |
| Group 5 - | 7 | 8 | 13 | 15 | 20 | 42 | 43 | 45 | 47 | 49 |
| | 50 | 85 | 99 | 100 | 120 | 125 | 128 | 136 | 137 | 139 |
| | 140 | 143 | | | | | | | | |
| Group 6 - | 6 | 16 | 17 | 18 | 19 | 41 | 48 | 51 | 73 | 133 |
| | 135 | 138 | 151 | 152 | 153 | 156 | 157 | 158 | 160 | |
| Group 7 - | 21 | 74 | 77 | 108 | 112 | 118 | 124 | 126 | 127 | 129 |
| Group 8 - | 1 | 4 | 5 | 9 | 11 | 52 | 53 | 54 | 56 | 57 |
| | 58 | 59 | 60 | 62 | 66 | 91 | 106 | 147 | | |
| Group 9 - | 72 | 81 | 82 | 83 | 84 | 86 | 87 | 88 | 89 | 90 |
| | 111 | 114 | 115 | 116 | 117 | 142 | 146 | 149 | 154 | |
| Group 10 - | 10 | 12 | 22 | 23 | 25 | 26 | 27 | 28 | 29 | 30 |
| | 65 | 67 | 68 | 69 | 96 | 97 | 104 | 119 | 150 | 159 |

SAMPLE-II - data converted to continuous type and using Euclidean distance.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 | - | 15 | 18 | 33 | 44 | 87 | 102 | 103 | 105 | 107 | 109 |
| | | 121 | 145 | 152 | | | | | | | |
| Group 2 | - | 5 | 63 | 64 | 70 | 80 | 94 | 95 | 110 | 135 | |
| Group 3 | - | 34 | 37 | 38 | 40 | 55 | 71 | 73 | 79 | 113 | 144 |
| Group 4 | - | 10 | 27 | 29 | 35 | 45 | 46 | 67 | 68 | 69 | 96 |
| | | 100 | 112 | 114 | 115 | 117 | 119 | 120 | 129 | 130 | 134 |
| | | 148 | 150 | | | | | | | | |
| Group 5 | - | 6 | 7 | 12 | 14 | 16 | 17 | 19 | 41 | 48 | 108 |
| | | 151 | 153 | 155 | 156 | 157 | 160 | | | | |
| Group 6 | - | 8 | 13 | 20 | 21 | 42 | 43 | 47 | 49 | 50 | 85 |
| | | 125 | 128 | 133 | 136 | 137 | 138 | 139 | 140 | 141 | 143 |
| Group 7 | - | 31 | 32 | 36 | 39 | 61 | 74 | 75 | 76 | 77 | 78 |
| | | 118 | 122 | 123 | 124 | 126 | 127 | 131 | 132 | 158 | |
| Group 8 | - | 1 | 4 | 9 | 11 | 51 | 52 | 53 | 54 | 56 | 57 |
| | | 58 | 59 | 60 | 62 | 66 | 91 | 99 | 106 | 147 | |
| Group 9 | - | 2 | 22 | 23 | 24 | 25 | 26 | 28 | 30 | 65 | 92 |
| | | 93 | 97 | 98 | 101 | 104 | | | | | |
| Group 10 | - | 3 | 72 | 81 | 82 | 83 | 84 | 86 | 88 | 89 | 90 |
| | | 111 | 116 | 142 | 146 | 149 | 154 | 159 | | | |

TABLE 4.8: Summary of the analysis "REGROUP" showing the family composition of each group.

(a) SAMPLE-I - using mixed-mode data and standard similarity coefficient.

| Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | - | - | - | - | 10 | - | - | - | - | - | - | - | - | - | - |
| 2 | - | 7 | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 9 |
| 3 | - | 3 | - | - | 10 | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | - | - | 1 | - | - | - | - | 3 | - | - | - | - | 5 | 10 | - | 1 |
| 6 | - | - | - | 10 | - | - | - | 1 | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | 10 | 5 | - | - | - | - | 4 | - | - | - |
| 8 | - | - | - | - | - | - | - | 1 | - | - | 6 | 10 | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - | 10 | - | - | - | - | - | 9 | - |
| 10 | - | - | - | - | - | - | - | - | - | 10 | 3 | - | 1 | - | - | - |

(b) SAMPLE-I - data converted to continuous type and used Euclidean distance

| Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | - | - | - | - | 10 | - | - | - | - | - | - | - | - | - | - |
| 2 | - | 9 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 9 |
| 3 | - | 1 | - | - | 10 | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 10 | - | - |
| 6 | - | - | - | 10 | - | - | - | 4 | - | - | - | - | 5 | - | - | 1 |
| 7 | - | - | - | - | - | - | 10 | 5 | - | - | - | - | 5 | - | - | - |
| 8 | - | - | - | - | - | - | - | 1 | - | - | 6 | 10 | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - | 10 | - | - | - | - | - | 10 | - |
| 10 | - | - | - | - | - | - | - | - | - | 10 | 3 | - | - | - | - | - |

(c) SAMPLE-II - using mixed-mode data and standard similarity coefficient

| Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 1 | - | - | - | 8 | 2 | - | - | 1 | 1 | - | - | - | 1 | - |
| 2 | 2 | 3 | - | - | 6 | - | - | - | 1 | 2 | - | 1 | 2 | 4 | 1 | - |
| 3 | 2 | 1 | - | - | 1 | - | - | - | - | 2 | 7 | - | - | - | 1 | 1 |
| 4 | 1 | 4 | - | - | 2 | 1 | - | 1 | - | - | - | - | - | 3 | - | 7 |
| 5 | 1 | 1 | 8 | - | - | - | 4 | - | - | 2 | 1 | 1 | - | - | 1 | 1 |
| 6 | - | - | 1 | - | - | 1 | 4 | 1 | - | 3 | - | - | - | - | - | - |
| 7 | - | - | 1 | - | - | - | - | 2 | - | - | 1 | 2 | 4 | - | - | - |
| 8 | - | - | - | 6 | 1 | - | - | 3 | - | - | - | 1 | 3 | 1 | 3 | - |
| 9 | - | - | - | 4 | - | - | - | 2 | - | - | - | - | 1 | 2 | - | - |
| 10 | - | - | - | - | - | - | - | 1 | 9 | - | - | 5 | - | - | 3 | 1 |

(d) SAMPLE-II - data converted to continuous type and using Euclidean distance

| | Family composition | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 3 | 1 | - | - | - | 9 | 2 | - | - | 2 | 1 | - | - | - | 1 | - |
| 2 | 2 | 5 | - | - | 2 | - | - | - | - | - | 1 | - | - | - | - | 6 |
| 3 | 1 | 2 | 1 | - | 5 | - | - | - | 1 | - | - | - | 2 | 6 | 2 | - |
| 4 | 1 | - | 7 | - | - | - | 1 | - | - | 4 | 2 | - | - | - | - | - |
| 5 | 1 | - | 2 | 1 | 2 | - | 3 | - | - | 2 | - | 6 | 2 | 1 | 2 | - |
| 6 | 1 | - | - | - | - | - | 3 | 1 | - | 2 | 1 | - | - | 1 | - | - |
| 7 | 1 | - | - | - | - | - | - | 1 | 8 | - | - | 2 | - | - | 3 | 2 |
| 8 | - | 2 | - | 1 | 1 | - | - | - | 1 | - | 5 | - | 1 | - | 1 | 1 |
| 9 | - | - | - | 4 | - | 1 | - | 3 | - | - | - | 1 | - | - | 1 | - |
| 10 | - | - | - | 4 | - | - | 1 | 5 | - | - | - | 1 | 5 | 2 | - | 1 |

The groups formed in Table 4.7 were very consistent for both the similarity coefficients used (standard coefficient and Euclidean distance) in SAMPLE I but very much less so in SAMPLE-II. This is summarised in Table 4.8. Also, individuals of the same family tended to group well in SAMPLE-I but in SAMPLE II multi-family groups were obtained.

As in the nearest neighbours list analysis, FAM-01 and FAM-06 fell into the same group and also between FAM-02 and FAM-16. The grouping of FAM-09 and FAM-15 together is logical because both have OCH 5422 as one of the parents but FAM-12 and FAM-13 both of which have OCH 5422 as one of the parents also, did not in any way seem to be related to FAM-09 and FAM-15 (Table 4.8(a) and (b)). However, they showed some degree of similarity in Table 4.8 (c) and (d). This may be due to the interactions between the different "genomes" (the parents used) and/or maternal effect. The grouping between FAM-08, FAM-13 and FAM-14 (Table 4.8(a)) may be explained because the parents OCH 5546, OCH 5758 and HJT 5493 respectively are all duplicates of the same clone, "Papa Amarilla". The similarity between FAM-07, FAM-08 and FAM-13 can be attributed to the parent OCH 6401, which is a form of S. goniocalyx bearing close similarity with "Papa Amarilla".

Principal coordinate analysis (PCO)

The coordinates of the first four vectors of the PCO analysis are given in Appendix VII . The percentage of variance

accounted for by the first four vectors was very low, in the order of 20-30% only (Table 4.9).

| | vector | | | | Trace (total) |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| SAMPLE-I | | | | | |
| (a) mixed-data & standard co-efficient | 4.394 | 3.596 | 2.991 | 2.736 | 70.380 |
| | 6.2 | 11.4 | 15.6 | 19.5 | 100.0 |
| (b) converted to continuous type & Euclidean dist. | 3.198 | 1.891 | 1.733 | 1.562 | 26.682 |
| | 12.0 | 19.1 | 25.6 | 31.4 | 100.0 |
| SAMPLE-II | | | | | |
| (a) mixed-data & standard co-efficient | 3.811 | 2.945 | 2.799 | 2.688 | 71.053 |
| | 5.4 | 9.5 | 13.4 | 17.2 | 100.0 |
| (b) converted to continuous type & Euclidean dist. | 2.675 | 1.826 | 1.628 | 1.594 | 25.861 |
| | 10.3 | 17.4 | 23.7 | 29.9 | 100.0 |

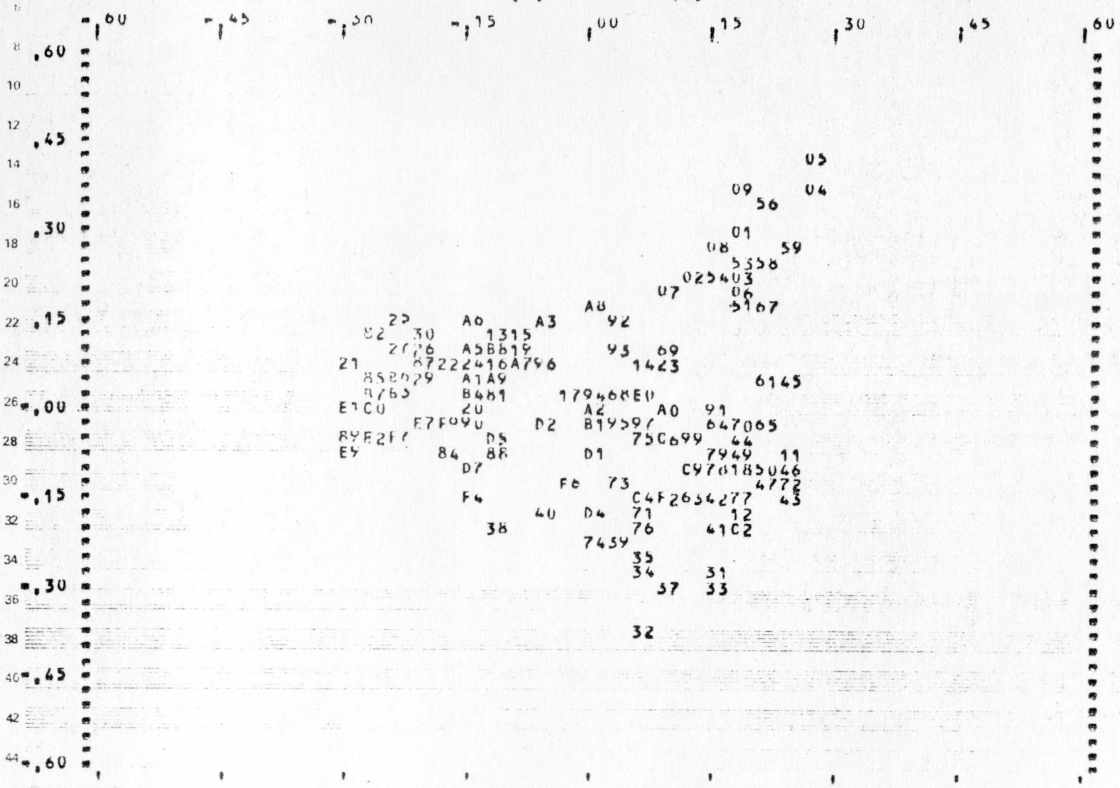
TABLE 4.9: Summary of the PCO analysis showing the values of the first four latent roots, the trace and the cumulative percentage of variance accounted for at each vector.

As already has been discussed in the previous section, the presentation of the results as scatter diagrams (Fig. 4.5) should be interpreted

Fig. 4.5 Scatter diagrams of PCO analysis between vector 1 ( across the page ) and vector 2 ( down the page ) of the sixteen families analysed together using all the characters.

PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2 (a) SAMPLE-I MIXED TYPE + STANDARD COEFFICIENT

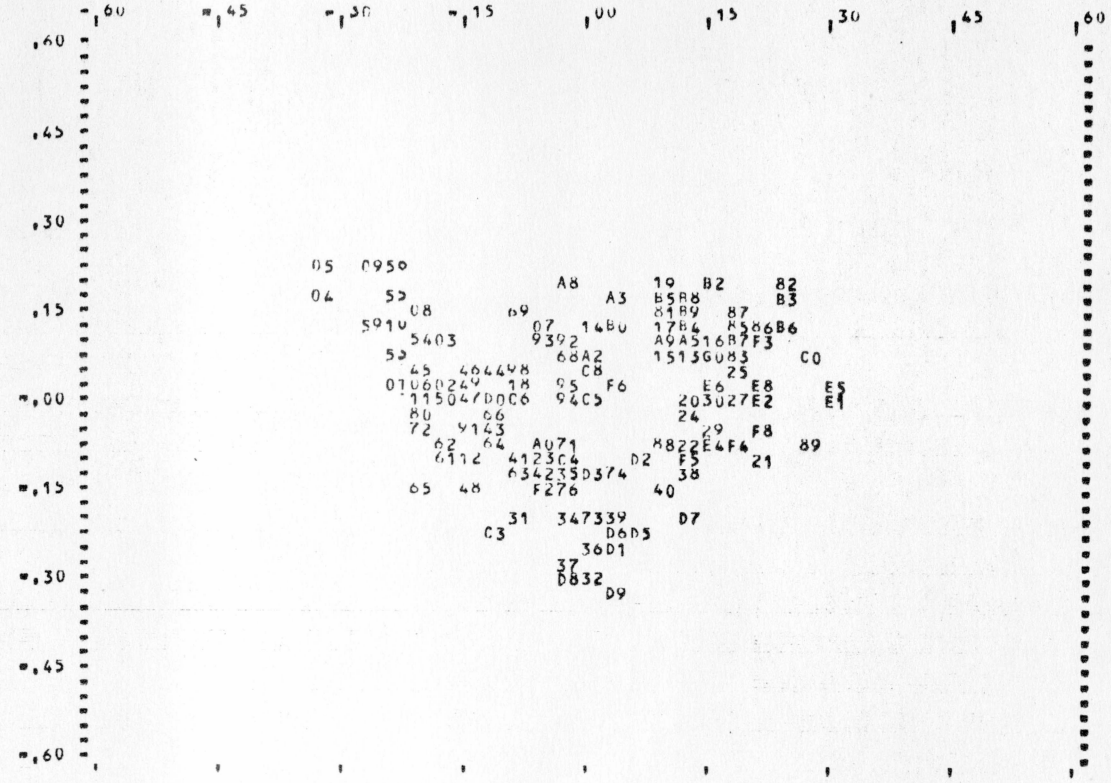
LETTER CODE IS USED FOR UNITS ABOVE 99, F,G, AS MEANS 105




UNIT 10 COINCIDES WITH UNIT 1
UNIT 60 COINCIDES WITH UNIT 1
UNIT 55 COINCIDES WITH UNIT 53
UNIT 52 COINCIDES WITH UNIT 51
UNIT 57 COINCIDES WITH UNIT 51
UNIT 26 COINCIDES WITH UNIT 25
UNIT 86 COINCIDES WITH UNIT 25
UNIT 83 COINCIDES WITH UNIT 27
UNIT 104 COINCIDES WITH UNIT 24
UNIT 110 COINCIDES WITH UNIT 96
UNIT 112 COINCIDES WITH UNIT 37
UNIT 115 COINCIDES WITH UNIT 22
UNIT 146 COINCIDES WITH UNIT 24
UNIT 148 COINCIDES WITH UNIT 22
UNIT 66 COINCIDES WITH UNIT 29
UNIT 143 COINCIDES WITH UNIT 113
UNIT 98 COINCIDES WITH UNIT 91
UNIT 119 COINCIDES WITH UNIT 20
UNIT 128 COINCIDES WITH UNIT 102
UNIT 125 COINCIDES WITH UNIT 95
UNIT 144 COINCIDES WITH UNIT 90
UNIT 135 COINCIDES WITH UNIT 90
UNIT 100 COINCIDES WITH UNIT 90
UNIT 133 COINCIDES WITH UNIT 75
UNIT 145 COINCIDES WITH UNIT 85
UNIT 150 COINCIDES WITH UNIT 86
UNIT 80 COINCIDES WITH UNIT 11
UNIT 121 COINCIDES WITH UNIT 49
UNIT 151 COINCIDES WITH UNIT 84
UNIT 130 COINCIDES WITH UNIT 129
UNIT 158 COINCIDES WITH UNIT 137
UNIT 62 COINCIDES WITH UNIT 47
UNIT 46 COINCIDES WITH UNIT 12
UNIT 136 COINCIDES WITH UNIT 134
UNIT 139 COINCIDES WITH UNIT 134
UNIT 155 COINCIDES WITH UNIT 40
UNIT 143 COINCIDES WITH UNIT 142
UNIT 127 COINCIDES WITH UNIT 76
UNIT 138 COINCIDES WITH UNIT 76
UNIT 36 COINCIDES WITH UNIT 34

PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2 (b) SAMPLE-I CONTINUOUS TYPE + EUCLIDEAN DIST.

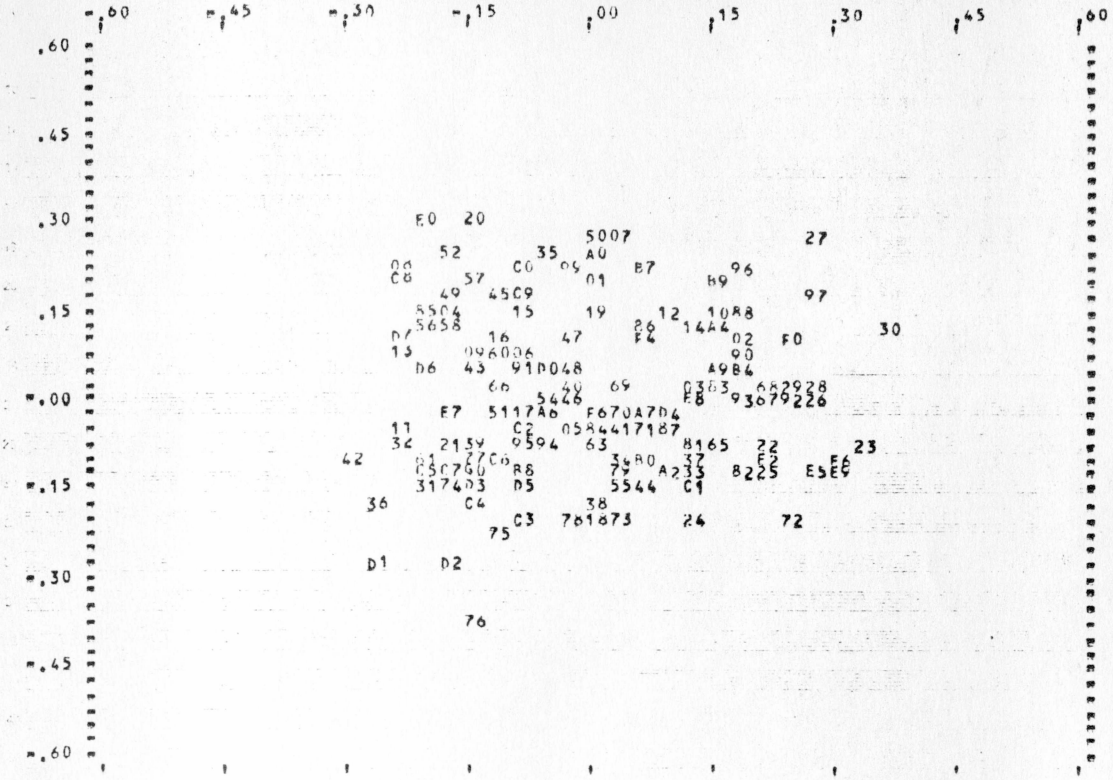
LETTER CODE IS USED FOR UNITS ABOVE 99, E.G, A5 MEANS 105




UNIT 60 COINCIDES WITH UNIT 56
UNIT 58 COINCIDES WITH UNIT 55
UNIT 111 COINCIDES WITH UNIT 103
UNIT 107 COINCIDES WITH UNIT 81
UNIT 101 COINCIDES WITH UNIT 17
UNIT 104 COINCIDES WITH UNIT 17
UNIT 52 COINCIDES WITH UNIT 3
UNIT 106 COINCIDES WITH UNIT 105
UNIT 75 COINCIDES WITH UNIT 68
UNIT 90 COINCIDES WITH UNIT 83
UNIT 96 COINCIDES WITH UNIT 15
UNIT 57 COINCIDES WITH UNIT 45
UNIT 67 COINCIDES WITH UNIT 2
UNIT 150 COINCIDES WITH UNIT 145
UNIT 26 COINCIDES WITH UNIT 20
UNIT 28 COINCIDES WITH UNIT 27
UNIT 51 COINCIDES WITH UNIT 11
UNIT 143 COINCIDES WITH UNIT 142
UNIT 147 COINCIDES WITH UNIT 27
UNIT 151 COINCIDES WITH UNIT 30
UNIT 157 COINCIDES WITH UNIT 142
UNIT 159 COINCIDES WITH UNIT 27
UNIT 70 COINCIDES WITH UNIT 66
UNIT 79 COINCIDES WITH UNIT 66
UNIT 129 COINCIDES WITH UNIT 66
UNIT 78 COINCIDES WITH UNIT 43
UNIT 121 COINCIDES WITH UNIT 91
UNIT 84 COINCIDES WITH UNIT 22
UNIT 140 COINCIDES WITH UNIT 100
UNIT 144 COINCIDES WITH UNIT 89
UNIT 33 COINCIDES WITH UNIT 23
UNIT 97 COINCIDES WITH UNIT 23
UNIT 99 COINCIDES WITH UNIT 41
UNIT 122 COINCIDES WITH UNIT 63
UNIT 127 COINCIDES WITH UNIT 35
UNIT 77 COINCIDES WITH UNIT 48
UNIT 134 COINCIDES WITH UNIT 131

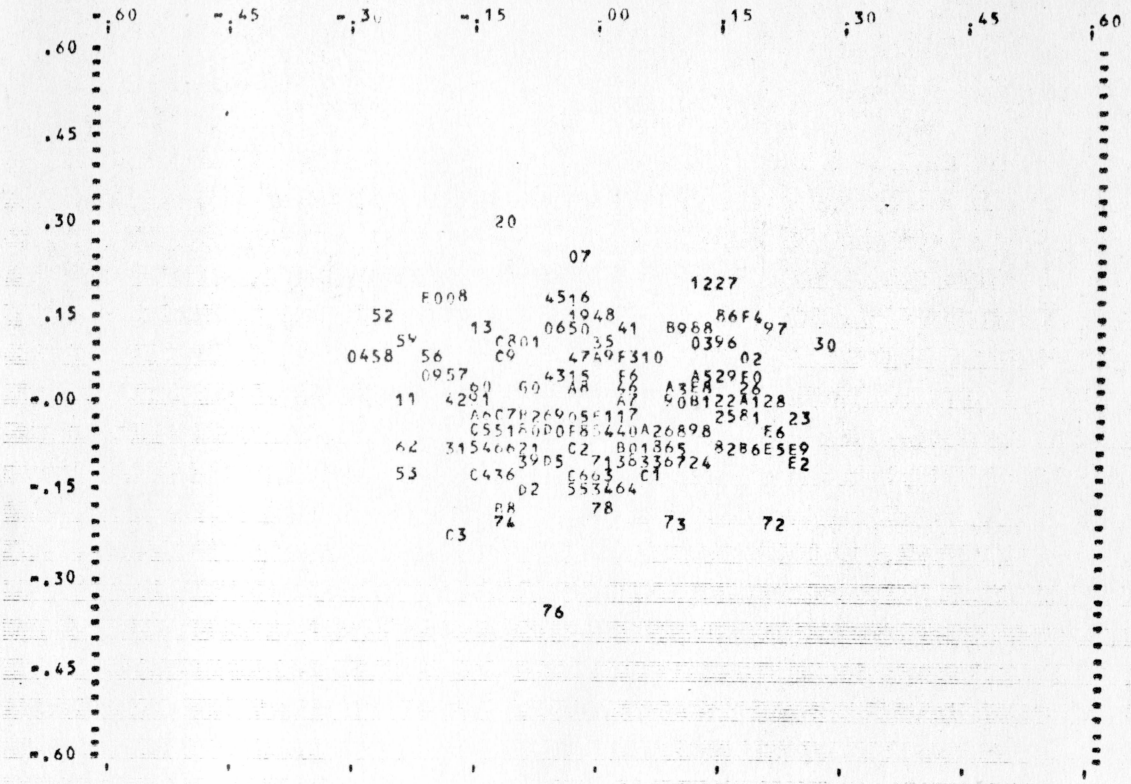
PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2 (c) SAMPLE-II MIXED TYPE + STANDARD COEFFICIENT

LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. AS MEANS 105




UNIT 59 COINCIDES WITH UNIT 57
UNIT 139 COINCIDES WITH UNIT 129
UNIT 143 COINCIDES WITH UNIT 16
UNIT 112 COINCIDES WITH UNIT 6
UNIT 115 COINCIDES WITH UNIT 90
UNIT 157 COINCIDES WITH UNIT 6
UNIT 159 COINCIDES WITH UNIT 90
UNIT 69 COINCIDES WITH UNIT 5
UNIT 105 COINCIDES WITH UNIT 3
UNIT 111 COINCIDES WITH UNIT 58
UNIT 153 COINCIDES WITH UNIT 40
UNIT 108 COINCIDES WITH UNIT 54
UNIT 99 COINCIDES WITH UNIT 93
UNIT 113 COINCIDES WITH UNIT 70
UNIT 144 COINCIDES WITH UNIT 87
UNIT 53 COINCIDES WITH UNIT 21
UNIT 103 COINCIDES WITH UNIT 25
UNIT 116 COINCIDES WITH UNIT 22
UNIT 141 COINCIDES WITH UNIT 94
UNIT 152 COINCIDES WITH UNIT 31
UNIT 158 COINCIDES WITH UNIT 25
UNIT 62 COINCIDES WITH UNIT 61
UNIT 151 COINCIDES WITH UNIT 126
UNIT 98 COINCIDES WITH UNIT 62
UNIT 101 COINCIDES WITH UNIT 25
UNIT 94 COINCIDES WITH UNIT 44
UNIT 138 COINCIDES WITH UNIT 135
UNIT 155 COINCIDES WITH UNIT 121

PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2 (d) SAMPLE-II CONTINUOUS TYPE + EUCLIDEAN DIST.
LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. AS MEANS 105




UNIT 14 COINCIDES WITH UNIT 12
UNIT 120 COINCIDES WITH UNIT 16
UNIT 100 COINCIDES WITH UNIT 19
UNIT 40 COINCIDES WITH UNIT 13
UNIT 65 COINCIDES WITH UNIT 13
UNIT 98 COINCIDES WITH UNIT 8
UNIT 130 COINCIDES WITH UNIT 6
UNIT 157 COINCIDES WITH UNIT 50
UNIT 104 COINCIDES WITH UNIT 3
UNIT 136 COINCIDES WITH UNIT 1
UNIT 117 COINCIDES WITH UNIT 109
UNIT 134 COINCIDES WITH UNIT 10
UNIT 137 COINCIDES WITH UNIT 129
UNIT 183 COINCIDES WITH UNIT 47
UNIT 150 COINCIDES WITH UNIT 2
UNIT 83 COINCIDES WITH UNIT 29
UNIT 151 COINCIDES WITH UNIT 15
UNIT 89 COINCIDES WITH UNIT 26
UNIT 82 COINCIDES WITH UNIT 58
UNIT 115 COINCIDES WITH UNIT 103
UNIT 93 COINCIDES WITH UNIT 22
UNIT 114 COINCIDES WITH UNIT 23
UNIT 147 COINCIDES WITH UNIT 64
UNIT 70 COINCIDES WITH UNIT 69
UNIT 155 COINCIDES WITH UNIT 25
UNIT 94 COINCIDES WITH UNIT 84
UNIT 113 COINCIDES WITH UNIT 60
UNIT 133 COINCIDES WITH UNIT 84
UNIT 138 COINCIDES WITH UNIT 84
UNIT 32 COINCIDES WITH UNIT 31
UNIT 44 COINCIDES WITH UNIT 18
UNIT 152 COINCIDES WITH UNIT 82
UNIT 37 COINCIDES WITH UNIT 24
UNIT 70 COINCIDES WITH UNIT 67
UNIT 87 COINCIDES WITH UNIT 78
UNIT 95 COINCIDES WITH UNIT 32
UNIT 144 COINCIDES WITH UNIT 33
UNIT 61 COINCIDES WITH UNIT 36
UNIT 77 COINCIDES WITH UNIT 86
UNIT 75 COINCIDES WITH UNIT 74

with caution. However, the coordinates of the first four vectors appeared to a certain extent to follow a trend for each individual family (Appendix VII ). If this is to be extended to even higher vectors then the scatter diagrams may convey some significant information.

No cluster was detected except perhaps that of SAMPLE-I between vector 1 and vector 2 (Fig. 4.5(a)) but sectors of very similar grouping of families showed up as for the nearest neighbours list analysis and "REGROUP". The scatter diagram of SAMPLE-II between vector 1 and vector 2 (Fig. 4.5(c)), as in the nearest neighbours list analysis and "REGROUP", did not show any grouping between individuals of the same family at all.

No attempt was made to do a cluster analysis on the vector scores because the first four vectors accounted for only 20-30% of the total variance. The working space of CLASP is too small for more vectors to be extracted.

There is quite a significant difference in the trace between the use of the standard coefficient and the use of Euclidean distance. They were around 70 and 26 respectively (Table 4.9). This difference was, mainly, due to the conversion of nominal data type (disordered multistate data) to that of continuous type resulting in a significant reduction in variability of the original data. Comparing the trace using the standard similarity coefficient with that when each family was analysed separately (Table 4.2), which had an average of

around 16 only, showed a significant increase in data variability in SAMPLE-I and SAMPLE-II. This is as expected.

PCA - principal components analysis

As in PCO, the eigenvalues were proportionately small and the percentage of variance accounted for was very low. Table 4.10 shows the eigenvalues and the percentage of cumulative variance accounted for by the first ten principal components.

In SAMPLE-I, the first component had all the positive values, the second mostly negative and the third again positive. No scatter diagrams were plotted. As for SAMPLE II, the component scores were even more orderly. It is therefore impossible to interpret the results. The first four component scores are presented in Appendix VIII.

Average linkage clustering

As was mentioned in Sect. 4.1 that PCA or PCO and cluster analysis are often used to compliment and to qualify each other's results. PCA and PCO tend to show up clusters if they are present but they are unable to detect the relationship within the clusters. For this, cluster analysis is more useful.

TABLE 4.10: Eigenvalues and percentage cumulative variance of the first ten components from the principal components analysis.

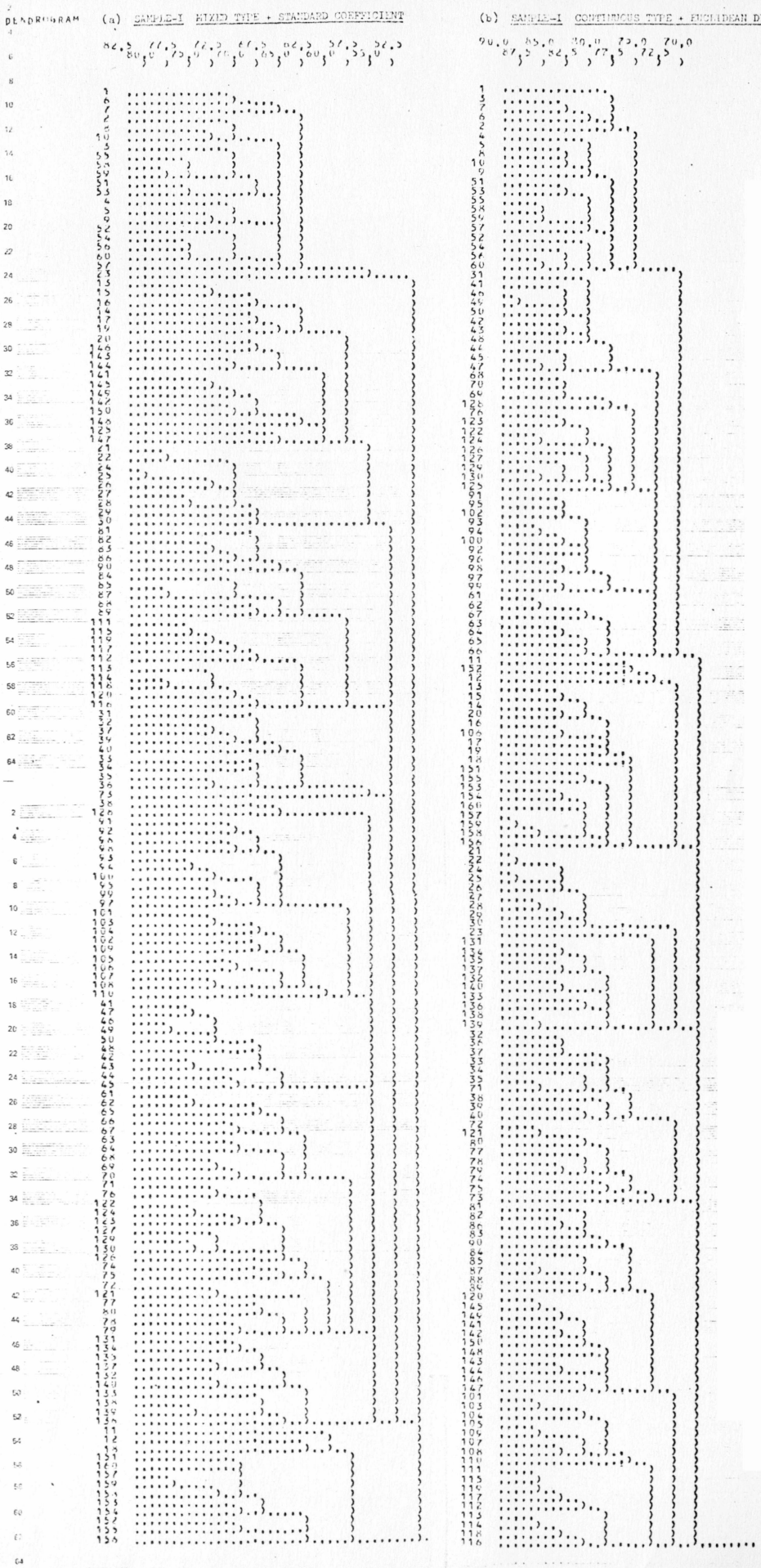
| | SAMPLE I | | SAMPLE-II | |
|---|---|---|---|---|
| Components | Eigenvalues | % cumulative variance | Eigenvalues | % cumulative variance |
| 1 | 9.768 | 9.87 | 11.318 | 11.44 |
| 2 | 9.288 | 19.25 | 8.330 | 19.85 |
| 3 | 7.604 | 26.93 | 7.288 | 27.21 |
| 4 | 5.377 | 32.37 | 4.781 | 32.04 |
| 5 | 4.742 | 37.16 | 4.183 | 36.27 |
| 6 | 3.670 | 40.86 | 3.278 | 39.58 |
| 7 | 3.086 | 43.98 | 2.974 | 42.58 |
| 8 | 2.883 | 46.89 | 2.696 | 45.31 |
| 9 | 2.442 | 49.36 | 2.448 | 47.78 |
| 10 | 2.296 | 51.68 | 2.251 | 50.05 |

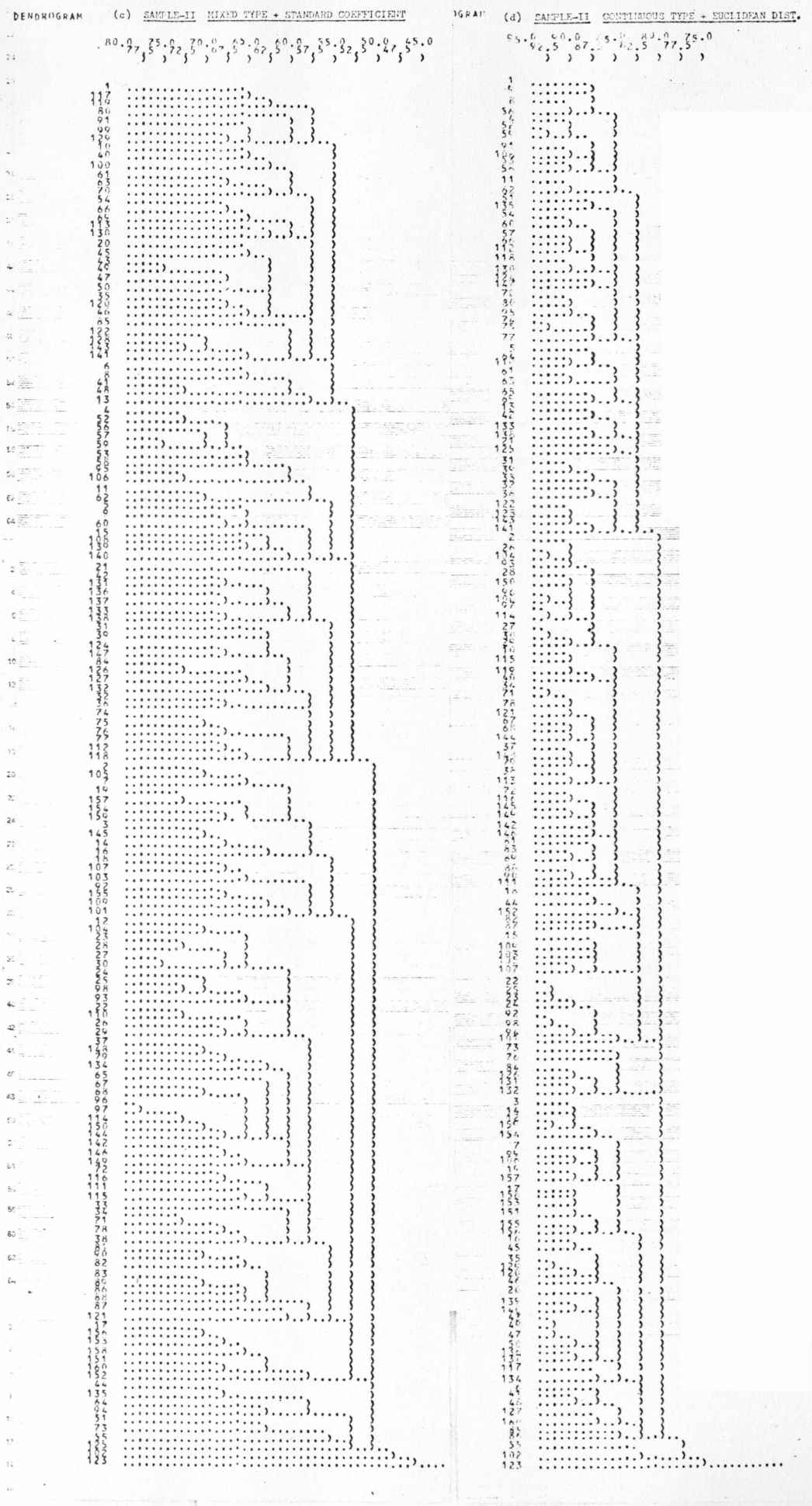
In this study, the dendrograms produced from the average linkage analysis (Fig. 4.6) coincide very well with those of PCO analysis. This can be shown by comparing the analysis of SAMPLE-I using the standard similarity coefficient between the two analyses, Fig. 4.5(a) and Fig. 4.6(a). In Fig. 4.5(a), three clusters may be marked out. They are (1) the small cluster of FAM-01 and FAM-06, (2) the cluster below it, composed of FAM-04, FAM-05, FAM-08, FAM-13 and part of FAM-02, FAM-07 and FAM-10, (3) the cluster to the left of these two, composed of FAM-03, FAM-09, FAM-11, FAM-12, FAM-15 and part of FAM-02. These three not very well defined clusters from PCO analysis were shown up again in the cluster analysis (Fig. 4.6(a)). There was a definite cluster of FAM-01 and FAM-06, and then a more complex cluster of FAM-02, FAM-15 and FAM-03 together, FAM-09 and FAM-12, and FAM-04. Finally, the third cluster consisted of FAM-10, FAM-11, FAM-05, FAM-07, FAM-13, FAM-08 and FAM-14. Other than those three, FAM-16 with a few members of FAM-02 formed another quite distinct cluster. The discrepancy between the two analyses was FAM-04 and FAM-11.

The interesting thing to note here is that members of the same family clustered together tightly in SAMPLE-I. This indicates the quality of this analysis for this particular study. The same is true when the data were converted to continuous type and Euclidean distance used (Fig. 4.6(b)).

However, the results did not reflect the presence of the common parent except in FAM-01 and FAM-06, and FAM-09 and FAM-12. This may be because the materials used were all very close to each

Fig. 4.6 Dendrograms produced by average linkage clustering of the sixteen families analysed together using all the characters.


DENDROGRAM
(a) SAMPLE-I MIXED TYPE + STANDARD COEFFICIENT
(b) SAMPLE-I CONTINUOUS TYPE + EUCLIDEAN DIST.


DENDROGRAM
(c) SAMPLE-II MIXED TYPE + STANDARD COEFFICIENT
80.0 77.5 75.0 72.5 70.0 67.5 65.0 62.5 60.0 57.5 55.0 52.5 50.0 47.5 45.0
(d) SAMPLE-II CONTINUOUS TYPE + EUCLIDEAN DIST.
95.0 90.0 85.0 80.0 75.0
92.5 87.5 82.5 77.5

other genetically and therefore the result of segregation depends very much on the nature of the other parent.

The close relationship between FAM-01 and FAM-06 is shown in all the analyses done so far. Both of them had a common parent, 702151, of that of the typical narrow leaved S. stenotomum. This relationship may indicate the overall dominant nature of this particular clone or its more homozygous nature, or both. The case of the clone OCH 5422, classified by Professor Ochoa as a hybrid between S. stenotomum and S. phureja gave quite a different result. Of the four families, FAM-09, FAM-12, FAM-13 and FAM-15, with OCH 5422 as a common parent, only FAM-09 and FAM-12 were clustered together (Fig. 4.6(a)). FAM-04 and FAM-07, FAM-07 and FAM-11, FAM-08 and FAM-12, and FAM-11 and FAM-16 were all pairs of hybrids with a common parent each. However, they were not clustered as such.

All this irregularity may be explained by examining FAM-08, FAM-13 and FAM-14, which all have "Papa Amarilla" as their female parent. They were OCH 5546, OCH 5758 and HJT 5493 of FAM-08, FAM-13 and FAM-14 respectively. They clustered together. This shows the dominance of "Papa Amarilla" over the other three parents. In addition, FAM-10 and FAM-11 both had an Ochoa hybrid form of S. goniocalyx x S. phureja, H/J 660 and H/J 352, and two typical S. stenotomum, 700341 and HJT 5457 as the other parent. Again they clustered together. All this type of interaction between parents affect the clustering. On the whole, the result of the average linkage analysis does reveal the genetic relationships between the different families. This method can then be applied confidently to analyse other materials of similar nature.

It was therefore decided to analyse the diploid cultivars in the same way.

This type of relationship is not reflected in the analysis based on the converted data to continuous form and using Euclidean distance as a measure of resemblance. It is therefore not recommended for further use.

The analysis of SAMPLE-II did not show any orderly grouping of members of the same family in their poorly defined clusters. It is therefore not possible to interpret the result.

From the results of SAMPLE-I and SAMPLE-II, it is quite clear that we can make use of the analyses used in the previous sections to detect a group of more similar individuals and a group of more different individuals even within a family. This again points to the sensitiveness of the techniques, namely, PCO, MST, average linkage clustering, "REGROUP", etc.

An alternative clustering analysis using Euclidean distance and Ward's method gave no better results than the average linkage clustering for both SAMPLE-I and SAMPLE-II. The dendrograms are given in Fig. 4.7(a) and (b). The allocation of members of the same family was not so consistent as that in the average linkage analysis in SAMPLE-I. As for SAMPLE-II, since the members of each cluster were not so orderly as in SAMPLE-I, visual judgement is therefore not possible to decide on which method is better but it did appear

Fig. 4.7 Dendrograms produced by Ward's method with Euclidean distance of the sixteen families analysed together using all the characters.

Case nos. for the dendrograms (reading down the dendrograms) :

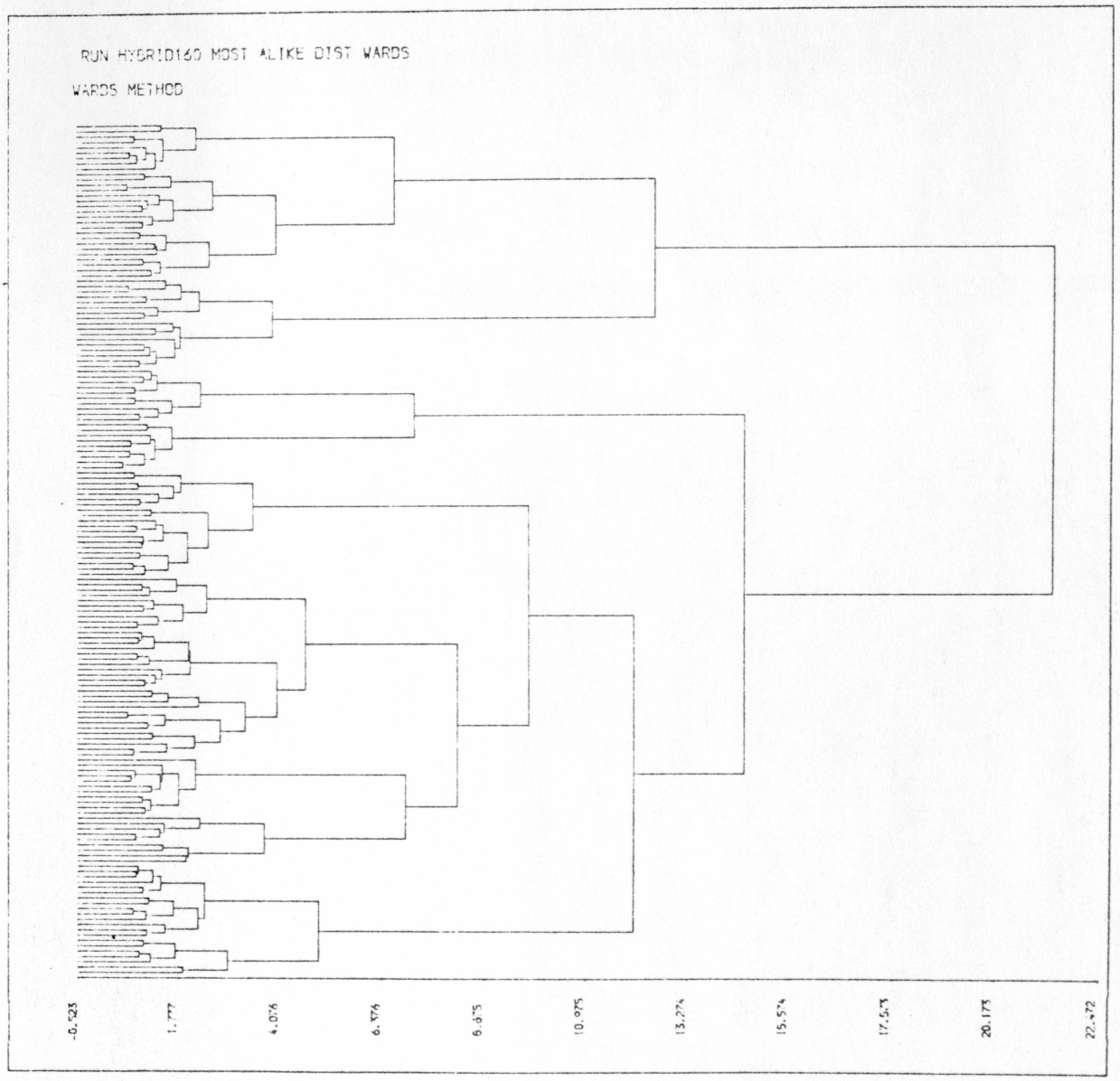
(a) SAMPLE I ('more similar' individuals from each of the families)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1* | 23 | 2 | 3 | 8 | 6 | 7 | 4 | 5 | 9 | 10 | 56 |
| 60 | 52 | 54 | 51 | 57 | 53 | 55 | 58 | 59 | 11 | 12 | 33 |
| 152 | 32 | 36 | 37 | 34 | 73 | 31 | 43 | 41 | 42 | 44 | 47 |
| 46 | 49 | 50 | 48 | 45 | 35 | 71 | 38 | 39 | 40 | 76 | 123 |
| 122 | 124 | 110 | 125 | 128 | 146 | 72 | 121 | 80 | 74 | 77 | 78 |
| 79 | 126 | 127 | 130 | 129 | 61 | 62 | 67 | 63 | 65 | 66 | 64 |
| 68 | 70 | 75 | 69 | 92 | 93 | 94 | 100 | 91 | 102 | 95 | 96 |
| 98 | 108 | 97 | 99 | 101 | 103 | 104 | 106 | 107 | 105 | 109 | 21 |
| 22 | 24 | 25 | 26 | 28 | 27 | 29 | 30 | 131 | 134 | 135 | 138 |
| 139 | 132 | 140 | 133 | 137 | 136 | 13 | 14 | 15 | 16 | 20 | 18 |
| 17 | 160 | 19 | 151 | 155 | 156 | 153 | 154 | 157 | 159 | 158 | 81 |
| 90 | 82 | 86 | 84 | 88 | 89 | 85 | 87 | 83 | 141 | 144 | 143 |
| 147 | 149 | 148 | 120 | 145 | 142 | 150 | 111 | 113 | 115 | 117 | 119 |
| 114 | 118 | 112 | 116 | | | | | | | | |

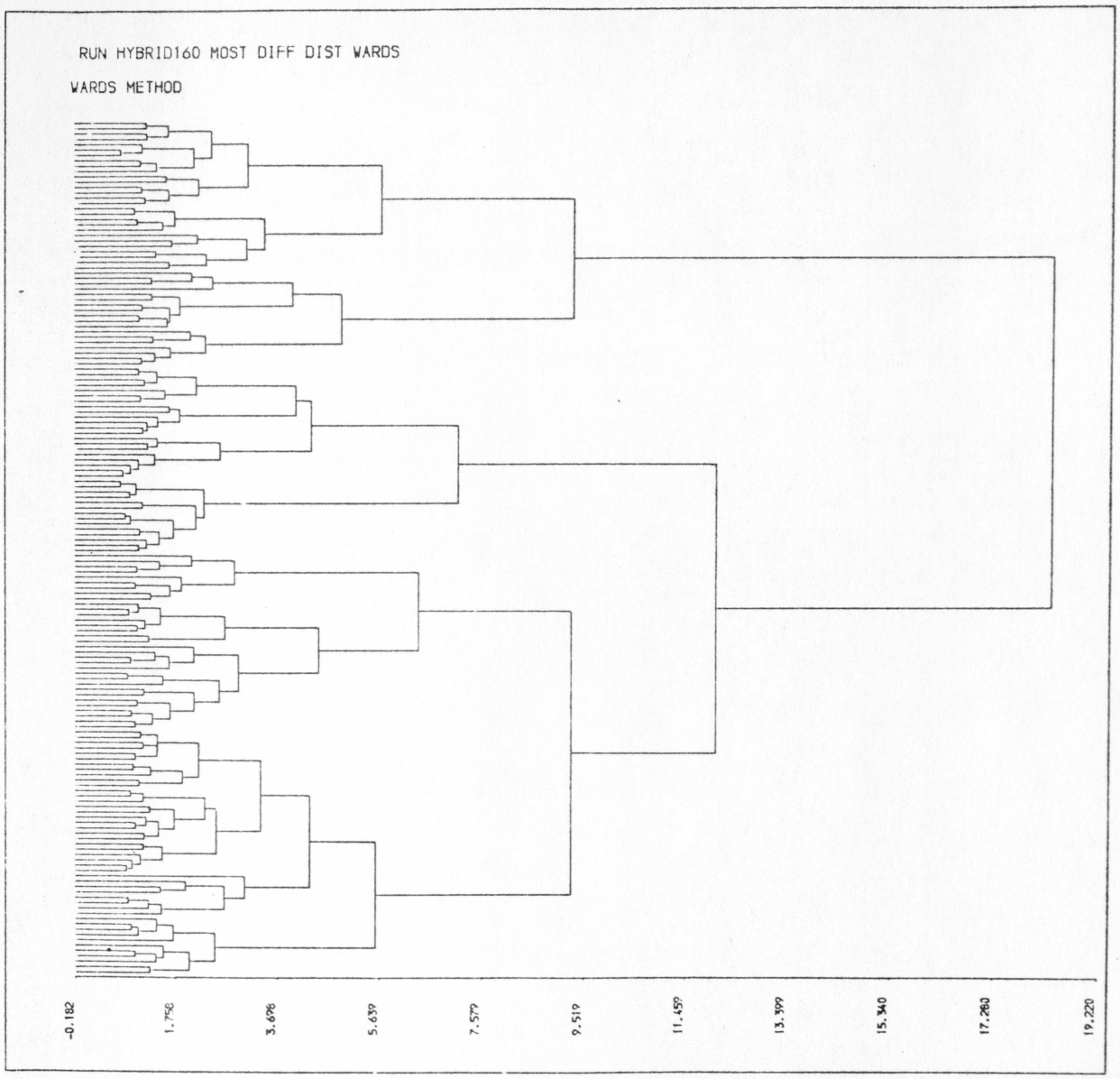
(b) SAMPLE II ('more dissimilar' individuals from each of the families)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 6 | 8 | 56 | 7 | 4 | 52 | 57 | 59 | 58 | 20 |
| 35 | 120 | 128 | 42 | 143 | 140 | 141 | 43 | 49 | 47 | 50 | 45 |
| 46 | 51 | 122 | 108 | 139 | 137 | 134 | 148 | 84 | 126 | 144 | 54 |
| 60 | 117 | 129 | 130 | 61 | 63 | 66 | 106 | 68 | 70 | 3 | 14 |
| 93 | 104 | 12 | 159 | 41 | 48 | 103 | 105 | 107 | 15 | 19 | 99 |
| 157 | 154 | 13 | 136 | 16 | 156 | 151 | 17 | 158 | 153 | 81 | 82 |
| 88 | 90 | 87 | 83 | 89 | 86 | 85 | 10 | 115 | 150 | 27 | 119 |
| 23 | 28 | 30 | 67 | 112 | 96 | 100 | 97 | 114 | 22 | 25 | 98 |
| 24 | 29 | 26 | 65 | 69 | 37 | 113 | 79 | 38 | 55 | 73 | 72 |
| 116 | 111 | 142 | 146 | 145 | 149 | 2 | 92 | 155 | 101 | 94 | 109 |
| 102 | 18 | 131 | 132 | 133 | 138 | 44 | 135 | 123 | 127 | 160 | 152 |
| 5 | 125 | 11 | 62 | 21 | 76 | 64 | 53 | 77 | 118 | 74 | 75 |
| 31 | 39 | 124 | 147 | 32 | 36 | 33 | 78 | 121 | 34 | 71 | 40 |
| 80 | 110 | 91 | 95 | | | | | | | | |

* read across the page


RUN HYBRID160 MOST ALIKE DIST WARDS
WARDS METHOD
-0.523
1.777
4.076
6.376
8.675
10.975
13.274
15.574
17.873
20.173
22.472

(a)


RUN HYBRID160 MOST DIFF DIST WARDS
WARDS METHOD
-0.182
1.758
3.698
5.639
7.579
9.519
11.459
13.399
15.340
17.280
19.220

(b)

that average linkage analysis gave more consistent grouping of the families other than the first two clusters of the Ward's analysis for FAM-01 and FAM-06. One must therefore note that the more definite clusters (using Ward's method) may not necessarily mean a better biological classification.

4.4.4.2.4. Analysis of the tuber, plant and fresh leaf, and leaf herbarium data separately.

Nearest neighbours list

The eight nearest neighbours list, were summarised as in the previous section. It is shown in Table 4.11(a) for the tuber characters, Table 4.11(b) for the plant and leaf characters and Table 4.11(c) for the leaf herbarium characters in SAMPLE-I. Results for SAMPLE-II are shown in Table 4.11(d), (e) and (f) in the same order as above.

In SAMPLE-1, tuber characters showed the highest member of within family neighbours with values almost approaching that of the overall data analysis (Table 4.6(a)) but the allocation for each family came from more families. As for the leaf herbarium characters the number of within family neighbours were very low and their neighbours came from almost all the sixteen families (Table 4.11(c)).

TABLE 4.11: Summary of the eight nearest neighbours list as for Table 4.6.

(a) SAMPLE I - Tuber characters

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 57 | 2 | 3 | 0 | 0 | 10 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1 |
| 2 | 5 | 16 | 4 | 0 | 4 | 2 | 2 | 5 | 1 | 1 | 4 | 0 | 6 | 4 | 15 | 11 |
| 3 | 5 | 2 | 51 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 3 | 2 | 0 | 1 | 0 | 12 |
| 4 | 0 | 0 | 0 | 60 | 2 | 0 | 3 | 5 | 0 | 2 | 1 | 0 | 4 | 0 | 0 | 3 |
| 5 | 0 | 0 | 0 | 2 | 73 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6 | 14 | 1 | 10 | 0 | 6 | 35 | 7 | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 2 |
| 7 | 0 | 1 | 0 | 8 | 4 | 0 | 38 | 4 | 0 | 17 | 2 | 0 | 5 | 0 | 0 | 1 |
| 8 | 0 | 1 | 0 | 8 | 5 | 0 | 4 | 24 | 0 | 6 | 11 | 0 | 14 | 0 | 0 | 6 |
| 9 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 65 | 0 | 0 | 8 | 0 | 0 | 1 | 3 |
| 10 | 1 | 0 | 2 | 2 | 4 | 1 | 13 | 4 | 0 | 36 | 7 | 0 | 5 | 3 | 1 | 1 |
| 11 | 0 | 4 | 8 | 2 | 0 | 0 | 4 | 10 | 0 | 7 | 25 | 4 | 1 | 2 | 6 | 7 |
| 12 | 0 | 0 | 5 | 6 | 0 | 0 | 1 | 2 | 7 | 0 | 5 | 41 | 1 | 3 | 4 | 5 |
| 13 | 0 | 4 | 0 | 7 | 3 | 0 | 4 | 15 | 0 | 7 | 1 | 0 | 33 | 1 | 1 | 4 |
| 14 | 0 | 4 | 8 | 3 | 4 | 1 | 2 | 6 | 0 | 4 | 1 | 3 | 4 | 39 | 0 | 1 |
| 15 | 0 | 13 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 5 | 2 | 0 | 25 | 20 |
| 16 | 0 | 4 | 11 | 3 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 1 | 2 | 0 | 7 | 47 |

(b) SAMPLE I - Plant and fresh leaf characters

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 50 | 0 | 0 | 0 | 0 | 27 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 2 | 4 | 17 | 1 | 1 | 12 | 0 | 4 | 6 | 0 | 4 | 8 | 2 | 4 | 6 | 1 | 10 |
| 3 | 1 | 3 | 46 | 0 | 5 | 0 | 0 | 0 | 2 | 4 | 10 | 6 | 1 | 1 | 1 | 0 |
| 4 | 0 | 1 | 0 | 30 | 7 | 1 | 4 | 6 | 3 | 1 | 1 | 1 | 7 | 10 | 6 | 2 |
| 5 | 1 | 10 | 2 | 2 | 29 | 4 | 5 | 4 | 1 | 2 | 0 | 0 | 12 | 4 | 0 | 4 |
| 6 | 36 | 0 | 0 | 0 | 1 | 38 | 2 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 |
| 7 | 4 | 4 | 0 | 3 | 3 | 11 | 23 | 3 | 2 | 6 | 4 | 3 | 12 | 0 | 0 | 2 |
| 8 | 2 | 5 | 1 | 10 | 9 | 0 | 7 | 18 | 0 | 2 | 0 | 4 | 18 | 4 | 0 | 0 |
| 9 | 0 | 4 | 6 | 1 | 4 | 0 | 3 | 0 | 27 | 3 | 8 | 3 | 3 | 8 | 8 | 2 |
| 10 | 1 | 2 | 0 | 1 | 2 | 0 | 3 | 2 | 0 | 32 | 10 | 13 | 8 | 1 | 3 | 2 |
| 11 | 1 | 6 | 6 | 0 | 1 | 1 | 2 | 1 | 7 | 18 | 27 | 5 | 1 | 2 | 0 | 2 |
| 12 | 0 | 3 | 4 | 0 | 0 | 0 | 3 | 2 | 1 | 20 | 4 | 32 | 0 | 1 | 8 | 2 |
| 13 | 2 | 2 | 1 | 6 | 12 | 2 | 10 | 10 | 3 | 12 | 1 | 0 | 14 | 3 | 1 | 1 |
| 14 | 1 | 7 | 0 | 6 | 7 | 0 | 0 | 3 | 5 | 6 | 2 | 5 | 5 | 29 | 1 | 3 |
| 15 | 1 | 3 | 1 | 5 | 0 | 0 | 1 | 0 | 10 | 7 | 3 | 13 | 0 | 2 | 28 | 6 |
| 16 | 2 | 16 | 0 | 1 | 11 | 0 | 3 | 0 | 2 | 7 | 3 | 5 | 4 | 3 | 3 | 20 |

(c) SAMPLE I - Leaf herbarium characters

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 0 | 7 | 2 | 4 | 20 | 6 | 3 | 5 | 8 | 4 | 4 | 6 | 1 | 7 | 0 |
| 2 | 5 | 22 | 0 | 6 | 10 | 3 | 0 | 0 | 3 | 0 | 4 | 6 | 3 | 0 | 2 | 16 |
| 3 | 6 | 0 | 19 | 2 | 1 | 3 | 9 | 3 | 3 | 4 | 0 | 0 | 7 | 14 | 9 | 0 |
| 4 | 3 | 5 | 5 | 12 | 5 | 4 | 0 | 6 | 8 | 6 | 1 | 3 | 4 | 5 | 5 | 8 |
| 5 | 2 | 0 | 0 | 3 | 20 | 9 | 1 | 1 | 11 | 0 | 3 | 1 | 9 | 0 | 10 | 10 |
| 6 | 10 | 0 | 0 | 1 | 10 | 30 | 1 | 4 | 3 | 3 | 5 | 7 | 3 | 0 | 3 | 0 |
| 7 | 7 | 0 | 14 | 1 | 1 | 3 | 25 | 0 | 6 | 0 | 1 | 7 | 3 | 3 | 9 | 0 |
| 8 | 6 | 0 | 4 | 7 | 3 | 6 | 1 | 15 | 3 | 4 | 5 | 11 | 5 | 5 | 4 | 1 |
| 9 | 3 | 0 | 2 | 4 | 7 | 8 | 7 | 2 | 12 | 1 | 2 | 11 | 9 | 0 | 8 | 4 |
| 10 | 8 | 0 | 7 | 4 | 2 | 7 | 0 | 6 | 0 | 26 | 12 | 0 | 2 | 3 | 2 | 1 |
| 11 | 5 | 3 | 0 | 1 | 4 | 15 | 3 | 8 | 3 | 11 | 15 | 9 | 1 | 1 | 0 | 1 |
| 12 | 0 | 0 | 0 | 1 | 1 | 11 | 5 | 3 | 10 | 1 | 8 | 35 | 3 | 0 | 2 | 0 |
| 13 | 8 | 0 | 3 | 2 | 7 | 8 | 4 | 6 | 7 | 0 | 1 | 7 | 14 | 0 | 12 | 1 |
| 14 | 3 | 0 | 18 | 8 | 1 | 0 | 5 | 3 | 6 | 3 | 0 | 0 | 1 | 23 | 9 | 0 |
| 15 | 6 | 0 | 4 | 2 | 11 | 5 | 4 | 3 | 9 | 3 | 1 | 2 | 15 | 2 | 12 | 1 |
| 16 | 0 | 5 | 0 | 2 | 23 | 3 | 0 | 1 | 12 | 3 | 1 | 1 | 3 | 0 | 5 | 21 |

(d) SAMPLE II - Tuber characters

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 6 | 8 | 2 | 6 | 8 | 0 | 1 | 3 | 3 | 12 | 3 | 0 | 9 | 7 | 2 |
| 2 | 8 | 2 | 4 | 1 | 8 | 2 | 6 | 4 | 1 | 3 | 7 | 4 | 4 | 10 | 5 | 11 |
| 3 | 1 | 3 | 48 | 1 | 4 | 1 | 1 | 3 | 0 | 5 | 3 | 1 | 1 | 2 | 2 | 4 |
| 4 | 1 | 1 | 2 | 29 | 4 | 0 | 5 | 13 | 1 | 0 | 1 | 6 | 3 | 0 | 7 | 7 |
| 5 | 3 | 4 | 5 | 5 | 31 | 5 | 10 | 3 | 1 | 2 | 1 | 3 | 0 | 4 | 0 | 3 |
| 6 | 5 | 1 | 3 | 0 | 2 | 35 | 3 | 3 | 0 | 6 | 8 | 4 | 5 | 1 | 2 | 2 |
| 7 | 0 | 6 | 3 | 10 | 15 | 4 | 19 | 4 | 1 | 3 | 4 | 3 | 4 | 0 | 1 | 3 |
| 8 | 1 | 2 | 5 | 11 | 0 | 1 | 3 | 23 | 0 | 0 | 3 | 2 | 10 | 2 | 5 | 12 |
| 9 | 0 | 3 | 2 | 6 | 3 | 0 | 4 | 1 | 40 | 1 | 1 | 12 | 4 | 0 | 2 | 1 |
| 10 | 3 | 3 | 9 | 4 | 7 | 9 | 3 | 0 | 0 | 20 | 4 | 6 | 2 | 2 | 7 | 1 |
| 11 | 9 | 6 | 12 | 0 | 4 | 5 | 2 | 4 | 1 | 8 | 9 | 1 | 2 | 4 | 6 | 7 |
| 12 | 1 | 1 | 5 | 10 | 5 | 2 | 3 | 6 | 6 | 5 | 3 | 14 | 7 | 1 | 8 | 3 |
| 13 | 0 | 3 | 3 | 3 | 2 | 3 | 2 | 13 | 2 | 2 | 0 | 4 | 21 | 6 | 11 | 5 |
| 14 | 4 | 9 | 11 | 1 | 8 | 3 | 1 | 5 | 0 | 2 | 1 | 3 | 6 | 21 | 1 | 4 |
| 15 | 8 | 3 | 7 | 8 | 1 | 2 | 1 | 6 | 2 | 5 | 5 | 3 | 11 | 0 | 11 | 7 |
| 16 | 0 | 7 | 10 | 10 | 2 | 1 | 0 | 7 | 0 | 1 | 6 | 3 | 3 | 3 | 5 | 22 |

(e) SAMPLE II - Plant and fresh leaf characters

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 18 | 10 | 6 | 4 | 5 | 14 | 2 | 0 | 0 | 6 | 7 | 2 | 1 | 2 | 2 | 1 |
| 2 | 8 | 15 | 3 | 1 | 14 | 5 | 1 | 1 | 1 | 5 | 7 | 5 | 7 | 3 | 0 | 4 |
| 3 | 7 | 4 | 18 | 1 | 4 | 0 | 2 | 1 | 4 | 19 | 6 | 5 | 3 | 2 | 2 | 2 |
| 4 | 4 | 1 | 2 | 19 | 5 | 8 | 7 | 15 | 0 | 1 | 0 | 2 | 7 | 3 | 6 | 0 |
| 5 | 7 | 19 | 2 | 4 | 15 | 0 | 2 | 6 | 1 | 3 | 3 | 4 | 4 | 5 | 0 | 5 |
| 6 | 15 | 5 | 0 | 7 | 1 | 18 | 6 | 3 | 2 | 5 | 5 | 3 | 4 | 2 | 2 | 2 |
| 7 | 5 | 3 | 4 | 6 | 3 | 9 | 11 | 6 | 3 | 4 | 5 | 5 | 1 | 4 | 8 | 3 |
| 8 | 1 | 2 | 0 | 12 | 4 | 4 | 4 | 9 | 5 | 4 | 3 | 9 | 10 | 4 | 7 | 2 |
| 9 | 3 | 2 | 5 | 0 | 5 | 2 | 4 | 8 | 13 | 6 | 4 | 7 | 8 | 4 | 7 | 2 |
| 10 | 7 | 3 | 10 | 3 | 3 | 4 | 1 | 2 | 2 | 18 | 4 | 11 | 3 | 2 | 3 | 4 |
| 11 | 13 | 10 | 13 | 0 | 3 | 4 | 2 | 3 | 2 | 9 | 12 | 2 | 3 | 0 | 4 | 0 |
| 12 | 3 | 5 | 7 | 3 | 6 | 1 | 4 | 11 | 2 | 10 | 3 | 8 | 8 | 3 | 4 | 2 |
| 13 | 6 | 7 | 1 | 7 | 5 | 5 | 2 | 8 | 5 | 4 | 4 | 9 | 5 | 8 | 3 | 1 |
| 14 | 8 | 8 | 0 | 5 | 4 | 4 | 3 | 10 | 4 | 3 | 2 | 5 | 9 | 11 | 0 | 4 |
| 15 | 3 | 5 | 7 | 7 | 3 | 3 | 5 | 8 | 4 | 7 | 4 | 9 | 2 | 2 | 9 | 2 |
| 16 | 5 | 16 | 2 | 2 | 9 | 3 | 2 | 6 | 0 | 10 | 1 | 3 | 1 | 4 | 1 | 15 |

(f) SAMPLE II - Leaf herbarium characters

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 4 | 4 | 1 | 8 | 9 | 5 | 3 | 8 | 10 | 6 | 5 | 5 | 1 | 4 | 1 |
| 2 | 4 | 10 | 5 | 2 | 11 | 5 | 3 | 1 | 4 | 8 | 4 | 4 | 4 | 6 | 1 | 8 |
| 3 | 4 | 2 | 12 | 6 | 3 | 11 | 11 | 8 | 3 | 3 | 6 | 3 | 3 | 3 | 2 | 0 |
| 4 | 3 | 3 | 11 | 11 | 6 | 2 | 3 | 6 | 3 | 4 | 4 | 3 | 3 | 5 | 10 | 3 |
| 5 | 4 | 7 | 2 | 6 | 12 | 8 | 0 | 1 | 9 | 3 | 1 | 2 | 5 | 8 | 7 | 5 |
| 6 | 4 | 4 | 7 | 2 | 6 | 9 | 16 | 3 | 5 | 4 | 5 | 6 | 3 | 2 | 3 | 1 |
| 7 | 4 | 0 | 14 | 3 | 1 | 11 | 16 | 6 | 2 | 3 | 5 | 4 | 5 | 1 | 5 | 0 |
| 8 | 0 | 1 | 12 | 8 | 1 | 3 | 7 | 3 | 2 | 6 | 5 | 7 | 8 | 4 | 2 | 1 |
| 9 | 3 | 2 | 4 | 2 | 6 | 3 | 3 | 1 | 18 | 8 | 3 | 7 | 11 | 0 | 5 | 4 |
| 10 | 5 | 5 | 7 | 4 | 1 | 6 | 1 | 2 | 10 | 8 | 10 | 8 | 7 | 1 | 1 | 4 |
| 11 | 6 | 3 | 7 | 5 | 3 | 5 | 8 | 6 | 4 | 13 | 7 | 0 | 8 | 3 | 0 | 2 |
| 12 | 5 | 2 | 5 | 1 | 1 | 9 | 5 | 8 | 10 | 10 | 0 | 10 | 8 | 1 | 4 | 1 |
| 13 | 2 | 3 | 4 | 3 | 4 | 6 | 5 | 8 | 12 | 4 | 7 | 6 | 5 | 2 | 5 | 4 |
| 14 | 1 | 6 | 9 | 3 | 10 | 5 | 0 | 4 | 6 | 3 | 2 | 1 | 3 | 10 | 8 | 9 |
| 15 | 6 | 1 | 3 | 8 | 10 | 8 | 6 | 3 | 9 | 3 | 2 | 4 | 7 | 4 | 5 | 1 |
| 16 | 0 | 8 | 0 | 2 | 5 | 2 | 0 | 1 | 14 | 8 | 4 | 3 | 7 | 8 | 3 | 15 |

Similar trends were obtained for SAMPLE-II.

The results of the three sets of characters appeared to vary proportionately so that the result of the overall data analysis seemed to be the sum total of the three sets combined together. If this is true it indicates the importance of using a wide range of characters from every part of the plant.

REGROUP

The results are presented in Appendix IX .

These results were summarised in Table 4.12. The grouping of the tuber, and plant and fresh leaf characters in SAMPLE-I (Table 4.12(a) and (b)) still showed some similarity to that of the full analysis (Table 4.7(a)). Whereas in all the others (Table 4.12 (c) - (f)), the groups became very disorderly especially in SAMPLE-II. The result is therefore consistent with that of the nearest neighbours list analysis.

PCO and MST

The first four latent roots and the cumulative percentage of variance accounted for are shown in Table 4.13. The MST length is

TABLE 4.12: Summary of "REGROUP" analysis showing the family composition of each group.

(a) SAMPLE I - Tuber characters

| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 1 | 1 | - | - | 7 | - | - | - | - | - | - | - | - | - | - |
| 2 | - | 4 | - | - | - | - | - | - | - | - | 4 | 1 | - | - | 7 | 6 |
| 3 | - | 3 | - | - | - | - | - | - | - | - | 2 | 3 | - | 4 | 2 | - |
| 4 | - | 1 | - | 1 | - | 1 | 3 | 4 | - | 2 | 2 | - | - | - | - | - |
| 5 | - | 1 | - | - | - | - | 6 | - | - | 7 | - | - | 3 | - | - | - |
| 6 | - | - | 9 | - | - | 2 | - | - | - | 1 | - | - | - | 5 | - | 3 |
| 7 | - | - | - | 9 | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | - | - | - | - | 10 | - | - | 1 | - | - | - | - | - | 1 | - | - |
| 9 | - | - | - | - | - | - | 1 | 5 | - | - | 2 | 1 | 7 | - | - | 1 |
| 10 | - | - | - | - | - | - | - | - | 10 | - | - | 5 | - | - | 1 | - |

(b) SAMPLE I - Plant and fresh leaf characters

family composition

| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | - | - | - | - | 10 | 1 | - | - | - | - | - | - | - | - | - |
| 2 | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | 9 |
| 3 | - | 3 | - | 5 | 7 | - | 1 | 1 | 2 | - | - | - | 1 | 4 | - | 1 |
| 4 | - | 2 | 1 | - | 3 | - | - | - | - | 6 | - | 1 | 1 | 4 | - | - |
| 5 | - | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | - | - | 1 | - | - | - | 3 | - | 2 | 2 | 10 | 4 | - | - | 1 | - |
| 7 | - | - | - | 4 | - | - | 3 | 2 | - | - | - | - | 2 | - | - | - |
| 8 | - | - | - | 1 | - | - | - | - | 1 | - | - | 3 | - | 1 | 7 | - |
| 9 | - | - | - | - | - | - | 2 | 7 | - | 2 | - | 1 | 5 | - | - | - |
| 10 | - | - | - | - | - | - | - | - | 5 | -- | - | 1 | 1 | 1 | 2 | - |

(c) SAMPLE I - Leaf herbarium characters

| | Family composition | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 3 | - | - | 1 | 1 | 2 | 1 | 1 | 4 | - | - | - | 6 | - | 7 | - |
| 2 | 2 | - | - | - | 1 | 3 | - | 1 | - | 6 | 6 | - | - | - | 1 | - |
| 3 | 1 | 5 | - | - | 3 | 1 | - | - | 1 | - | 1 | 1 | 1 | - | 1 | 2 |
| 4 | 1 | - | 8 | - | - | - | 5 | 1 | - | 1 | - | - | 1 | 2 | 1 | - |
| 5 | 1 | - | 1 | 4 | - | - | - | 3 | - | 2 | - | - | 1 | 3 | - | - |
| 6 | 1 | - | - | - | - | 4 | - | - | 3 | - | 1 | 7 | - | - | - | - |
| 7 | 1 | - | - | - | - | - | 4 | 3 | - | - | 2 | 2 | 1 | - | - | - |
| 8 | - | 3 | - | 4 | - | - | - | - | 1 | 1 | - | - | - | - | - | 4 |
| 9 | - | 2 | - | 1 | 5 | - | - | - | 1 | - | - | - | - | - | - | 4 |
| 10 | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - | 5 | - | - |

(d) SAMPLE II - Tuber characters

| | Family composition | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 4 | 2 | - | - | 1 | - | - | - | - | - | 2 | 1 | - | 4 | - | - |
| 2 | 3 | 1 | - | - | - | - | - | 1 | - | - | - | - | - | - | 4 | 2 |
| 3 | 1 | 2 | 1 | 2 | - | 2 | 1 | 1 | - | - | 4 | 1 | 4 | 2 | 1 | 5 |
| 4 | 1 | 1 | - | - | 4 | - | 2 | - | - | 2 | - | - | 3 | 4 | 2 | - |
| 5 | 1 | 1 | - | - | - | 8 | 1 | 1 | - | 3 | 3 | 1 | - | - | - | - |
| 6 | - | 2 | - | 3 | 1 | - | 2 | - | 2 | - | - | - | - | - | - | - |
| 7 | - | 1 | 1 | - | 2 | - | 4 | 1 | - | 4 | 1 | 2 | 1 | - | 1 | - |
| 8 | - | - | 8 | - | 2 | - | - | 1 | - | 1 | - | - | - | - | - | 2 |
| 9 | - | - | - | 5 | - | - | - | 5 | - | - | - | 1 | 2 | - | 2 | 1 |
| 10 | - | - | - | - | - | - | - | - | 8 | - | - | 4 | - | - | - | - |

(e) SAMPLE II - plant and fresh leaf characters

| | Family composition | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 3 | 3 | - | - | 3 | - | - | 1 | - | 2 | - | 1 | - | 3 | - | 2 |
| 2 | 2 | 1 | - | 2 | - | 6 | 1 | - | - | - | - | - | 2 | - | - | - |
| 3 | 2 | - | 3 | - | - | - | 2 | - | 1 | - | 6 | 1 | - | - | - | 1 |
| 4 | 1 | 2 | 1 | - | - | - | - | 1 | 1 | 6 | - | 2 | - | 1 | 1 | 2 |
| 5 | 1 | - | 1 | 1 | 1 | 1 | - | 4 | - | 1 | 2 | 2 | 1 | 4 | 1 | - |
| 6 | 1 | - | 1 | 1 | 3 | - | - | 1 | 2 | 1 | - | 1 | - | - | - | - |
| 7 | - | 4 | - | - | 1 | 1 | 1 | 1 | 2 | - | 1 | - | 2 | 1 | - | 5 |
| 8 | - | - | 4 | 1 | - | 1 | 3 | 1 | 3 | - | 1 | - | 1 | - | 6 | - |
| 9 | - | - | - | 4 | - | - | 1 | 1 | - | - | - | - | 1 | 1 | 2 | - |
| 10 | - | - | - | 1 | 2 | 1 | 2 | - | 1 | - | - | 3 | 3 | - | - | - |

(f) SAMPLE II - leaf herbarium characters

| | Family composition | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 3 | 4 | - | - | 4 | - | - | - | 1 | - | - | - | 2 | 2 | 1 | 2 |
| 2 | 3 | 1 | - | 1 | - | 3 | 1 | 1 | 1 | 3 | - | 1 | - | - | 1 | - |
| 3 | 2 | 1 | 1 | 1 | - | 1 | - | - | - | 2 | 4 | - | - | - | 1 | - |
| 4 | 1 | - | 1 | - | - | - | 2 | 4 | - | 1 | 2 | 1 | 1 | - | - | - |
| 5 | 1 | - | - | 1 | 3 | 1 | 1 | - | 6 | - | - | 1 | 1 | 1 | 3 | 1 |
| 6 | - | 2 | 2 | 1 | 1 | - | - | 1 | 1 | 1 | 3 | - | 2 | 2 | - | 1 |
| 7 | - | 1 | 3 | 1 | - | 2 | - | - | - | 2 | - | 4 | - | - | 1 | - |
| 8 | - | 1 | - | 2 | - | - | - | - | 1 | 1 | - | - | 2 | 2 | - | 6 |
| 9 | - | - | 2 | 3 | 2 | 1 | - | 1 | - | - | 1 | - | 1 | 3 | 3 | - |
| 10 | - | - | 1 | - | - | 2 | 5 | 3 | - | - | - | 3 | 1 | - | - | - |

TABLE 4.13: Values of the first four latent roots and the cumulative percentage of variance accounted for at each vector.

| Data sets | Vectors 1 | 2 | 3 | 4 | Trace (total) |
|---|---|---|---|---|---|
| SAMPLE-I | | | | | |
| (a) tuber characters | 8.464[a] | 6.227 | 5.067 | 4.289 | 79.802 |
| | 10.6[b] | 18.4 | 24.8 | 30.1 | 100.0 |
| (b) plant and fresh leaf characters | 7.869 | 6.218 | 4.539 | 4.002 | 91.273 |
| | 8.6 | 15.4 | 20.4 | 24.8 | 100.0 |
| (c) leaf herbarium characters | 4.898 | 3.649 | 3.370 | 2.200 | 40.246 |
| | 12.2 | 21.1 | 29.6 | 35.1 | 100.0 |
| SAMPLE-II | | | | | |
| (a) tuber characters | 6.519 | 5.607 | 4.874 | 4.132 | 79.189 |
| | 8.2 | 15.3 | 21.5 | 26.7 | 100.0 |
| (b) plant and fresh leaf characters | 7.259 | 5.065 | 4.830 | 4.210 | 93.422 |
| | 7.8 | 13.2 | 18.4 | 22.9 | 100.0 |
| (c) leaf herbarium characters | 5.713 | 4.074 | 3.467 | 2.445 | 43.365 |
| | 13.2 | 22.6 | 30.6 | 36.2 | 100.0 |

a - latent root

b - percentage of the total variance

TABLE 4.14: Summary of the MST analysis

| Data sets | Total length | Average length |
|---|---|---|
| SAMPLE-I | | |
| (a) overall analysis | 11480.1 | 71.75 |
| (b) overall (continuous & Euclidean distance) | 14603.9 | 91.27 |
| (c) tuber characters | 12180.1 | 76.13 |
| (d) plant & fresh leaf characters | 10898.7 | 68.12 |
| (e) leaf herbarium characters | 14051.6 | 87.82 |
| SAMPLE-II | | |
| (a) overall analysis | 11009.6 | 68.81 |
| (b) overall (continuous & Euclidean distance) | 14493.2 | 90.58 |
| (c) tuber characters | 11778.2 | 73.61 |
| (d) plant & fresh leaf characters | 10475.0 | 65.47 |
| (e) leaf herbarium characters | 13895.1 | 86.84 |

shown in Table 4.14. The component scores presented in Appendix X and the scatter diagrams in Fig. 4.8. The points were more widespread in all cases and no cluster was detected except for the very poor clusters of the plant and fresh leaf characters of SAMPLE-I (Fig. 4.8(b)).

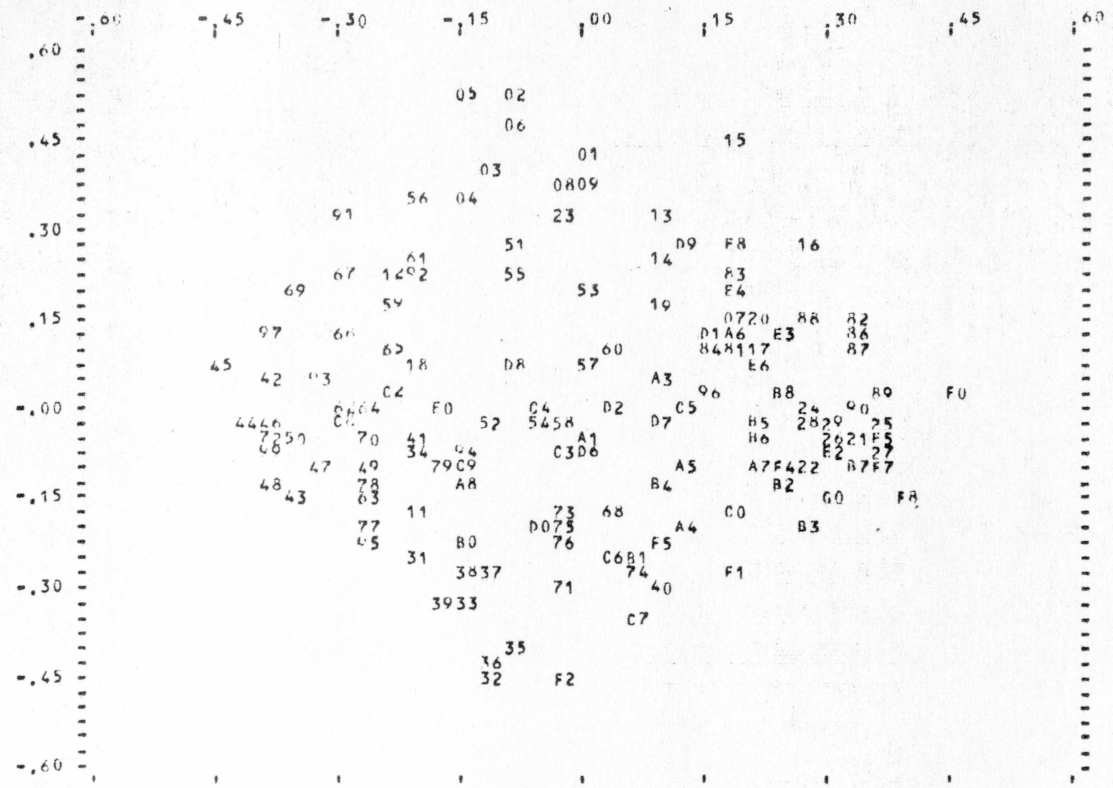
The points were too close for the MST to be plotted on to the scatter diagrams.

Average linkage analysis

The dendrograms are shown in Fig. 4.9. Again the dendrograms for the tuber characters, and the plant and fresh leaf characters (Fig. 4.9, (a) and (b)) conformed more to that of the overall analysis for SAMPLE-I. Results from SAMPLE-II were very disorderly.

Fig. 4.8 Scatter diagrams of PCO analysis between vector 1 (across the page) and vector 2 (down the page) of the sixteen families analysed together using tuber, plant and fresh leaf, and leaf herbarium characters separately.

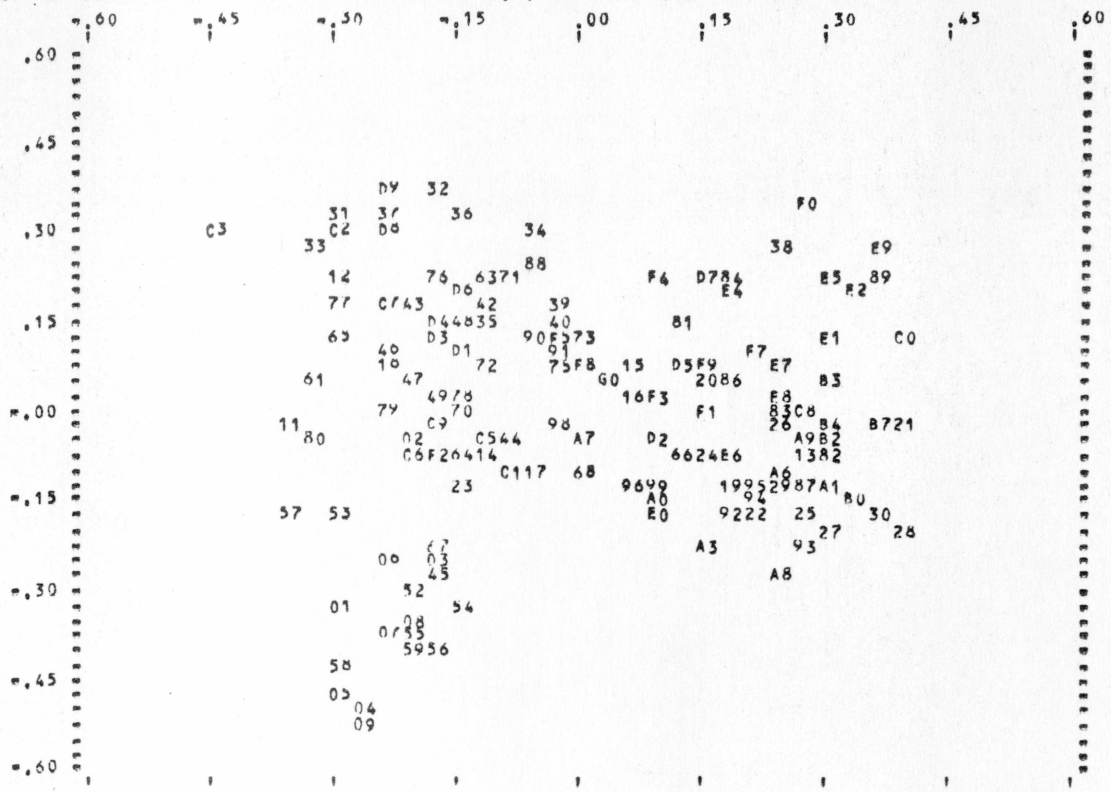
PRINCIPAL COORDINATE PLOT (a) SAMPLE-I TUBER CHARACTERS
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2
LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105



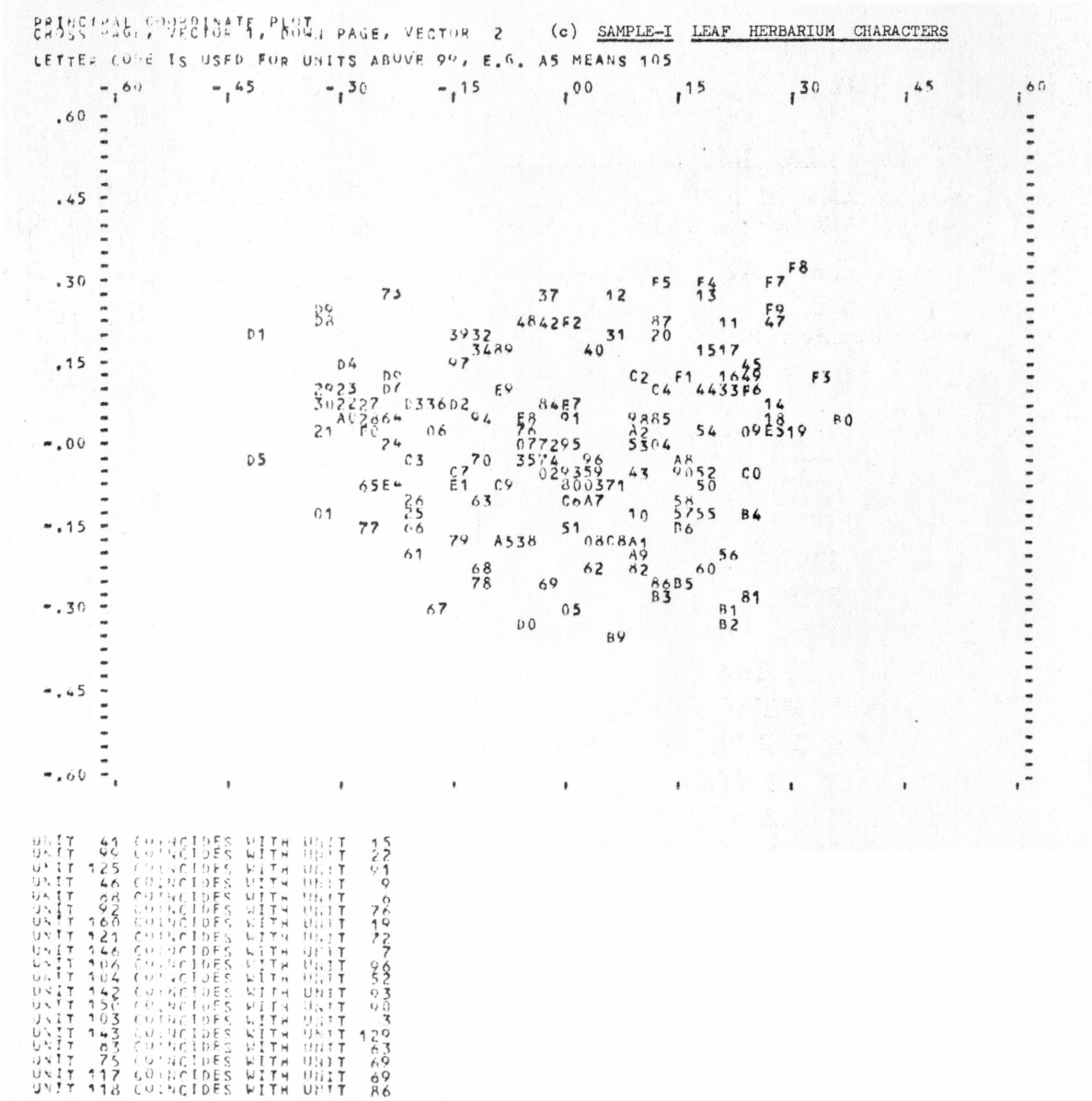

UNIT 10 COINCIDES WITH UNIT 3
UNIT 133 COINCIDES WITH UNIT 53
UNIT 99 COINCIDES WITH UNIT A2
UNIT 30 COINCIDES WITH UNIT 17
UNIT 103 COINCIDES WITH UNIT 93
UNIT 141 COINCIDES WITH UNIT 60
UNIT 157 COINCIDES WITH UNIT 116
UNIT 121 COINCIDES WITH UNIT 62
UNIT 134 COINCIDES WITH UNIT 125
UNIT 140 COINCIDES WITH UNIT 24
UNIT 65 COINCIDES WITH UNIT 28
UNIT 147 COINCIDES WITH UNIT 28
UNIT 150 COINCIDES WITH UNIT 21
UNIT 110 COINCIDES WITH UNIT 22
UNIT 135 COINCIDES WITH UNIT 105
UNIT 156 COINCIDES WITH UNIT 107
UNIT 80 COINCIDES WITH UNIT 28
UNIT 109 COINCIDES WITH UNIT 75
UNIT 102 COINCIDES WITH UNIT 31

PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2 (b) SAMPLE-I PLANT AND FRESH LEAF CHARACTERS

LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105

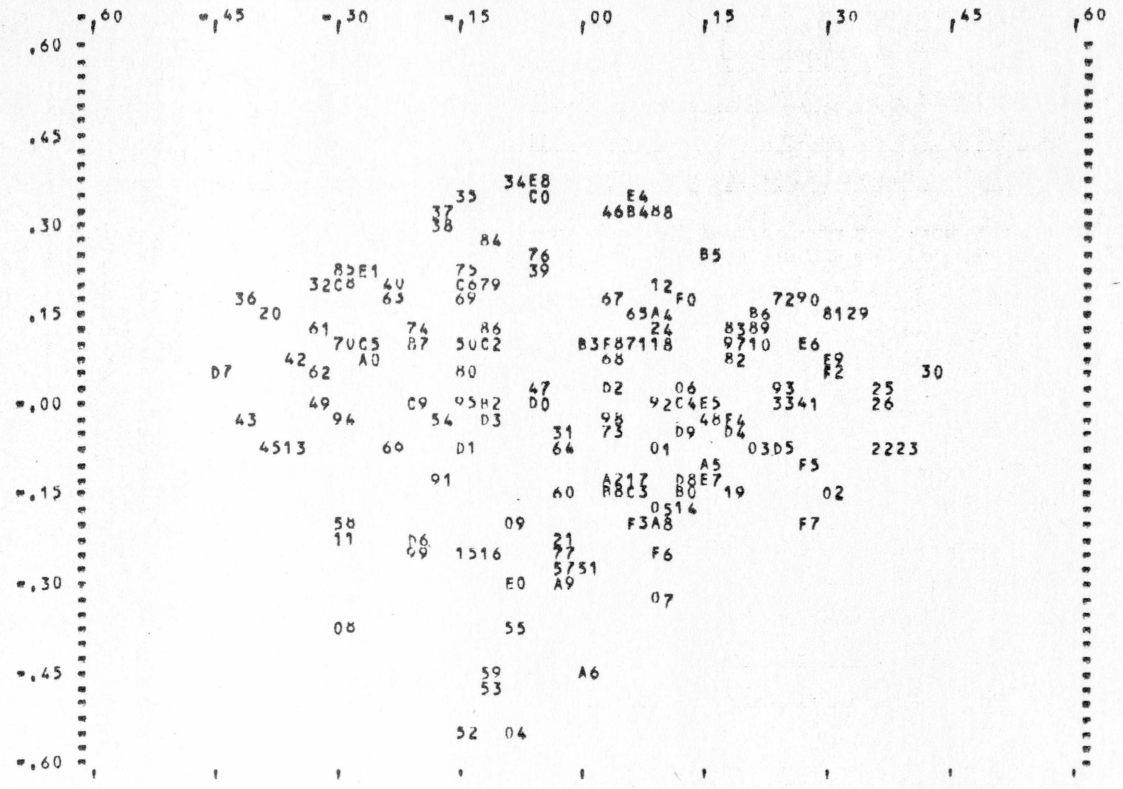



UNIT 41 COINCIDES WITH UNIT 37
UNIT 74 COINCIDES WITH UNIT 34
UNIT 62 COINCIDES WITH UNIT 12
UNIT 143 COINCIDES WITH UNIT 89
UNIT 124 COINCIDES WITH UNIT 42
UNIT 156 COINCIDES WITH UNIT 43
UNIT 50 COINCIDES WITH UNIT 46
UNIT 119 COINCIDES WITH UNIT 20
UNIT 130 COINCIDES WITH UNIT 28
UNIT 102 COINCIDES WITH UNIT 26
UNIT 111 COINCIDES WITH UNIT 98
UNIT 116 COINCIDES WITH UNIT 114
UNIT 51 COINCIDES WITH UNIT 2
UNIT 69 COINCIDES WITH UNIT 64
UNIT 85 COINCIDES WITH UNIT 33
UNIT 97 COINCIDES WITH UNIT 24
UNIT 104 COINCIDES WITH UNIT 82
UNIT 115 COINCIDES WITH UNIT 13
UNIT 118 COINCIDES WITH UNIT 63
UNIT 105 COINCIDES WITH UNIT 87
UNIT 10 COINCIDES WITH UNIT 7
UNIT 60 COINCIDES WITH UNIT 59




UNIT 41 COINCIDES WITH UNIT 15
UNIT 40 COINCIDES WITH UNIT 22
UNIT 125 COINCIDES WITH UNIT 91
UNIT 46 COINCIDES WITH UNIT 9
UNIT 88 COINCIDES WITH UNIT 0
UNIT 92 COINCIDES WITH UNIT 76
UNIT 160 COINCIDES WITH UNIT 19
UNIT 121 COINCIDES WITH UNIT 72
UNIT 146 COINCIDES WITH UNIT 7
UNIT 106 COINCIDES WITH UNIT 96
UNIT 104 COINCIDES WITH UNIT 52
UNIT 142 COINCIDES WITH UNIT 93
UNIT 150 COINCIDES WITH UNIT 90
UNIT 103 COINCIDES WITH UNIT 3
UNIT 143 COINCIDES WITH UNIT 129
UNIT 83 COINCIDES WITH UNIT 63
UNIT 75 COINCIDES WITH UNIT 69
UNIT 117 COINCIDES WITH UNIT 69
UNIT 118 COINCIDES WITH UNIT 86

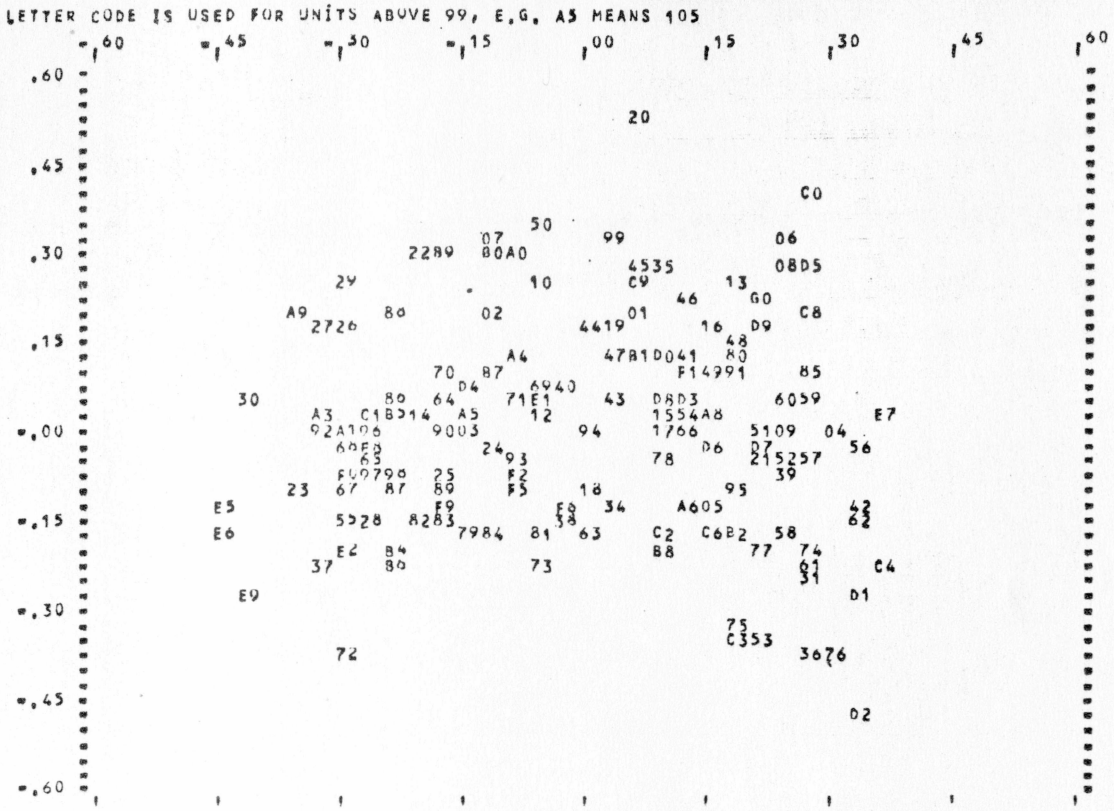
PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2 (d) SAMPLE-II TUBER CHARACTERS
LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105




UNIT 96 COINCIDES WITH UNIT 86
UNIT 119 COINCIDES WITH UNIT 89
UNIT 142 COINCIDES WITH UNIT 89
UNIT 111 COINCIDES WITH UNIT 97
UNIT 121 COINCIDES WITH UNIT 71
UNIT 27 COINCIDES WITH UNIT 25
UNIT 78 COINCIDES WITH UNIT 6
UNIT 28 COINCIDES WITH UNIT 26
UNIT 44 COINCIDES WITH UNIT 33
UNIT 103 COINCIDES WITH UNIT 82
UNIT 107 COINCIDES WITH UNIT 92
UNIT 143 COINCIDES WITH UNIT 95
UNIT 159 COINCIDES WITH UNIT 26
UNIT 101 COINCIDES WITH UNIT 68
UNIT 117 COINCIDES WITH UNIT 98
UNIT 127 COINCIDES WITH UNIT 102
UNIT 151 COINCIDES WITH UNIT 60
UNIT 160 COINCIDES WITH UNIT 108
UNIT 56 COINCIDES WITH UNIT 16

PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2 (e) SAMPLE-II PLANT AND FRESH LEAF CHARACTERS

LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105

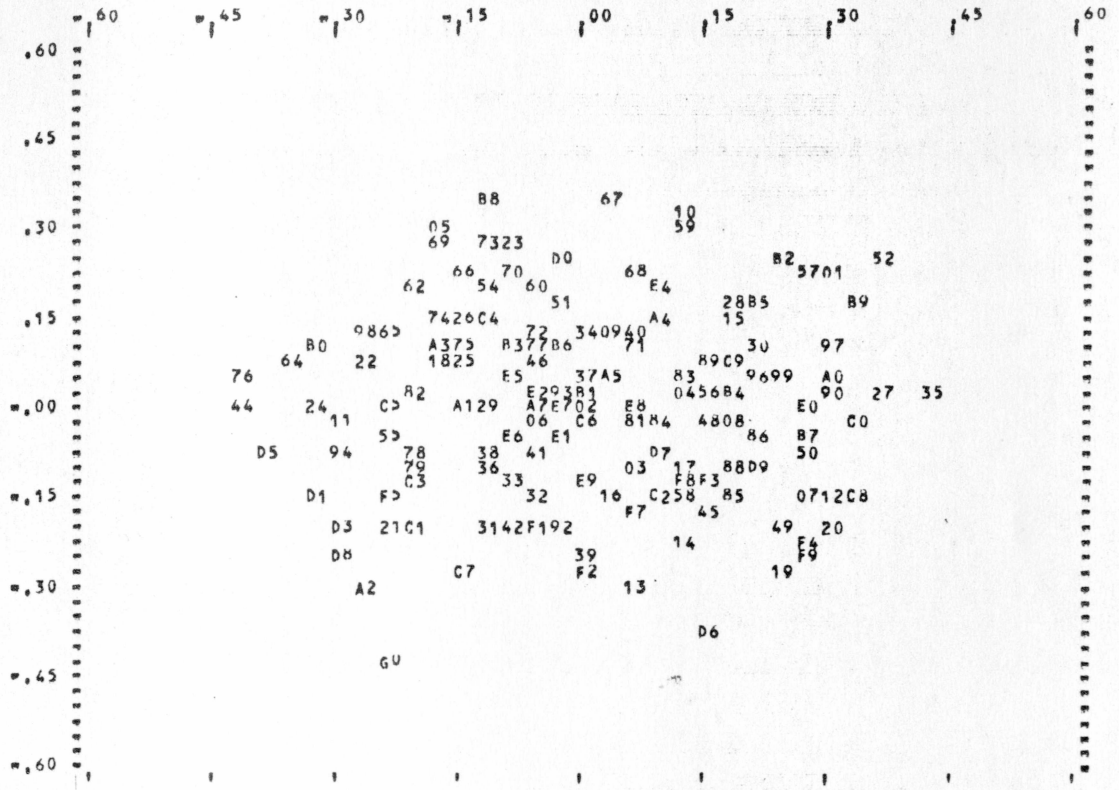



UNIT 140 COINCIDES WITH UNIT 8
UNIT 143 COINCIDES WITH UNIT 1
UNIT 157 COINCIDES WITH UNIT 139
UNIT 115 COINCIDES WITH UNIT 104
UNIT 153 COINCIDES WITH UNIT 47
UNIT 107 COINCIDES WITH UNIT 71
UNIT 156 COINCIDES WITH UNIT 133
UNIT 11 COINCIDES WITH UNIT 4
UNIT 33 COINCIDES WITH UNIT 24
UNIT 125 COINCIDES WITH UNIT 21
UNIT 127 COINCIDES WITH UNIT 57
UNIT 102 COINCIDES WITH UNIT 89
UNIT 144 COINCIDES WITH UNIT 23
UNIT 154 COINCIDES WITH UNIT 73
UNIT 32 COINCIDES WITH UNIT 31

PRINCIPAL COORDINATE PLOT
CROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2

(f) SAMPLE-II LEAF HERBARIUM CHARACTERS

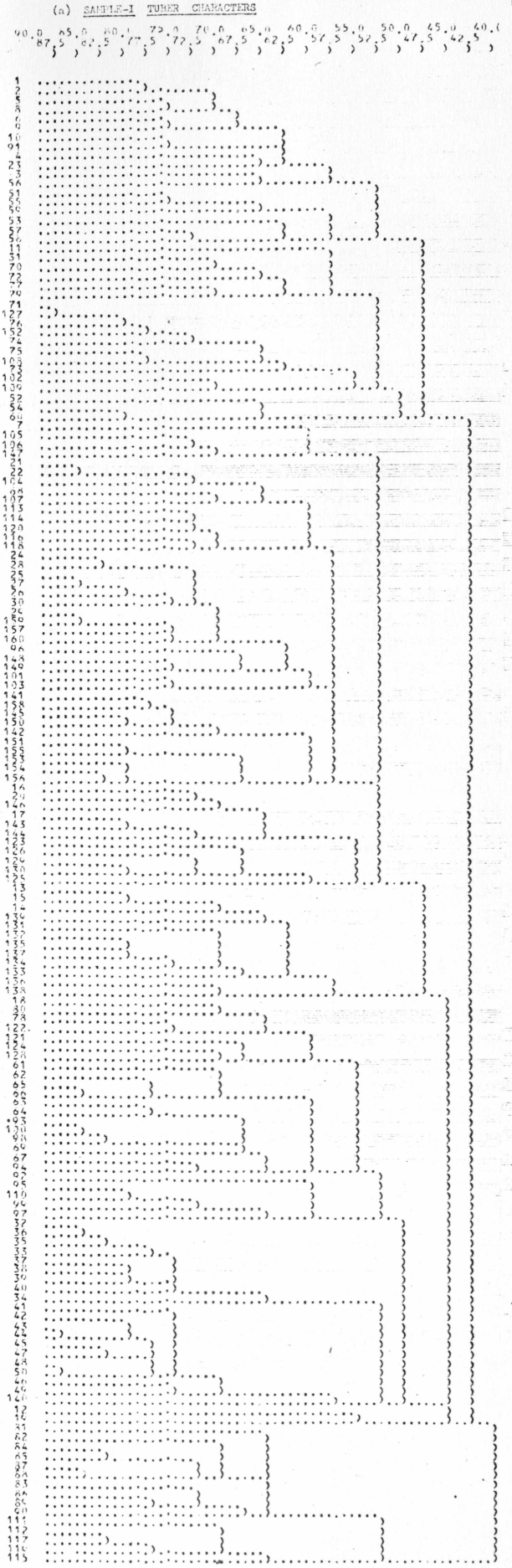
LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105



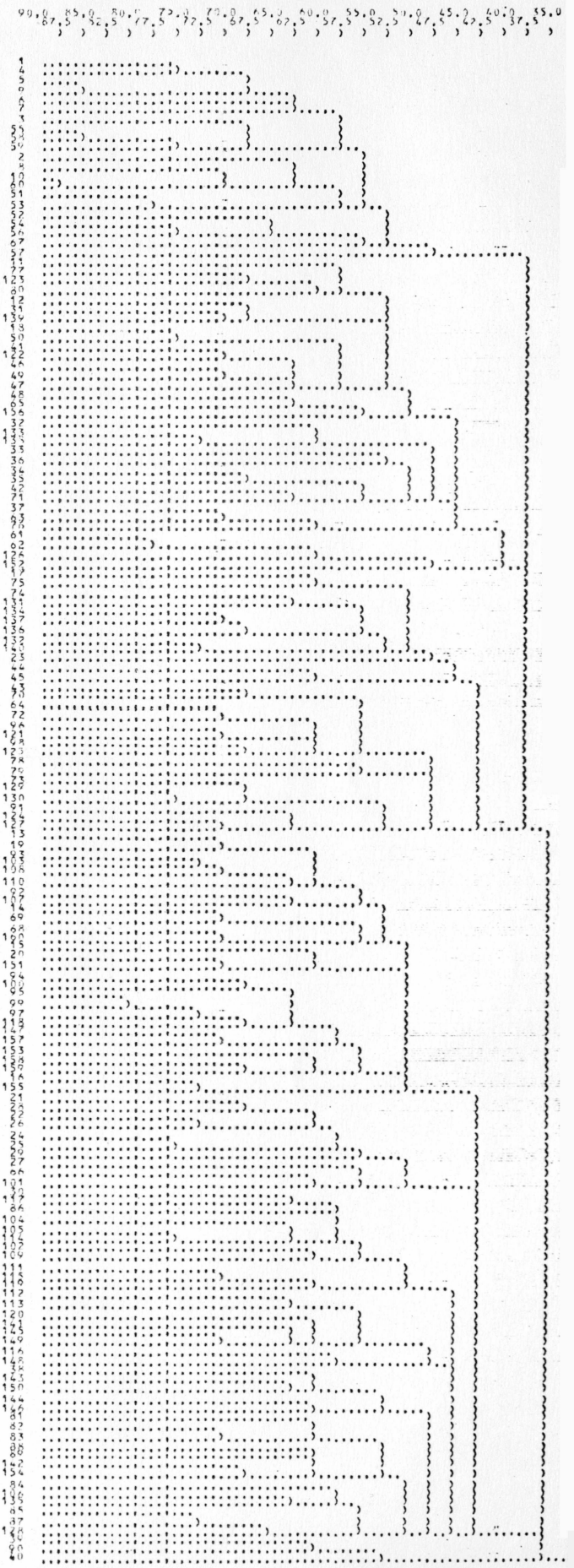

UNIT 106 COINCIDES WITH UNIT 51
UNIT 150 COINCIDES WITH UNIT 28
UNIT 53 COINCIDES WITH UNIT 26
UNIT 95 COINCIDES WITH UNIT 26
UNIT 61 COINCIDES WITH UNIT 54
UNIT 63 COINCIDES WITH UNIT 54
UNIT 91 COINCIDES WITH UNIT 9
UNIT 80 COINCIDES WITH UNIT 77
UNIT 108 COINCIDES WITH UNIT 6
UNIT 134 COINCIDES WITH UNIT 38
UNIT 109 COINCIDES WITH UNIT 36
UNIT 47 COINCIDES WITH UNIT 16
UNIT 143 COINCIDES WITH UNIT 85
UNIT 156 COINCIDES WITH UNIT 45
UNIT 67 COINCIDES WITH UNIT 42
UNIT 132 COINCIDES WITH UNIT 31
UNIT 43 COINCIDES WITH UNIT 39

Fig. 4.9 Dendrograms produced by average linkage clustering of the sixteen families analysed together using tuber, plant and fresh leaf, and leaf herbarium characters separately.

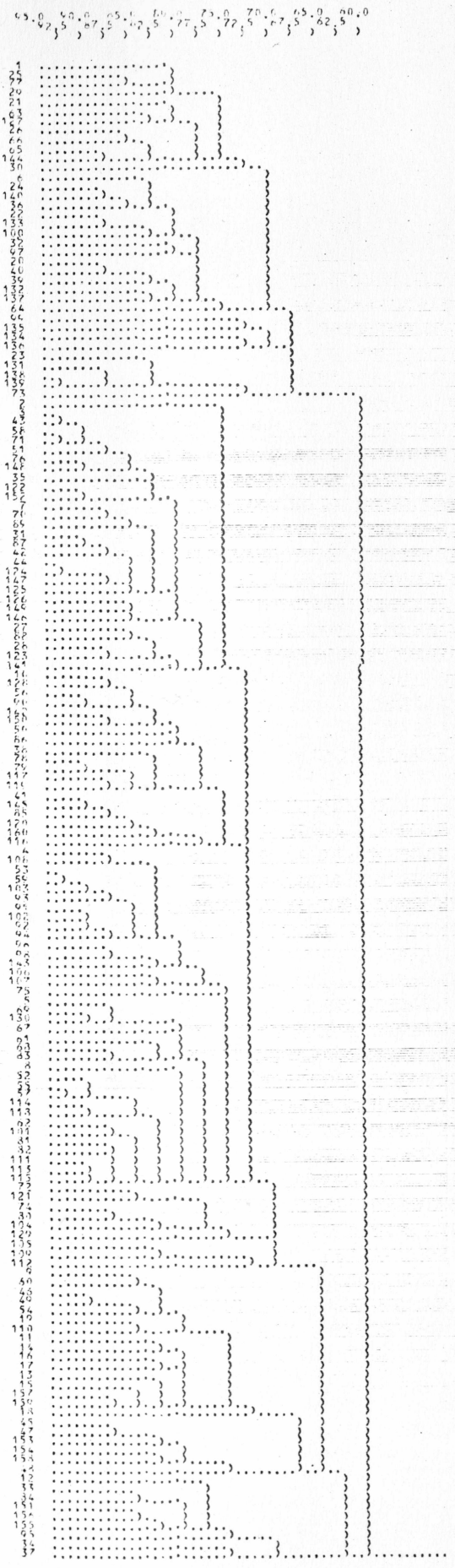
DENDROGRAM (a) SAMPLE-I TUBER CHARACTERS



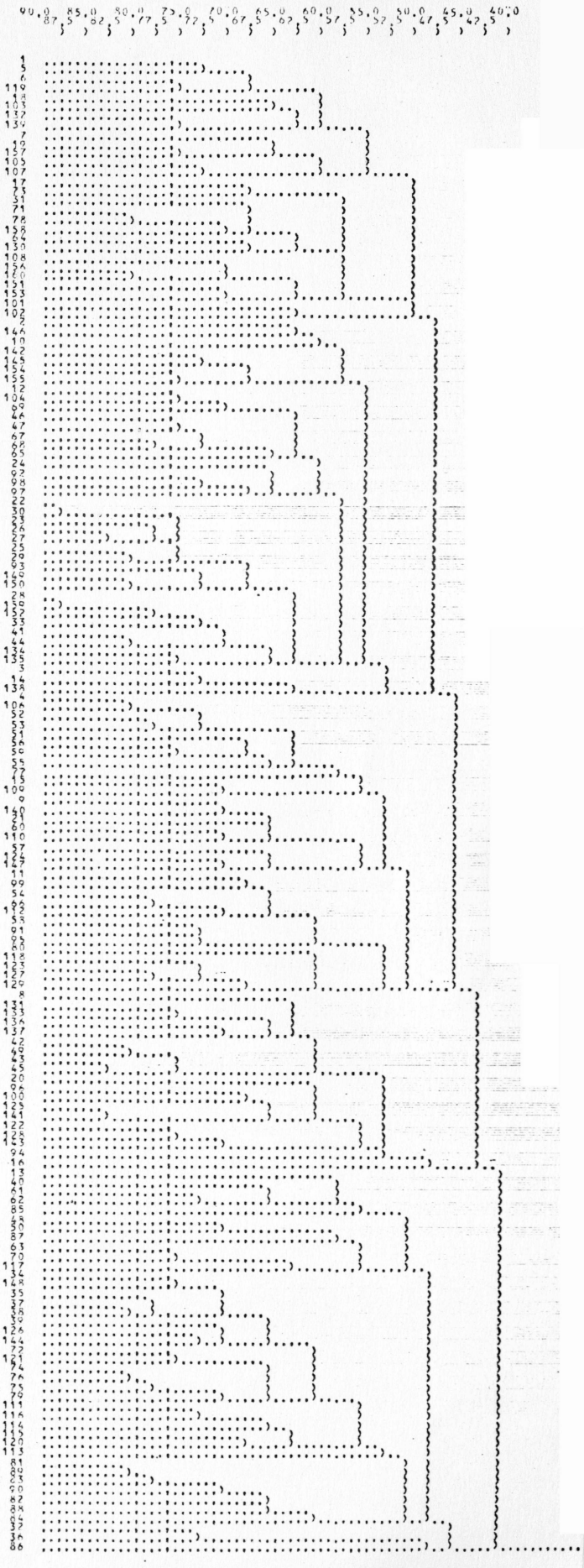

DENDROGRAM (b) SAMPLE-I PLANT AND FRESH LEAF CHARACTERS



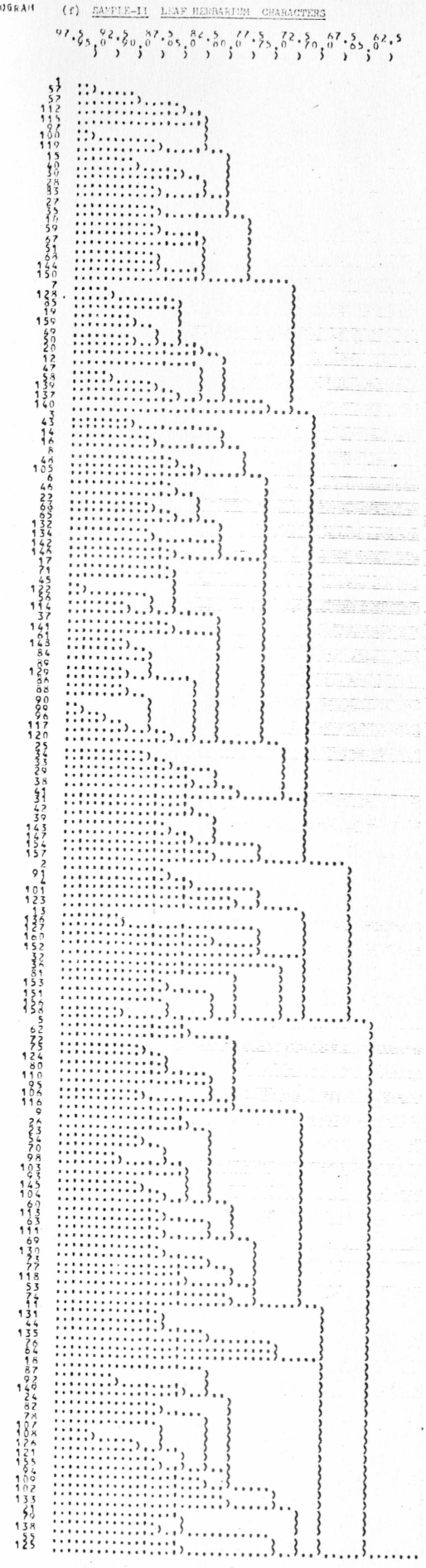
DENDROGRAM (c) SAMPLE-I LEAF HERBARIUM CHARACTERS



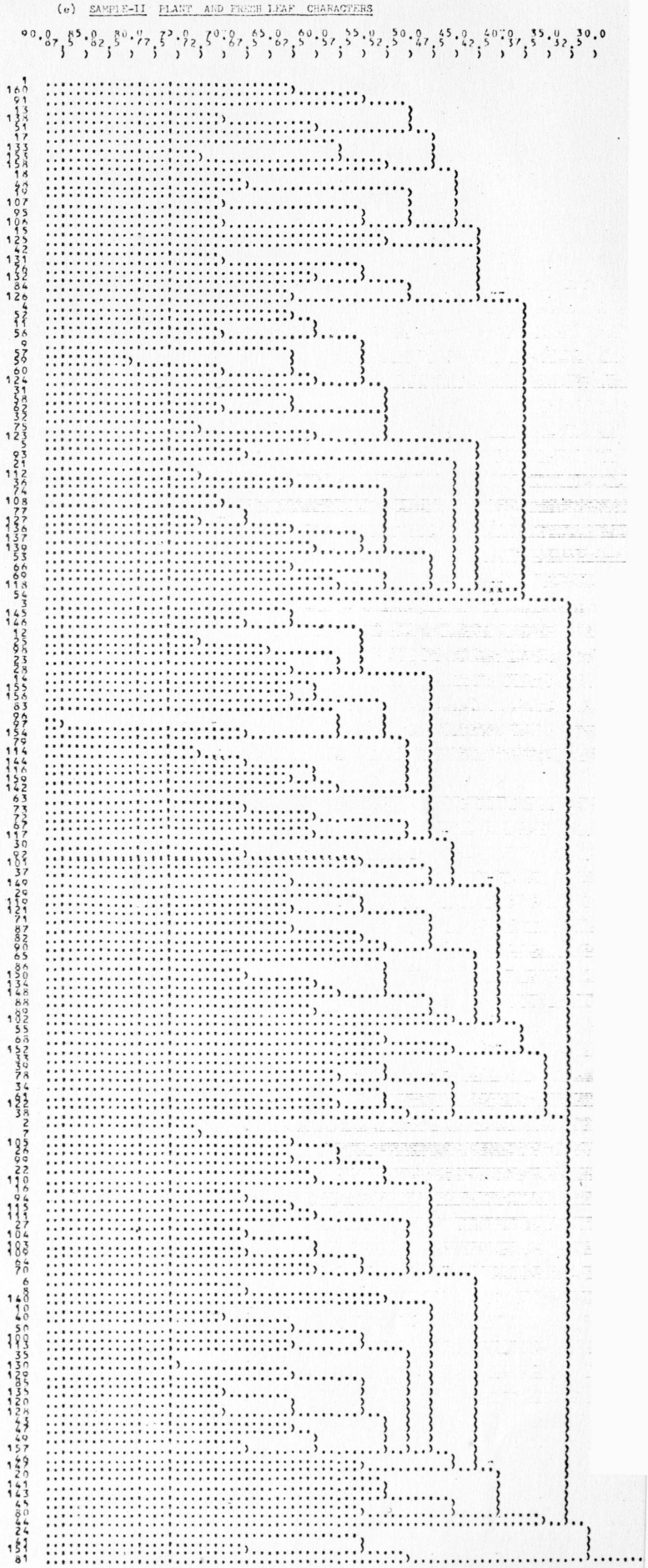

DENDROGRAM (d) SAMPLE-II TUBER CHARACTERS



DENDROGRAM (f) SAMPLE-II LEAF HERBARIUM CHARACTERS




DENDROGRAM (e) SAMPLE-II PLANT AND FRESH LEAF CHARACTERS



4.4.4.2.5. Relating the characters used to the vectors of the PCO analysis

As compared to the result obtained from the analysis of each family separately in sect. 4.4.4.1., the contribution of most of the characters increased significantly on the first four components (Appendix XI ). This may be due to the more defined data structure. In many cases, a character loaded significantly for more than one component. The loadings were different when the data were analysed altogether and when they were split into tuber characters, plant and fresh leaf characters, and leaf herbarium characters. Also, SAMPLE-I and SAMPLE-II gave different loadings. All these may be attributed to the difference in data structure and the interaction between the different sets of characters.

There were indications that the following groups of characters may be related:-

(1) No. of non-dormant tubers (6) and degree of tuber dormancy (7).

(2) No. of eyes per tuber (16) and length of tuber eye-brow (17).

(3) Secondary tuber flesh colour (22) and distribution of secondary tuber flesh colour (23).

(4) Colour of sprout (27) and distribution of the sprout pigment (28).

(5) Shape of stem (35), width of stem wing (37) and shape of stem wing (38).

(6) Intensity of stem pigment (40) and Distribution of stem pigment (41).

(7) Pubescence of upper surface of primary leaflet (54) and

pubescence of lower surface of primary leaflet (55).

(8) Pigmentation of upper surface of leaf rachis (58), intensity of the pigmentation in character - 58 (59), pigmentation of the nodal area of leaf rachis (60), intensity of pigmentation in Character - 60 (61) and pigmentation of the midrib of the terminal leaflet (62).

(9) Length of leaf (65) and width of leaf (66).

(10) Number of primary lateral leaflets (69), number of secondary lateral leaflets (70), number of tertiary lateral leaflets (71), number of acroscopic leaflets (72), number of basiscopic leaflets (73), number of semibasiscopic leaflets (74) and number of secondary nad tertiary leaflets on terminal petiolules (75).

(11) Length of terminal leaflet lamina (87) and length of the first lateral leaflet lamina (91).

(12) Width of terminal leaflet (88) and width of the first lateral leaflet lamina (92).

(13) Length of the biggest secondary lateral leaflet (96), width of the biggest secondary lateral leaflet (97), distance from the base to the widest part of the biggest secondary lateral leaflet (98) and length of the longest petiolule (99).

However, no firm decision is possible to eliminate some of these related characters because the four components only accounted

for a very low percentage of the total variance of the original variables. Decision depends on how each character loads in the subsequent components. It is recommended to carry out further analysis using ratios to correct for possible 'size' and 'density' factors, or even after eliminating some of those characters suspected to be duplicate measurements. (These were not done because of the time factor).

## 4.5. Validity of the Numerical analysis

The segregation of sixteen known hybrid families was used to test the sensitivity of a series of multivariate analysis to cluster according to the genetic make-up of the material. The analyses tested were PCO, PCA, MST, "REGROUP" (a technique to maximise within group similarity), nearest neighbours list, single linkage clustering, average linkage clustering and Ward's method. The two resemblance coefficients used were the standard similarity coefficient in CLASP and Euclidean distance. They were all procedures from the computer classification packages, CLASP and CLUSTAN 1A.

In the first part of the analysis, each family was analysed separately to give more insight into the nature of the segregation. Two types of segregation were detected. Firstly, there were those that formed clusters e.g. FAM-03, FAM-05, FAM-10 and FAM-14 and then those without any clusters formed e.g. FAM-06 and FAM-07. This may be attributed to the interaction of the different genomes (the parents).

The results of all these analyses, namely PCO, MST, "REGROUP" and average linkage clustering coincided well. Groups were formed for all the families and some families had more defined groups than others. Members of the same group were supposed to be more similar than those of another group. This was tested and confirmed in the second part of the analyses (see below).

In the second part of the analysis, two samples of 160 individuals each were taken, i.e. each sample had ten representations from a family. The first sample, SAMPLE-I, had all the 10 individuals of a family from one single group whenever possible, if not, the next closest group were also sampled. The data were therefore believed to be more well structured. The second sample, SAMPLE-II, had the ten individuals of each family from all the groups found in the family. The data should then be more diverse.

Analyses done on these two samples (Sect. 4.4.4.2.3) showed consistently the orderly clustering of SAMPLE-I according to the family. This was not so for SAMPLE-II. Results from the use of the standard similarity coefficient and mixed-mode data were better than that obtained by converting all the data into continuous type and then using Euclidean distance as a measure of resemblance.

These analyses to a certain extent were able to identify any genetic relationship present (sect. 4.4.4.2.3). However, since most of diploid clones may be related to each other in some complex way the ability to predict any such relationships depends on the

parents involved (i.e. the interaction of the different genomes). No firm conclusion was reached here. More organised crosses involving better selected parents may reveal more information on this. These were carried out and are given in Chapter 6.

On the whole, the results indicated that the variables used, the coding done and the numerical methods used were sensitive enough even to find out segregating groups within a family.

## 4.6 Numerical taxonomic study on the morphology of the diploid cultivars

### 4.6.1 Materials and Methods

The whole diploid collection from the International Potato Centre cultivated potato gene bank was used for this study. This included about 938 accessions from the established collection and an additional 178 accessions from the new collection made in southern Peru in the Ayacucho, Apurimac and Cuzco areas in the 1977/78 season. After eliminating the duplicates about 500 clones were left for study in the established collection. No detailed studies were carried out on the southern Peru collection.

Since it was not possible to finish all the work in the 1977/78 season, it was scheduled to have it completed in the 1978/79 season. The planting in the 1978/79 season was not an exact replication of that in the 1977/78 season planting. This is because the whole collection is replicated twice, one in the field and the other in the cold store. Due to the difference in the elimination of duplicates in each replicate and also other causes they now differ in their compositions.

As a result many clones have to be excluded from analysis. A summary of the number of clones examined for each part of the plant is given below.

| Part of plant | No. of clones measured |
|---|---|
| Tuber | 435 |
| Plant & fresh leaf | 490 |
| Leaf herbarium | 509 |
| Flower | 436 |
| Whole plant | 327 |

The growing materials were part of the yearly propagating cycle in the maintenance of the germplasm collection at Huancayo, Peru (3,300 m). The growing season lasts from October to April. Each clone was planted in a row of ten hills. The field was arranged in blocks of 24 rows each, with a spacing of 1m between rows and between blocks. Standard agronomic practice was followed to allow optimal growth and disease-free stand. Plenty of good healthy materials were therefore available for study. However, quite a large number of clones were infected with virus and in several cases, no morphological study was possible.

4.6.2. Characters used

A total of 124 characters were used. They are:-

TUBER CHARACTERS

1. Shape of tuber (N)*

   1. compressed from base to apex.

   2. normal - round, oval, oblong, cylindrical

3. fusiform.

4. pyriform.

5. falcate.

2. Type of tuber end (N)

1. acute

2. round

3. obtuse

4. slightly flattened

5. flattened

3. Primary tuber skin colour (N)

1. yellow

2. brown

3. red

4. purple

5. black

4. Intensity of the primary tuber skin colour (O)

1. light

2. moderate

3. dense

5. Secondary tuber skin colour (N)

0. none

1. red

2. red-purple

3. purple

6. Distribution of the secondary tuber skin colour (N)

0. none

1. scattered - when the secondary colour is distributed at random in one or more areas around the tuber.

2. splashed - when the secondary colour is confined to areas around the eyes
3. spectacled - when the primary colour is confined to areas around the eyes and the remainder of the tuber is of secondary colour.

7. Type of boundary between the primary and the secondary colour (N)
   0. not define
   1. define
8. Location of skin pigment (N)
   0. none
   1. cork
   2. cork and hypodermis
   3. hypodermis
   4. cork and hypodermis and cortex
   5. cortex
9. Number of lenticel (O)
   1. few
   2. moderate
   3. many
10. Depth of tuber eyes (O)
   1. shallow
   2. moderate
   3. deep
11. Distribution of tuber eyes (N)
   1. evenly distributed
   2. predominantly apical
12. Number of tuber eye (O)
   1. few
   2. moderate
   3. many

13. Length of eye-brow (O)

    1. short
    2. medium
    3. long

14. Degree of tuber dormancy (O)

    0. dormant
    1. fairly dormant
    2. weakly dormant
    3. very weakly dormant
    4. not dormant

15. Shapes of area behind the tuber eyebrow (N)

    1. strongly bulging uniformly
    2. bulging uniformly
    3. slightly bulging uniformly
    4. flat
    5. slightly bulging skewly toward the eye
    6. bulging skewly toward the eye
    7. strongly bulging skewly toward the eye

16. Primary tuber flesh colour (N)

    1. white
    2. yellow white
    3. light yellow
    4. yellow
    5. deep yellow

17. Secondary tuber flesh colour (N)

    0. none
    1. light red
    2. red

3. red-purple

4. purple

5. dark purple

18. Length of tuber (cm) (C).

19. Greater width of tuber (cm) (C).

20. Smaller width of tuber (cm) (C).

21. Size of stem (O)

1. thin

2. intermediate

3. thick

22. Width of stem wing (O)

0. none

1. narrow

2. wide

23. Type of wing (N)

0. none

1. smooth

2. wavy

24. Colour of stem (N)

1. yellowish green

2. green

3. dark green

4. chocolate

25. Pigmentation of stem (N)

0. none

1. red

2. purple

3. chocolate

26. Intensity of stem pigmentation (O)

    0. none
    1. light
    2. medium
    3. dense

27. Type of stem pigmentation (N)

    0. none
    1. spotted
    2. patchy

28. Colour of apical shoot (bud) (N)

    1. yellow
    2. green
    3. red
    4. purple

29. Colour of leaf (N)

    1. yellowish green
    2. green
    3. dark green

30. Pigmentation of rachis (N)

    0. none
    1. red
    2. purple
    3. chocolate

31. Intensity of rachis pigmentation (O)

    0. none
    1. light
    2. medium
    3. dense

32. Pigmentation of the nodal area of rachis (N)

    0. none

    1. red

    2. purple

33. Degree of leaf arch (O)

    1. curved down

    2. straight

    3. curved up

34. Degree of leaflet involution (O)

    0. none

    1. slight

    2. strong

35. Type of leaflet margin (N)

    0. smooth

    1. wavy

36. Degree of leaflet glossiness (O)

    1. dull

    2. moderate

    3. shiny

37. Depth of leaflet vein (O)

    1. weak

    2. moderate

    3. strong

38. Pubescence of rachis wing (O)

    1. sparse

    2. moderate

    3. dense

39. Pubescence of upper surface of leaflet (O)

    1. sparse
    2. moderate
    3. dense

40. Pubescence of lower surface vein of leaflet (O)

    1. sparse
    2. moderate
    3. dense

41. Size of pseudostipule (O)

    1. small
    2. intermediate
    3. big

42. Degree of curving of pseudostipule toward the stem (O)

    1. straight
    2. slightly curved
    3. strongly curved

43. Pattern of the terminal and the first pair of lateral leaflets (O)

    1. close
    2. intermediate
    3. open

44. The pair of primaries where the leaf is widest (O)

    1. first pair
    2. between first and second pairs
    3. second pair
    4. between second and third pairs

45. Length of leaf (cm) (C)

46. Width of leaf (cm) (C)

47. Distance from base to the widest part of leaf (cm) (C)
48. Length of petiole (cm) (C)
49. Length of terminal petiolule (cm) (C)
50. Length of terminal leaflet lamina (cm) (C)
51. Width of terminal leaflet lamina (cm) (C)
52. Distance from base to the widest part of terminal leaflet (cm) (C)
53. Length of first petiolule (cm) (C)
54. Length of first lateral lamina (cm) (C)
55. Width of first lateral lamina (cm) (C)
56. Distance from base to the widest part of first lateral lamina (cm) (C)
57. Length of rachis between the first and second pair of laterals (cm) (C)
58. Length of longest petiolule (cm) (C)
59. Length of the largest secondary leaflet (cm) (C)
60. Width of the largest secondary leaflet (cm) (C)
61. Distance from base to the widest part of largest secondary leaflet (cm) (C)
62. Number of primary lateral leaflets (M)
63. Number of secondary lateral leaflets (M)
64. Number of tertiary lateral leaflets (M)
65. Number of acroscopic leaflets (M)
66. Number of basiscopic leaflets (M)
67. Number of semibasiscopic leaflets (M)
68. Type of terminal leaflet apex (N)
    1. acute
    2. obtuse
69. Type of terminal leaflet base (N)
    1. cordate

2. truncate

3. obtuse

4. cuneate

70. Symmetry of first lateral leaflet base (N)

1. upper side longer

2. symmetry

3. lower side longer

71. Type of inflorescence (N)

1. compact

2. semi-compact

3. loose

72. Number of flowers per inflorescence (O)

1. 1-5

2. 6-10

3. 11 or more

73. Length of peduncle (cm) (C)

74. Length of pedicel from base to articulation (cm) (C)

75. Length of pedicel from articulation to calyx (cm) (C)

76. Pigmentation of pedicel (N)

0. none

1. red

2. brown

3. purple

4. black

77. Intensity of pedicel pigmentation below articulation (O)

0. none

1. light

2. moderate

3. dense

78. Intensity of pedicel pigmentation at articulation (O)

    0. none
    1. light
    2. moderate
    3. dense

79. Intensity of pedicel pigmentation above articulation (O)

    0. none
    1. light
    2. moderate
    3. dense

80. Distribution of pigmentation in pedicel (O)

    0. none
    1. ¼-pigmented
    2. ½-pigmented
    3. ¾-pigmented
    4. all pigmented

81. Type of pedicel pubescence (N)

    1. short
    2. intermediate
    3. long

82. Intensity of pedicel pubescence (O)

    1. sparse
    2. intermediate
    3. dense

83. Length of calyx (mm) (C)

84. Length of calyx lobe (mm) (C)

85. Length of calyx acumen (mm) (C)

86. Symmetry of calyx lobe (N)

    1. uniform
    2. 2 + 3

3. 1 + 2 + 2

4. 1 + 4

87. Presence of calyx rib (O)

0. none

1. slight

2. moderate

3. strong

88. Presence of calyx ring (O)

0. none

1. slight

2. moderate

3. strong

89. Presence of leafy calyx lobe (O)

0. absent

1. slight

2. leafy

90. Shape of calyx acumen (N)

1. very acuminate

2. acuminate

3. slightly acuminate

4. not acuminate

91. Diameter of calyx base (N)

1. small

2. medium

3. large

92. Pigmentation of calyx (N)

0. None

1. red

2. reddish brown

3. brown

4. purplish brown

5. purple

6. black

93. Distribution of pigmentation of calyx (N)

0. none

1. ¼-pigmented

2. ½-pigmented

3. ¾-pigmented

4. all pigmented

94. Intensity of calyx pubescence (O)

1. sparse

2. moderate

3. dense

95. Diameter of corolla (cm) (C)

96. Length of petal (cm) (C)

97. Length of interpetallary area (cm) (C)

98. Length of petal lobe (mm) (C)

99. Length of petal acumen (mm) (C)

100. Length of petal lobe star (cm) (C)

101. Width of petal lobe (cm) (C)

102. Width of petal acumen (mm) (C)

103. Shape of corolla (O)

1. stellate

2. pentagonal

3. semi-rotate

4. rotate

104. Shape of corolla shoulder (O)

1. absent

2. present, flattened

3. present, lobed

105. Colour of corolla (N)

0. white

1. very red

2. red

3. red-purple

4. purple

5. blue-purple

106. Colour intensity of the central petal streak (O)

0. white

1. light

2. medium

3. dense

107. Colour of corolla star (N)

1. green

2. yellow

3. silvery

4. chocolate

108. Intensity of corolla acumen pubescence (O)

1. sparse

2. moderate

3. dense

109. Length of anther (mm) (C)

110. Length of anther filament (mm) (C)

111. Length of anther filament attachment (mm) (C)

112. Shape of anther column (cf. Fig. 4.10) (N)

113. Grouping of anthers (N)

0. uniform
1. 1 + 4
2. 1 + 2 + 2
3. 2 + 3
4. 2 + 2 + 1
5. 3 + 2
6. 4 + 1

114. Curvature of anther (N)

0. straight
1. base curve
2. lower quarter curve
3. smooth curve

115. Basal sinus of anther (O)

0. none
1. slight
2. moderate
3. strong

116. Colour of anther (O)

1. light yellow
2. yellow
3. dark yellow

117. Length of style (mm) (C)

118. Style exsertion (O)

0. none
1. short
2. medium
3. long

119. style thickness (O)

1. thin
2. moderate
3. thick

120. shape of ovary (N)

1. thin cone
2. high cone
3. cone
4. fat cone

121. Colour of ovary (N)

1. white
2. white-green
3. light green
4. green

122. Internal pigmentation of ovary (O)

0. none
1. ¼-pigmented
2. ½-pigmented
3. all pigmented

123. Shape of stigma (N)

0. oval
1. round
2. round capitate
3. capitate
4. flat capitate
5. double crown

124. Size of stigma (O)

1. small
2. intermediate
3. big

* N - nominal type

O - ordinal type

M - meristic type

C - continuous type

It was not possible to use the whole set of characters that were used to study the hybrids here. Several of them had to be deleted and others were added. For example, in the case of tuber number, it could not possibly be counted as for the hybrids because it is very much affected by the field environment. Also, some diseases and physiological stresses affect the number of tubers produced. This is also true for several other characters. In other cases, the character states were modified instead of eliminating the character totally.

It should also be noted that a very strong hailstorm on the 19.1.79 had badly damaged the diploid germplasm plots. That was the season that plant habit, fresh leaf and flower characters were taken. Several of these characters had to be omitted.

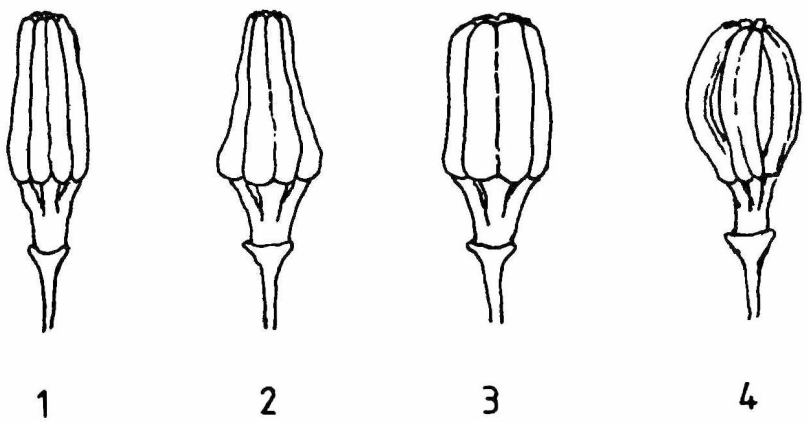



Fig. 4.10 The four character states of anther column shape.

4.6.3. Numerical analysis

Results from Sect. 4.4.4.1. and Sect. 4.4.4.2. have indicated the validity of the variables used, the coding done and the efficiency of the numerical techniques used, namely PCO, MST, "REGROUP" and average linkage analysis when used with the standard similarity coefficient provided in CLASP.

The full data set had a matrix size of 327 x 124 which was far too big for the CLASP at the University of Manchester Regional Computer Centre (CDC 7600) to handle. It was instead done at the Department of Statistics, Rothamsted Experimental Station with the help of Drs. R. White and G. J. S. Ross. Their help and cooperation were very much appreciated.

No attempts were made to carry out an analysis on the data for different parts of the plant separately as this was shown to be unnecessary or even misleading (Sect. 4.4.4.2.4.). However, if time would have allowed analyses using various combinations of characters from every part of the plant might have given some interesting results. The use of ratios to correct for suspected "size" and "density" effect would have been tried out also.

4.6.4. Results and discussion

"REGROUP"

The procedure "REGROUP" gave rise to eleven groups with a mean similarity of 58.4% within the groups. They are shown in Table 4.15.

The result will be compared with that of other analyses below before any detailed correlation study with the visual morphological grouping carried out in the field and the data on the collection site is to be done.

The mean similarity between and within groups is shown in Table 4.16. These values were quite low compared to that of the highest similarity of 79.4% between HUA 822 and OCH 5392 and that of the average value of 67.7% from MST analysis. There is not much difference between the between- and the within- groups values. All these may point to the close relationship between most of the clones in the population.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 57.7 | | | | | | | | | | |
| 2 | 55.5 | 57.9 | | | | | | | | | |
| 3 | 53.0 | 55.0 | 59.4 | | | | | | | | |
| 4 | 53.1 | 52.4 | 52.5 | 58.3 | | | | | | | |
| 5 | 53.9 | 52.7 | 54.2 | 53.8 | 57.8 | | | | | | |
| 6 | 52.2 | 53.4 | 54.3 | 52.1 | 54.2 | 59.7 | | | | | |
| 7 | 54.0 | 53.2 | 54.3 | 54.1 | 54.1 | 52.8 | 58.8 | | | | |
| 8 | 54.9 | 54.3 | 52.6 | 54.7 | 54.2 | 55.8 | 53.7 | 60.1 | | | |
| 9 | 52.7 | 52.7 | 52.9 | 55.0 | 54.6 | 54.5 | 53.7 | 53.7 | 57.7 | | |
| 10 | 52.3 | 52.5 | 53.0 | 51.3 | 53.5 | 55.3 | 52.0 | 53.6 | 53.5 | 57.6 | |
| 11 | 54.3 | 52.1 | 53.8 | 53.8 | 55.1 | 54.5 | 55.6 | 55.0 | 53.5 | 53.3 | 58.5 |

TABLE 4.16: Mean similarity between and within groups.

Table 4.15 Result of 'REGROUP' analysis of the cultivars.

GROUP 1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 42 | C701915 | 66 | C702505 | 73 | C702742 | 80 | C702991 |
| 132 | HJT5653 | 137 | HJT5711 | 138 | HJT5773 | 146 | HJT5826 |
| 157 | HJT5903 | 161 | HJT5937 | 197 | H/J 49 | 202 | H/J 97 |
| 210 | H/J 274 | 211 | H/J 301 | 214 | H/J 351 | 217 | H/J 441 |
| 223 | H/J 609 | 226 | JAK 56 | 230 | OCH3409 | 242 | OCH3567 |
| 280 | OCH5721 | 281 | OCH5734 | 289 | OCH5919 | 292 | OCH5948 |
| 306 | OCH6279 | 315 | OCH6421 | | | | |

TOTAL S 1501.4 MEAN S 57.7

GROUP 2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | C700427 | 24 | C701165 | 30 | C701592 | 32 | C701739 |
| 49 | C702151 | 84 | C703089 | 87 | C703125 | 95 | CUS 117 |
| 104 | CUS 102 | 113 | CUS 549 | 120 | HAW5564 | 121 | HAW5593 |
| 125 | HJT5442 | 126 | HJT5500 | 127 | HJT5515 | 139 | HJT5777 |
| 155 | HJT5873 | 156 | HJT5882 | 171 | HJT6147 | 184 | HUA 884 |
| 219 | H/J 495 | 244 | OCH3571 | 259 | OCH5226 | 269 | OCH5561 |
| 272 | OCH5644 | 282 | OCH5762 | 317 | OCH6471 | 319 | OCH6498 |
| 320 | OCH6506 | | | | | | |

TOTAL S 1678.5 MEAN S 57.9

GROUP 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | C700403 | 17 | C700936 | 18 | C700939 | 21 | C701119 |
| 22 | C701137 | 37 | C701886 | 86 | C703117 | 88 | C703150 |
| 114 | CUS 632 | 136 | HJT5668 | 154 | HJT5871 | 158 | HJT5894 |
| 159 | HJT5919 | 172 | HJT6158 | 180 | HUA 863 | 186 | HUA 899 |
| 194 | H/J 3 | 195 | H/J 26 | 222 | H/J 591 | 225 | JAK 48 |
| 230 | JAK 100 | 326 | OCH6538 | | | | |

TOTAL S 1306.5 MEAN S 59.4

GROUP 4

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20 | C701109 | 27 | C701266 | 29 | C701518 | 35 | C701864 |
| 43 | C701937 | 46 | C701954 | 47 | C701966 | 48 | C701970 |
| 53 | C702234 | 54 | C702241 | 61 | C702418 | 65 | C702472 |
| 78 | C702951 | 107 | CUS 172 | 145 | HJT5816 | 147 | HJT5835 |
| 164 | HJT6033 | 181 | HUA 864 | 187 | HUA 915 | 189 | HUA 962 |
| 193 | HUA1022 | 199 | H/J 60 | 206 | H/J 206 | 207 | H/J 222 |
| 209 | H/J 238 | 218 | H/J 472 | 245 | OCH3582 | 247 | OCH4731 |
| 258 | OCH5193 | 266 | OCH5407 | 270 | OCH5590 | 271 | OCH5623 |
| 273 | OCH5648 | 276 | OCH5679 | 290 | OCH5929 | 293 | OCH5957 |
| 304 | OCH6232 | 312 | OCH6384 | 313 | OCH6388 | | |

TOTAL S 2273.8 MEAN S 58.3

GROUP 5

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 41 | C701913 | 44 | C701947 | 60 | C702378 | 62 | C702421 |
| 81 | C702998 | 110 | CUS 342 | 112 | CUS 545 | 124 | HJT5430 |
| 128 | HJT5623 | 131 | HJT5643 | 133 | HJT5661 | 144 | HJT5806 |
| 151 | HJT5859 | 205 | H/J 179 | 255 | OCH5182 | 274 | OCH5664 |
| 275 | OCH5678 | 278 | OCH5687 | 283 | OCH5815 | 291 | OCH5933 |
| 294 | OCH5975 | 295 | OCH5997 | 297 | OCH6064 | 299 | OCH6147 |
| 301 | OCH6186 | 303 | OCH6220 | 308 | OCH6332 | 314 | OCH6401 |
| 318 | OCH6478 | 321 | OCH6507 | 324 | OCH6518 | 325 | OCH6524 |

TOTAL S 1851.0 MEAN S 57.8

GROUP 6

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | C700313 | 3 | C700320 | 4 | C700344 | 6 | C700362 |
| 45 | C701948 | 55 | C702287 | 63 | C702450 | 67 | C702547 |
| 69 | C702586 | 76 | C702886 | 93 | CUP 58 | 97 | CUP 149 |
| 100 | CUP 192 | 103 | CUS 100 | 105 | CUS 103 | 111 | CUS 484 |
| 117 | HAW5520 | 118 | HAW5526 | 119 | HAW5529 | 122 | HAW5698 |
| 123 | HAW6105 | 176 | HUA 770 | 177 | HUA 822 | 178 | HUA 847 |
| 182 | HUA 868 | 183 | HUA 870 | 185 | HUA 885 | 237 | OCH3517 |
| 239 | OCH3536 | 240 | OCH3537 | 261 | OCH5316 | 263 | OCH5375 |
| 264 | OCH5392 | 265 | OCH5405 | 285 | OCH5835 | | |

TOTAL S 2089.4 MEAN S 59.7

GROUP 7

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | C700304 | 10 | C700469 | 25 | C701205 | 28 | C701466 |
| 34 | C701863 | 36 | C701882 | 38 | C701893 | 39 | C701905 |
| 40 | C701910 | 82 | C703027 | 85 | C703096 | 142 | HJT5785 |
| 152 | HJT5864 | 162 | HJT5894 | 169 | HJT6142 | 201 | H/J 78 |
| 256 | OCH4985 | 268 | OCH5525 | 277 | OCH5685 | 279 | OCH5697 |
| 302 | OCH6193 | 309 | OCH6357 | 311 | OCH6377 | 322 | OCH6510 |

TOTAL S 1410.3 MEAN S 58.8

GROUP 8

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 64 | C702464 | 72 | C702700 | 77 | C702841 | 92 | CUP 56 |
| 101 | CUP 194 | 190 | H/J 50 | 212 | H/J 306 | 215 | H/J 398 |
| 216 | H/J 417 | 231 | JAK 247 | 235 | OCH3477 | 243 | OCH3569 |
| 252 | OCH5157 | 253 | OCH5159 | 254 | OCH5162 | 256 | OCH5188 |
| 257 | OCH5192 | 262 | OCH5356 | 288 | OCH5967 | 296 | OCH6028 |

TOTAL S 1201.5 MEAN S 60.1

GROUP 9

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | C700390 | 13 | C700791 | 15 | C700894 | 23 | C701153 |
| 26 | C701207 | 33 | C701840 | 79 | C702966 | 89 | C703151 |
| 130 | HJT5626 | 134 | HJT5663 | 141 | HJT5783 | 153 | HJT5865 |
| 165 | HJT6053 | 180 | HUA 956 | 191 | HUA 996 | 203 | H/J 100 |
| 224 | JAK 12 | 229 | JAK 108 | 239 | OCH3515 | 248 | OCH4735 |
| 249 | OCH4769 | 267 | OCH5419 | 300 | OCH6140 | 305 | OCH6237 |
| 307 | OCH6298 | 323 | OCH6511 | 327 | OCH6573 | | |

TOTAL S 1557.8 MEAN S 57.7

GROUP 10

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | C700348 | 11 | C700640 | 12 | C700690 | 14 | C700827 |
| 31 | C701633 | 50 | C702216 | 51 | C702219 | 52 | C702223 |
| 56 | C702288 | 57 | C702319 | 58 | C702332 | 59 | C702353 |
| 70 | C702608 | 71 | C702624 | 75 | C702834 | 83 | C703042 |
| 94 | CUP 72 | 98 | CUP 156 | 106 | CUS 122 | 109 | CUS 277 |
| 116 | CUS 672 | 150 | HJT5857 | 163 | HJT6000 | 168 | HJT6135 |
| 174 | HJT6184 | 175 | HJT6189 | 179 | HUA 833 | 202 | H/J 225 |
| 212 | H/J 302 | 221 | H/J 572 | 227 | JAK 66 | 232 | OCH2703 |
| 241 | OCH3552 | 251 | OCH5131 | 260 | OCH5307 | 284 | OCH5833 |
| 286 | OCH5839 | 287 | OCH5888 | | | | |

TOTAL S 2186.9 MEAN S 57.6

GROUP 11

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16 | C700896 | 19 | C701052 | 68 | C702556 | 74 | C702815 |
| 90 | C703167 | 91 | CUP 13 | 96 | CUP 140 | 99 | CUP 173 |
| 102 | CUS 14 | 108 | CUS 271 | 115 | CUS 656 | 120 | HJT5517 |
| 135 | HJT5666 | 140 | HJT5782 | 143 | HJT5787 | 148 | HJT5841 |
| 149 | HJT5848 | 160 | HJT5982 | 166 | HJT6065 | 167 | HJT6085 |
| 170 | HJT6144 | 173 | HJT6164 | 190 | HUA 979 | 192 | HUA1009 |
| 196 | H/J 33 | 200 | H/J 65 | 204 | H/J 113 | 220 | H/J 501 |
| 228 | JAK 68 | 233 | OCH3408 | 234 | OCH3413 | 246 | OCH3815 |
| 298 | OCH6096 | 310 | OCH6371 | 316 | OCH6462 | | |

TOTAL S 2046.6 MEAN S 58.5

PCO

The trace (sum of all the latent roots) is 151.494 which is relatively bigger than that for the hybrids. This indicates the greater variability of the material than the hybrid populations but the number of characters used in each case has to be taken into account also. The percentage of total variance accounted for by the first four vectors was only 12%. The latent roots and the cumulative percentage of variance accounted for were as follows:-

| Vectors | 1 | 2 | 3 | 4 | Trace |
|---|---|---|---|---|---|
| Latent roots | 5.464 | 4.853 | 4.121 | 3.671 | 151.494 |
| Percent of trace | 3.6 | 6.8 | 9.5 | 12.0 | 100.0 |

They were very low and were in an order even less than that for the hybrids. This may be attributed to the poor data structure. The vector scores for the four vectors are in Appendix XII . However, the presentation of the analysis as scatter diagrams seemed to be quite consistant for the various pairs of plots (Fig. 4.11 (a), (b) and (c)). Groups of individuals tended to stay together consistantly at least for the first four vectors but no cluster was formed. It is therefore impossible to draw any boundary on to the total distribution of points. This again indicates the close relationship between numbers of the population as a whole.

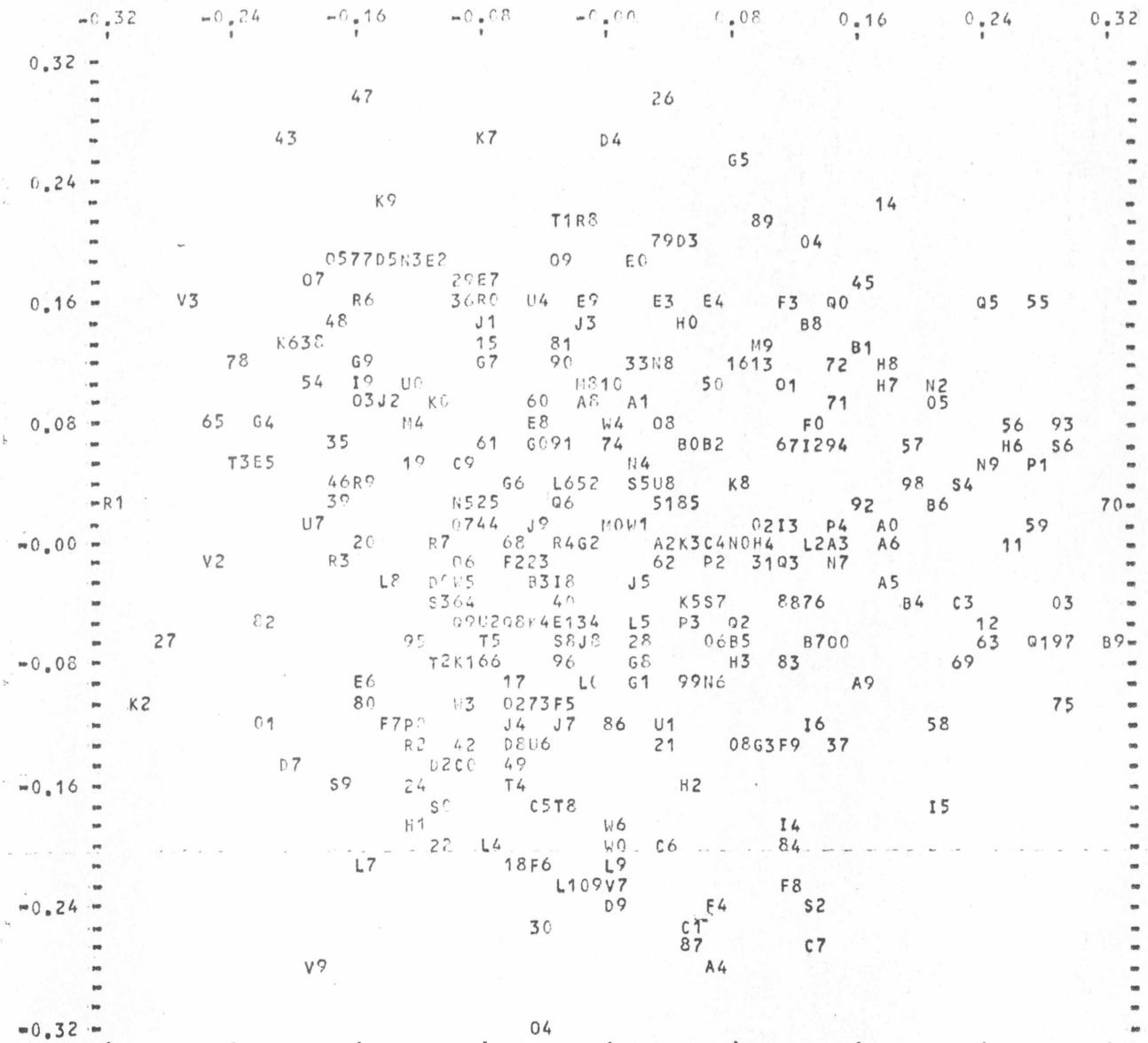
However, by superimposing the result of "REGROUP" on to the scatter diagrams, it is quite clear that the two analyses coincided fairly well. (Fig. 4.12 (a) and (b)). The eleven groups formed by

Fig. 4.11 Scatter diagrams of PCO analysis of the cultivars.

(a)

PRINCIPAL COORDINATE PLOT
ACROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2

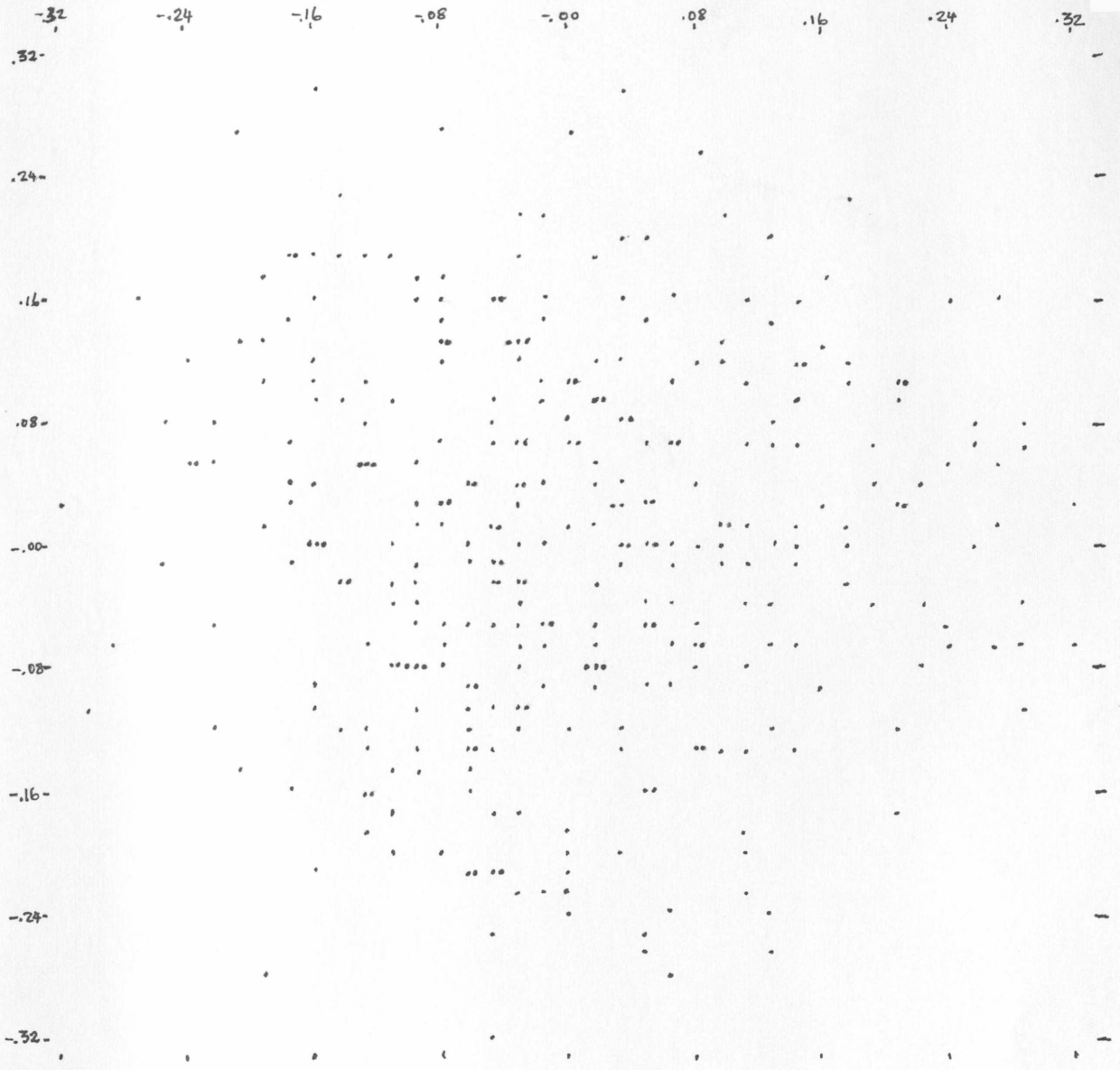
LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105




LIST OF COINCIDENCES

| | | | | |
|---|---|---|---|---|
| 318 AND 304 | 107 AND 81 | 181 AND 81 | 231 AND 15 | 227 AND 72 |
| 264 AND 178 | 258 AND 10 | 151 AND 101 | 255 AND 5 | 327 AND 248 |
| 131 AND 91 | 267 AND 112 | 275 AND 74 | 190 AND 19 | 305 AND 19 |
| 309 AND 293 | 314 AND 216 | 322 AND 166 | 122 AND 116 | 128 AND 85 |
| 196 AND 51 | 316 AND 25 | 175 AND 2 | 213 AND 199 | 221 AND 203 |
| 290 AND 20 | 303 AND 102 | 310 AND 20 | 53 AND 23 | 296 AND 152 |
| 187 AND 113 | 257 AND 188 | 315 AND 218 | 41 AND 34 | 256 AND 253 |
| 136 AND 115 | 180 AND 168 | 281 AND 201 | 297 AND 168 | 299 AND 201 |
| 311 AND 292 | 223 AND 17 | 179 AND 8 | 226 AND 138 | 225 AND 172 |
| 259 AND 24 | 32 AND 18 | 222 AND 156 | | |

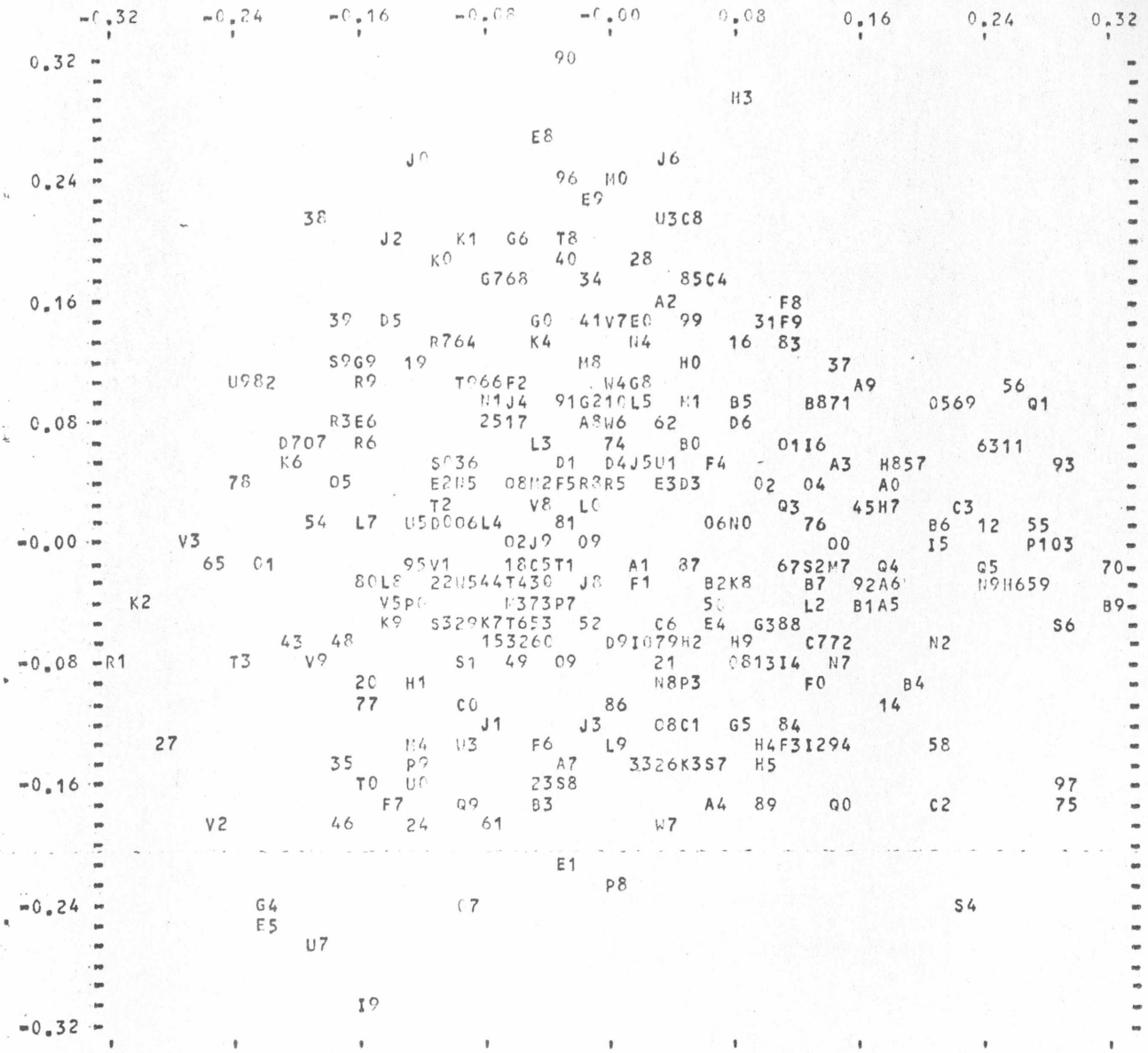
(a) I - Replot of all the cases of (a)



(b)

PRINCIPAL COORDINATE PLOT
ACROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 3

LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105



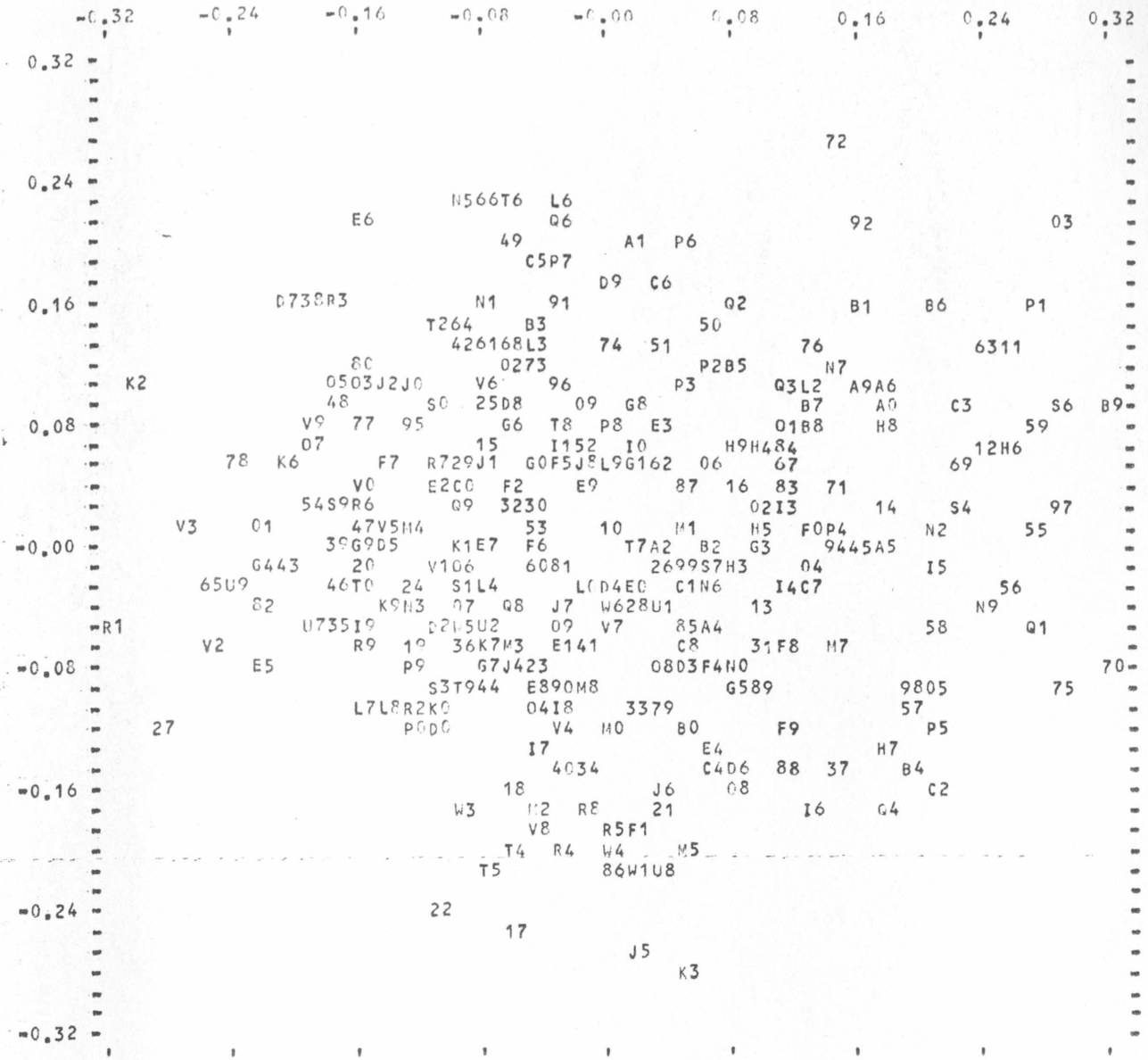

LIST OF COINCIDENCES

| | | | | |
|---|---|---|---|---|
| 274 AND 40 | 138 AND 68 | 302 AND 167 | 161 AND 140 | 233 AND 19 |
| 310 AND 169 | 295 AND 66 | 197 AND 91 | 216 AND 91 | 316 AND 231 |
| 42 AND 36 | 98 AND 57 | 129 AND 36 | 236 AND 154 | 297 AND 195 |
| 225 AND 133 | 322 AND 268 | 211 AND 81 | 270 AND 214 | 314 AND 81 |
| 306 AND 199 | 205 AND 87 | 254 AND 227 | 132 AND 22 | 147 AND 44 |
| 267 AND 112 | 285 AND 151 | 244 AND 73 | 266 AND 257 | 183 AND 88 |
| 252 AND 144 | 308 AND 126 | 255 AND 232 | 256 AND 172 | 321 AND 180 |
| 51 AND 21 | 226 AND 49 | 262 AND 8 | 47 AND 20 | 243 AND 20 |
| 320 AND 86 | 272 AND 224 | 181 AND 107 | 229 AND 175 | 304 AND 23 |
| 187 AND 113 | 188 AND 141 | | | |

(c)

PRINCIPAL COORDINATE PLOT
ACROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 4

LETTER CODE IS USED FOR UNITS ABOVE 09, E.G. A5 MEANS 105




LIST OF COINCIDENCES

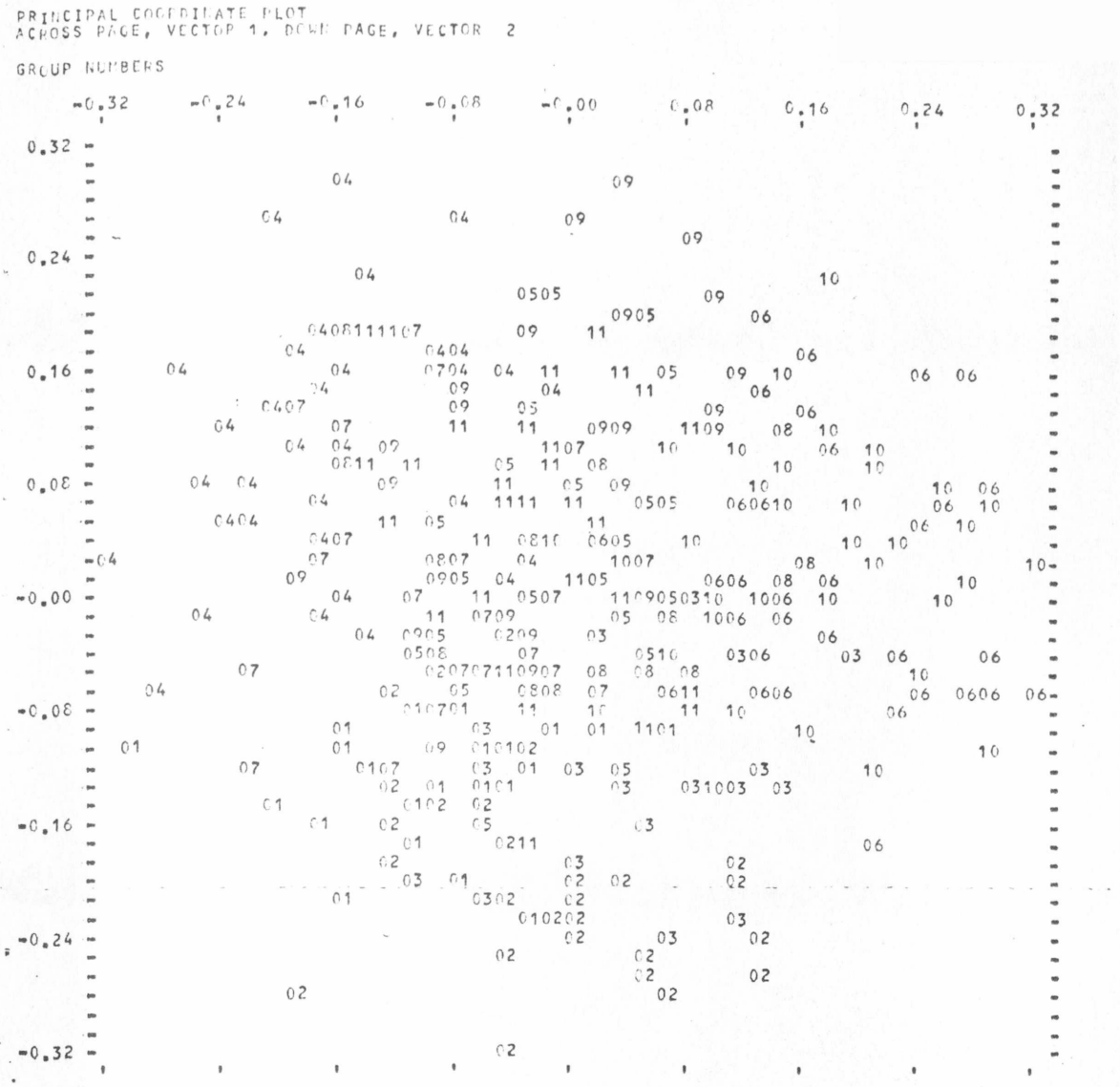
| | | | | |
|---|---|---|---|---|
| 215 AND 101 | 306 AND 213 | 107 AND 96 | 193 AND 9 | 285 AND 168 |
| 171 AND 95 | 182 AND 118 | 208 AND 179 | 199 AND 160 | 211 AND 155 |
| 238 AND 62 | 270 AND 191 | 288 AND 155 | 291 AND 155 | 293 AND 78 |
| 320 AND 219 | 226 AND 152 | 240 AND 71 | 294 AND 53 | 260 AND 254 |
| 282 AND 150 | 103 AND 94 | 131 AND 81 | 304 AND 60 | 267 AND 236 |
| 229 AND 13 | 265 AND 239 | 170 AND 85 | 108 AND 41 | 129 AND 36 |
| 162 AND 41 | 322 AND 223 | 205 AND 133 | 305 AND 259 | 327 AND 248 |
| 93 AND 75 | 303 AND 79 | 172 AND 110 | 300 AND 250 | 153 AND 88 |
| 234 AND 151 | | | | |

Fig. 4.12 Superimposing the result of 'REGROUP' on to the scatter diagrams of PCO analysis :

(a) - (b) individuals were plotted.

(c) - (h) mean coordinates of 'REGROUP' groups were plotted.

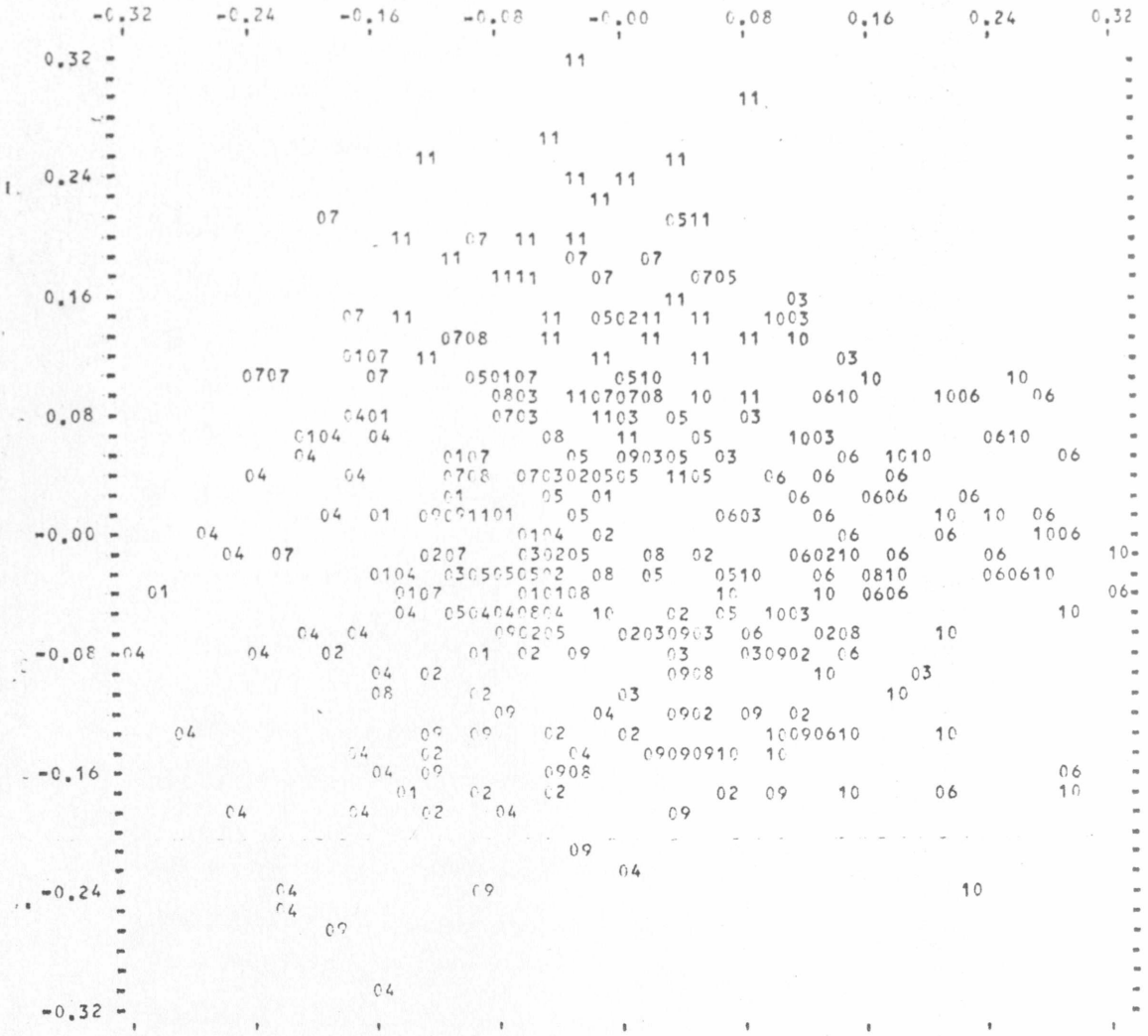
(a)

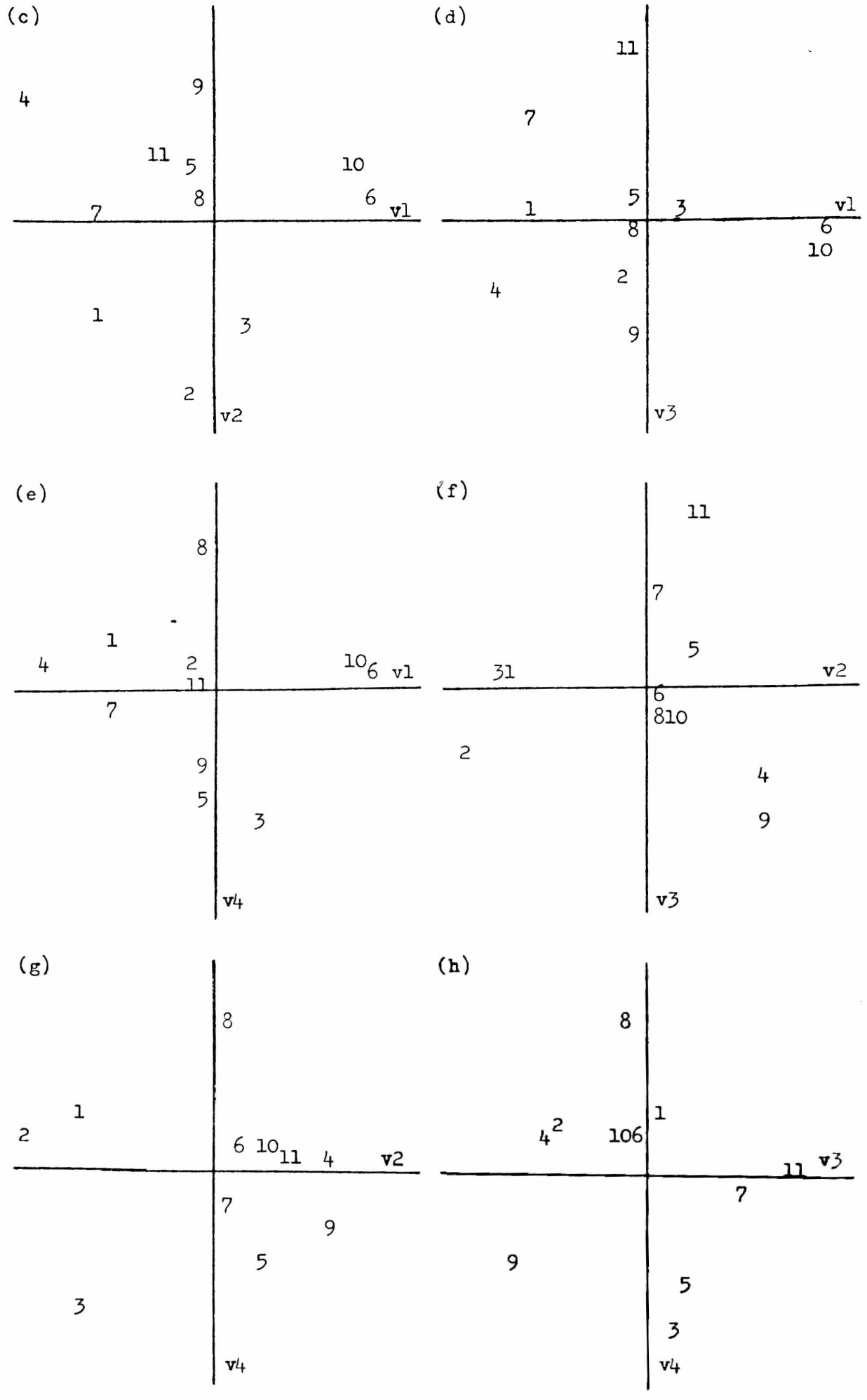

PRINCIPAL COORDINATE PLOT
ACROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2
GROUP NUMBERS
-0.32
-0.24
-0.16
-0.08
-0.00
0.08
0.16
0.24
0.32

(b)

PRINCIPAL COORDINATE PLOT
ACROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 3

GROUP NUMBERS




(c)
4
9
11
5
10
8
6
v1
7
1
3
2
v2
(d)
11
7
1
5
3
v1
8
6
10
2
4
9
v3
(e)
8
1
4
2
10
6
v1
11
7
9
5
3
v4
(f)
11
7
5
31
v2
6
810
2
4
9
v3
(g)
8
1
2
6
10
11
4
v2
7
9
5
3
v4
(h)
8
1
4
2
106
11
v3
7
9
5
3
v4

"REGROUP" may then be used to mark out the different sectors of the scatter diagram. There was a great deal of overlapping between groups and this made it very difficult to assess the relationships between the groups. Instead, the mean coordinates for each group were plotted (Fig. 4.12(c)-(h)). Groups 6 and 10 tended to stay together in all the six plots and groups 1, 4 and 7 which were loosely connected seemed to be the opposite 'pole' of groups 6 and 10 (Fig. 4.12(c)-(e)).

Average linkage analysis

The full dendrogram is shown in Fig. 4.13. Small clusters can be observed between the 55.0 and 57.5% similarity level. At the level between 52.5 to 55.0% similarity, four big clusters and some eight smaller clusters were present.

By comparing the result with that of "REGROUP", a certain amount of regularity is shown (the group number of "REGROUP" is in between the accession number and the case number in Fig. 4.13). It can therefore be broadly concluded that the three analyses agreed fairly well. The clusters from average linkage analysis and the groups from "REGROUP" indicate the presence of groups in the diploid potatoes. Since it was shown in Sect. 4.4.4.2 that not only hybrids from the same family were being grouped together but it was also possible for hybrids from different families to fall into the same cluster if they were similar enough, we have no clue as to the composition of these clusters formed in the above analysis. This makes it almost impossible to interpret the results. However by comparing them with results from the visual morphological field study and relating them to their sites of collection a better insight may be gained on the nature of the population.

Fig. 4.13 Dendrogram produced by average linkage clustering of the diploid cultivars.

DENDROGRAM

80.0 75.0 70.0 65.0 60.0 55.0 50.0
77.5 72.5 67.5 62.5 57.5 52.5

| a | b | c | d | e |
|---|---|---|---|---|
| C7U0304 | 7 | 1 | F | |
| JAK 12 | 9 | 224 | B3 | |
| C7U0300 | 9 | 7 | C..2 | |
| OCH6208 | 9 | 307 | | |
| OCH5226 | 2 | 270 | J1 | |
| OCH6511 | 9 | 323 | H1 | |
| OCH5644 | 2 | 272 | M | |
| OCH5734 | 1 | 201 | | |
| OCH6401 | 5 | 314 | ..3 | |
| OCH6421 | 1 | 315 | E2 | |
| C7L2216 | 10 | 50 | | |
| C7L2219 | 10 | 51 | | |
| H/J 55 | 8 | 198 | ..1 | |
| C7U2556 | 11 | 68 | J2 | |
| C7U2815 | 11 | 74 | J1 | |
| CUP 194 | 8 | 101 | | |
| OCH5835 | 6 | 285 | | |
| C7U1915 | 1 | 42 | G | |
| OCH6279 | 1 | 306 | | |
| C7U2991 | 1 | 80 | C | |
| OCH3567 | 1 | 242 | | |
| H/J 97 | 1 | 262 | | |
| OCH5948 | 1 | 292 | | |
| HJT5711 | 1 | 137 | F | |
| HJT5826 | 1 | 146 | F | |
| HUA 979 | 11 | 190 | E2..e | |
| HUA1009 | 11 | 192 | E2 | |
| OCH5648 | 4 | 273 | H1..e | |
| C7U1864 | 4 | 35 | | |
| CUS 172 | 4 | 107 | | |
| C7U2418 | 4 | 61 | | |
| OCH5356 | 8 | 262 | K | |
| OCH5561 | 2 | 269 | | |
| HJT5643 | 5 | 131 | | |
| OCH6462 | 11 | 316 | | |
| OCH6237 | 9 | 305 | | |
| OCH6371 | 11 | 310 | | |
| OCH5590 | 4 | 270 | C..2 | |
| C7U1893 | 7 | 38 | C..2 | |
| C7U1905 | 7 | 39 | C..2 | |
| C7U1970 | 4 | 48 | F..2 | |
| OCH6357 | 7 | 309 | F | |
| C7U2241 | 4 | 54 | | |
| OCH3582 | 4 | 245 | | |
| H/J 206 | 4 | 266 | H1 | |
| C7U0313 | 6 | 2 | K | |
| CUP 173 | 11 | 99 | F | |
| HJT5873 | 2 | 155 | | |
| HJT5922 | 11 | 180 | H2 | |
| HJT6065 | 11 | 186 | J2 | |
| C7U1913 | 5 | 41 | | |
| OCH6193 | 7 | 300 | | |
| OCH6220 | 5 | 303 | | |
| C7U1947 | 5 | 44 | G | |
| H/J 113 | 11 | 204 | E3 | |
| C7U1205 | 7 | 25 | J1 | |
| OCH5685 | 7 | 277 | M | |
| OCH5697 | 7 | 279 | L..2 | |
| C7U3027 | 7 | 82 | ..2 | |
| HJT5664 | 7 | 152 | L | |
| OCH5525 | 7 | 268 | ..2 | |
| OCH6377 | 7 | 311 | | |
| OCH651 | 7 | 322 | | |
| C7U1863 | 7 | 34 | F | |
| C7U3096 | 7 | 85 | B | |
| HJT6104 | 11 | 173 | F | |
| C7U1910 | 7 | 40 | | |
| HJT5994 | 7 | 162 | | |
| C7U0344 | 6 | 4 | | |
| HJT6144 | 11 | 170 | | |
| OCH4769 | 9 | 249 | F | |
| JAK 68 | 11 | 228 | | |
| OCH5419 | 9 | 267 | E1..1 | |
| C7U1052 | 11 | 10 | J1 | |
| CUS 271 | 11 | 108 | J1 | |
| C7U2941 | 8 | 77 | I..1.. | |
| OCH3569 | 8 | 243 | | |
| OCH5623 | 4 | 271 | I | |
| C7U0469 | 7 | 10 | B | |
| HJT5785 | 7 | 142 | F..2 | |
| HJT5663 | 9 | 134 | B | |
| HJT6142 | 7 | 169 | BE.13 | |
| C7L1937 | 4 | 43 | | |
| HJT5666 | 11 | 135 | | |
| C7U2951 | 4 | 78 | F | |
| OCH4731 | 4 | 247 | | |
| OCH5679 | 4 | 276 | ..1.. | |
| OCH6388 | 4 | 313 | E3 | |
| C7U1207 | 9 | 26 | I | |
| OCH6232 | 4 | 304 | D1..2 | |
| HJT5865 | 9 | 153 | J2 | |
| C7U1966 | 4 | 47 | | |
| OCH5933 | 5 | 281 | J2 | |
| H/J 222 | 4 | 207 | | |
| H/J 238 | 4 | 209 | M | |
| C7U1109 | 4 | 20 | | |
| C7U1518 | 4 | 29 | ...3 | |
| C7U2472 | 4 | 65 | F..2 | |
| C7U1954 | 4 | 46 | D3 | |
| OCH6384 | 4 | 312 | ..1 | |
| HUA 915 | 4 | 187 | D1..2 | |
| HUA 956 | 9 | 188 | D2 | |
| HUA 962 | 4 | 189 | D2..2 | |
| HUA1022 | 4 | 193 | CE3.2 | |
| OCH5193 | 4 | 258 | ...2 | |
| C7U0894 | 9 | 15 | L | |
| HJT5816 | 4 | 145 | E3 | |
| OCH5929 | 4 | 280 | | |
| OCH5957 | 4 | 283 | G | |
| HUA 864 | 4 | 184 | FL..2 | |
| OCH4735 | 9 | 248 | | |
| C7L1082 | 7 | 36 | E3J1 | |
| OCH3402 | 11 | 233 | E2 | |
| HJT6085 | 11 | 187 | I | |
| C7U0934 | 3 | 17 | | |
| C7U0935 | 3 | 18 | G | |
| C7L1137 | 3 | 22 | G..3 | |
| H/J 591 | 3 | 222 | G | |
| C7L3117 | 3 | 86 | J | |
| H/J 100 | 9 | 203 | J1 | |
| OCH5815 | 5 | 283 | H1 | |
| OCH5925 | 5 | 284 | K | |
| H/J 26 | 3 | 195 | | |
| H/J 472 | 4 | 218 | G | |
| C7L1266 | 4 | 27 | ..2 | |
| HJT5626 | 9 | 136 | ..2 | |
| OCH6140 | 9 | 308 | E2..2 | |
| HJT6033 | 4 | 164 | E2 | |
| OCH4985 | 7 | 250 | E2..2 | |
| C7U6427 | 2 | 9 | | |
| C7L3125 | 2 | 87 | | |
| OCH5721 | 1 | 280 | M | |
| C7L1592 | 2 | 30 | | |
| HJT5500 | 2 | 126 | I1..2 | |
| HJT5515 | 2 | 127 | ..2 | |
| C7U3089 | 2 | 84 | H1 | |
| OCH5762 | 2 | 282 | ..2..) | |
| C7U1406 | 7 | 28 | J1 | |
| H/J 49 | 1 | 197 | | |
| OCH6147 | 5 | 299 | L | |
| C7U1732 | 2 | 32 | F..2 | |
| HJT5653 | 1 | 132 | E2 | |
| H/J 274 | 1 | 210 | | |
| H/J 609 | 1 | 223 | E2 | |
| H/J 301 | 1 | 211 | F | |
| OCH3815 | 11 | 246 | | |
| H/J 441 | 1 | 217 | | |
| H/J 78 | 7 | 201 | | |
| OCH6471 | 2 | 317 | F | |
| C7U1165 | 2 | 24 | | |
| HJT6147 | 2 | 171 | | |
| HJT5882 | 2 | 156 | | |
| HJT5883 | 1 | 157 | | |
| HJT5777 | 2 | 139 | J1 | |
| OCH6498 | 2 | 319 | E2 | |
| HAK5564 | 2 | 120 | H1 | |
| HAK5593 | 2 | 121 | E3 | |
| HJT5783 | 9 | 141 | K..11 | |
| OCH5919 | 1 | 289 | | |
| OCH6096 | 11 | 298 | | |
| C7U0348 | 10 | 5 | | |
| HJT5732 | 11 | 140 | E2 | |
| C7U3167 | 11 | 90 | E2 | |
| H/J 501 | 11 | 220 | ...2 | |
| H/J 33 | 11 | 196 | ...2 | |
| H/J 65 | 11 | 200 | | |
| OCH3413 | 11 | 234 | E | |
| HJT5517 | 11 | 128 | L | |
| HJT5548 | 11 | 129 | ...2 | |
| HJT5648 | 11 | 149 | J2 | |

KEY:

a – accession nos.

b – 'REGROUP' group nos.

c – case nos.

d – electrophoretic pattern groups

e – chromatographic cluster nos.

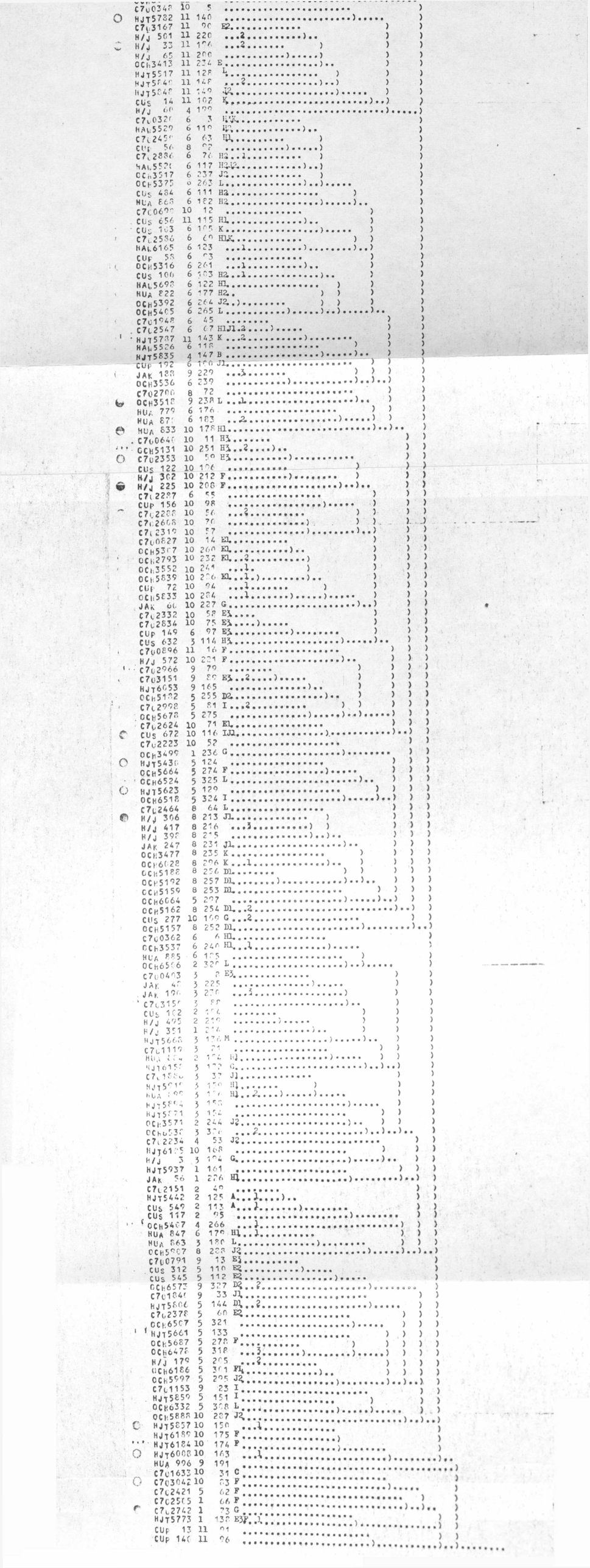
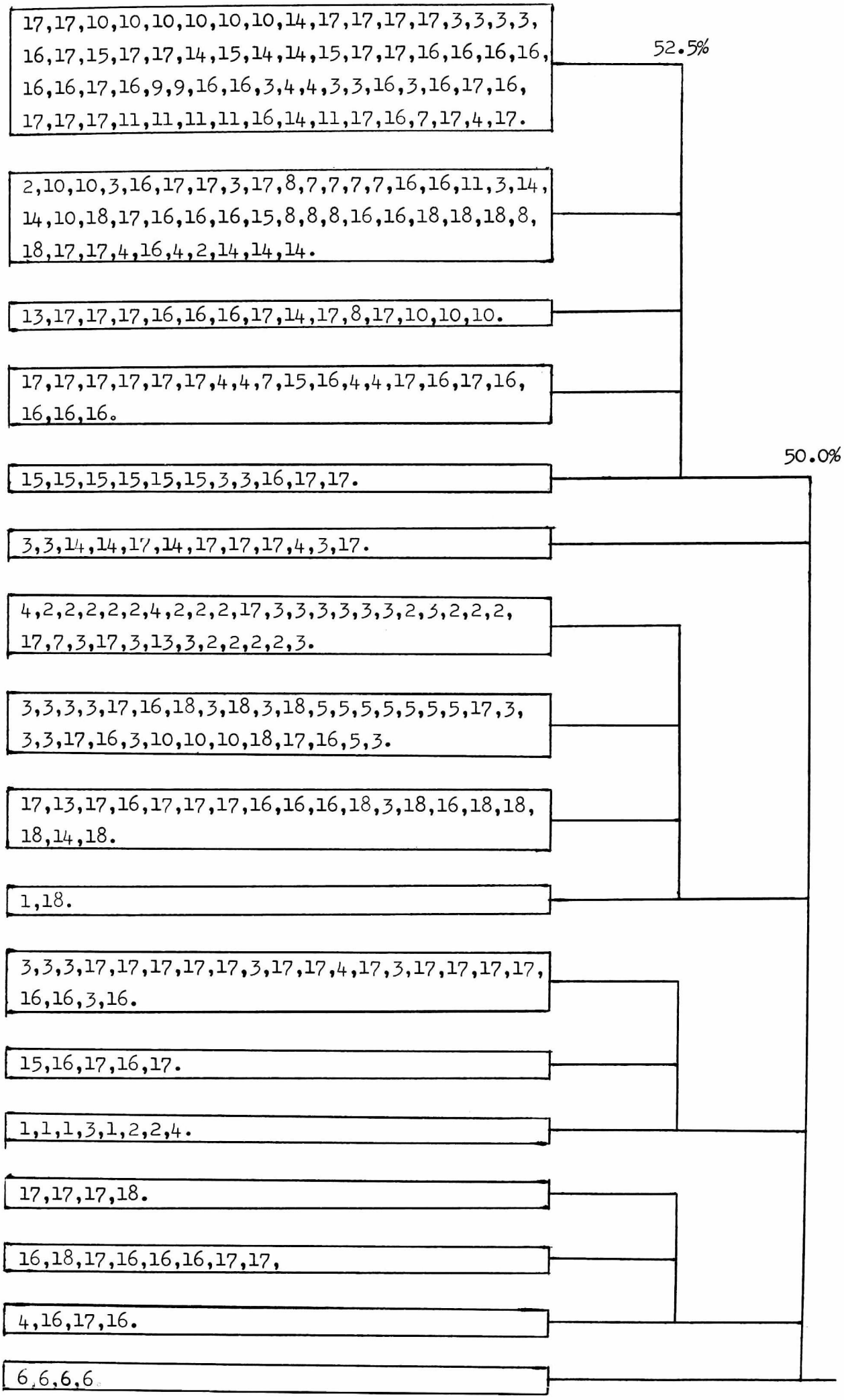


Fig. 4.13 (b) Summarised dendrogram of Fig. 4.13 (page 176) with the Visual Groups.



## 4.7. Preliminary grouping by visual inspection

A visual classification based on the total morphology of the plant was necessary during the course of the experimental work. Since no clearly distinct boundaries between the three entities, S. stenotomum, S. goniocalyx and S. phureja were present and groupings from the numerical study were not possible until the end of the study, the planning of the crossing programme was almost impossible without a preliminary grouping. For example, a cross between S. stenotomum and and S. stenotomum can be between the typical narrow-leaved southern form with itself or a wide range of other forms. Which one should we use to give us the maximum amount of information about the population?

Visual grouping was thus carried out in the 1977/78 season and rechecked in the 1978/79 season. This gave rise to eighteen groups. A brief general note about the nature of these groups is given below and their composition (accessions) is available for consultation if required. It is summarised in Table 4.17.

Group 1

(Ref. Fig. 4. 14 , Map 4 .1 )

This conforms with the original description of S. stenotomum and consists of only the small white flowered form. The leaflet surface does not appear flat and the leaf-margin looks a bit wavy. It includes several variants which differ in some flower, leaf dissection and pigmentation characters and also vigour. On the whole it is easily recognised.

The centre of distribution is in Cuzco but it extends to

Huancavelica in the north and Puno and northern Bolivia in the south.

Group 2

(Ref. Fig. 4. 15 , Map 4.1 )

This also conforms with the original description of S. stenotomum. It can be differentiated from Group 1 by the apparently flatter and dull leaflet surface. The whole leaflet looks well pressed. It flowers sparsely and has a prostrate growth habit. It is easily identified.

The centre of distribution is in north Bolivia and Puno but it extends northward to Cuzco and Apurímac.

Group 3

(Ref. Fig. 4.16 , Map 4.1 )

This group is related to Group 2, but the plant is vigorous and larger. It flowers more profusely and the plant is more pigmented. The leaflets appear to be relatively thicker and shiny. It can be identified quite easily except that some S. phureja have the same morphotype. Because of this, it may be thought to be related to S. phureja.

The centre of distribution is as Group 2.

Group 4

(Ref. Fig. 4.17 , Map 4. 1 )

This is a more difficult group. It consists of clones bearing a certain resemblance to Group 1 and Group 2 but which cannot be

accommodated in Group 3. There may be many misclassifications here. The leaflets are broader and more ovate.

It is widely distributed from Ancash to north Bolivia.

Group 5

(Ref. Fig. 4.18 , Map 4.1 )

This group is vigorous with unique dull green leaves. The plant has a dense short pubescence. On the whole, it is distinct and can therefore be identified easily. It has a very narrow variability.

The centre of distribution is in Puno and north Bolivia but it spreads to Cuzco and Apurímac.

Group 6

(Ref. Fig. 4.19 , Map 4.2 )

This is a very distinct group and may be a single clone. It has narrowly ovate shiny green leaflets. It may be related to Group 4.

The centre of distribution is in Junín and northern Huancavelica.

Group 7

(Ref. Fig. 4.20 , Map 4.2 )

This is a very distinct group with a fair amount of variants. The plant is yellowish green and the leaflets are rather flat,

the edges smooth and appearing to cup up a bit. Most of the clones appear diseased. It is a form of S. goniocalyx.

The centre of distribution is from the central Peruvian highlands to Cuzco.

Group 8

(Ref. Fig. 4. 21 , Map 2 )

This is the "Papa Amarilla". The amount of variability is low. It conforms to the type description of S. goniocalyx. One clone appears to be related to Group 13.

The centre of distribution is the central Peruvian highlands but it is found as far north as Cajamarca and south to Cuzco.

Group 9

(Ref. Fig. 4. 22 , Map 4.2 )

This is also a very distinct group, with very narrow variability. The plant is yellowish green with very highly dissected leaves. It flowers profusely. It is a form of S. goniocalyx.

The centre of distribution is in Huánuco and Pasco.

Group 10

(Ref. Fig. 4.23 , Map 4. 3 )

This is a fairly distinct group except for some clones which may belong to Group 14 or Group 15. It is a form of S. goniocalyx

and is yellowish green in colour. The whole plant is a bit smaller than that of other groups of S. goniocalyx.

The centre of distribution is in the central Peruvian highlands, around northern Junín to Huánuco.

Group 11

(Ref. Fig. 4. 24 , Map 4.3 )

This is Ochoa's S. stenotomum x S. goniocalyx hybrid form. The plant is yellowish green with quite narrow leaflets compared to other yellowish green groups. The leaves are very dissected.

The centre of distribution is as Group 10.

Group 12

(Ref. Fig. 4.25 , Map 4.3 )

This is Ochoa's S. stenotomum x S. phureja hybrid form. It has only a few variants. The plant has a typical S. phureja plant and leaf habit but a S. stenotomum flower.

The centre of distribution is in Puno (dept. Sandia).

Group 13

(Ref. Fig. 4.26 , Map 4.3 )

This is Ochoa's S. phureja x S. goniocalyx hybrid form. The leaflets are large and ovate in shape. The colour of the plant relates it to S. goniocalyx.

The centre of distribution is in the northern central Peruvian highlands.

Group 14

(Ref. Fig. 4. 27 , Map 4. 4 )

This is a quite distinct form of S. goniocalyx with large broad leaves. The plant is yellowish green and the leaflets rounded.

The centre of distribution is from Ancash to Huánuco.

Group 15

(Ref. Fig. 4. 28 , Map 4. 4 )

This is a very polymorphic group. The boundary is not clear in relation to Group 16 and Group 17. Together with Group 16 and Group 17, they appear to be a "hybrid swarm". They are now mostly classified as S. stenotomum.

The centre of distribution is the central Peruvian highlands.

Group 16

(Ref. Fig. 4. 29 , Map 4. 5 )

This is very similar to Group 15 and the centre of distribution is the same also.

Group 17

(Ref. Fig. 4. 30 , Map 4. 6 )

This is another of the group that is related to Group 15.

Group 18

(Ref. Fig. 4. 31 , Map 4. 7 )

This includes all the S. phureja. It is highly polymorphic. It has individuals of similar morphotype to Group 3, Group 15, Group 16 and Group 17.

It is found from Colombia in the north to northern Bolivia in the south.

Table 4.17: The composition of the visual groups formed by visual grouping in the field, in terms of the number of clones occuring in each group.

| Visual groups | Number of clones* |
|---|---|
| 1 | 31 |
| 2 | 30 |
| 3 | 91 |
| 4 | 36 |
| 5 | 10 |
| 6 | 5 |
| 7 | 16 |
| 8 | 13 |
| 9 | 4 |
| 10 | 21 |
| 11 | 15 |
| 12 | 3 |
| 13 | 7 |
| 14 | 16 |
| 15 | 44 |
| 16 | 60 |
| 17 | 143 |
| 18 | 51 |
| Total | 606 |

*excluding the duplicates.



Fig. 4.14 VG 1, OCH 11846.




Fig. 4.15 VG 2, HAW 5561.



Fig. 4.16 (a) VG 3, CUP 140.



Fig. 4.16 (b) VG 3, 702608.



Fig. 4.17 (a) VG 4, OCH 6506.



Fig. 4.17 (b) VG 4, OCH8086.




Fig. 4.18 VG 5, OCH 5307.



Fig. 4.19 VG 6, HJT 6094.

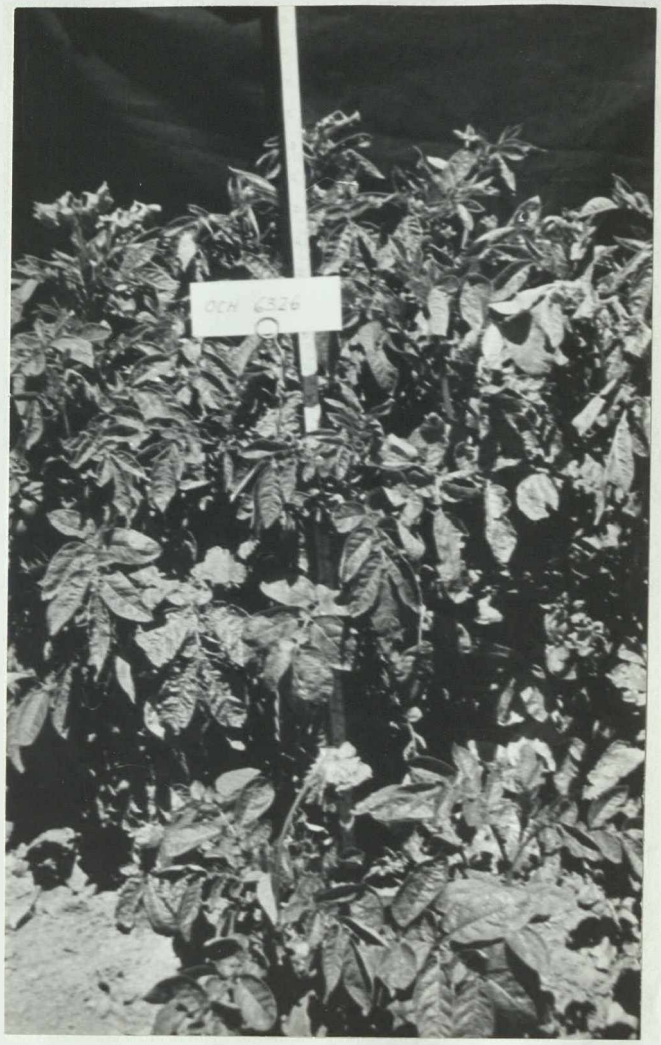


Fig. 4.20 VG 7, OCH 6326.



Fig. 4.21 VG 8, OCH 5497.




Fig. 4.22 VG 9, OCH 5941.



Fig. 4.23 VG 10, OCH 6136.



Fig. 4.24 VG 11, HJT 5994.



Fig. 4.25 VG 12, OCH 11208.



Fig. 4.26 VG 13, H/J 660.



Fig. 4.27 (a) VG 14, OCH 5623.



Fig. 4.27 (b) VG 14, OCH 6388.



Fig. 4.28 VG 15, OCH 7505.



Fig. 4.29 VG 16, OCH 9986.



Fig. 4.30 (a) VG 17, HJT 5919.



Fig. 4.30 (b)  VG 17, 701425.



Fig. 4.31 (a)  VG 18, 702287.



Fig. 4.31 (b) VG 18, CCC 4499.



Fig. 4.31 (c) VG 18, OCH 5164.




Map 4.1. The geographical distribution of Visual Groups (VGs) 1, 2, 3, 4 and 5.




Map 4.2 The geographical distribution of Visual Groups (VGs) 6, 7, 8 and 9.




Map 4.3 The geographrical distribution of Visual Groups (VGs) 10, 11, 12 and 13.



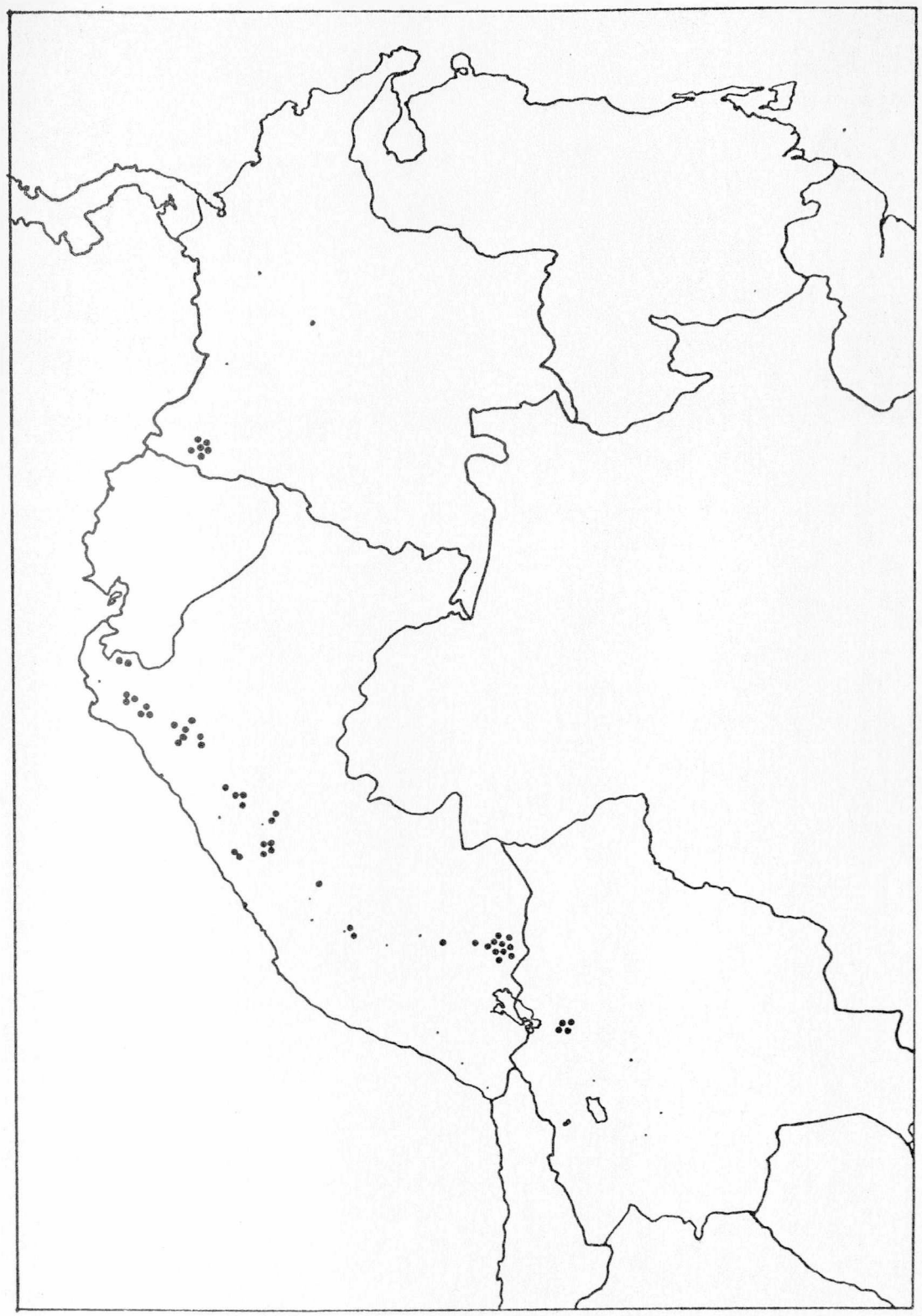

Map 4.4 The geographical distribution of Visual Groups (VGs) 14 and 15.



Map 4.5 The geographical distribution of Visual Group(VG) 16.



Map 4.6 The geographical distribution of Visual Group(VG) 17.



Map 4.7 The geographical distribution of Visual Group(VG) 18.

## 4.8 Relating the results from the numerical analysis to that of visual classification

The result from the average linkage analysis is mainly used here for the interpretation because it is easier to visualise. It was detected that a line drawn across the dendrogram between the 57.5 and 60.0% similarity level would give a maximum number of coincidences between the results from the numerical analysis and the visual grouping. A summary of the clusters from average linkage analysis, visual grouping and "REGROUP" is given in Table 4.18.

TABLE 4.18: Relationships between the clusters formed by the average linkage analysis and the "REGROUP" analysis to the groupings resulting from the visual resemblance study.

Notes: (1) the group number underlined in columns under "visual groups" and "REGROUP groups" indicates a concentration of that group in the average linkage cluster.

(2) the dotted lines across the page indicate average linkage clusters at the level between 52.5 to 55.0% similarity.

| Cluster no. | Average linkage clusters | No.of indiv-iduals | Visual groups | "REGROUP" groups |
|---|---|---|---|---|
| 1. | 700390 (7) to OCH 6421 (315) | 8 | 10,16 | 1,2,5,9 |
| 2. | 702216 (50) to H/J 50 (198) | 3 | 17 | 8,10 |
| 3. | 702556 (68) to OCH 5835 (285) | 4 | 3 | 6,8,11 |
| 4. | 701915 (42) to OCH 5648 (273) | 11 | 14,15,16,17 | 1,4,11 |
| 5. | 701864 (35) to OCH 5590 (270) | 10 | 15,16,17 | 2,4,5,8,9,11 |
| 6. | 701893 (38) to 701905 (39) | 2 | 9 | 7 |
| 7. | 701970 (48) to H/J 206 (206) | 5 | 3,4,16 | 4,7 |
| 8. | 700313 (2) to HJT 6065 (166) | 5 | 3,16 | 2,6,11 |
| 9. | 701913 (41) to H/J 113 (204) | 5 | 16,17 | 5,7,11 |
| 10. | 701205 (25) to OCH 6510 (322) | 8 | 11,14,16,17 | 7 |
| 11. | 701863 (34) to HJT 5994 (162) | 5 | 7,16,17 | 7,11 |
| 12. | 700344 (4) to OCH 5623 (271) | 10 | 2,3,8,10,16,17 | 4,6,8,9,11 |
| 13. | 700469 (10) to HJT 6142 (169) | 4 | 7 | 7,9 |
| 14. | 701937 (43) to OCH 6388 (313) | 6 | 11,14,16 | 4,11 |
| 15. | 701207 (26) to H/J 238 (209) | 7 | 10,15,16,17,18 | 4,5,9 |
| 16. | 701109 (20) to OCH 6384 (312) | 5 | 8,15,18 | 4 |
| 17. | HUA 915 (187) to OCH 5193 (258) | 5 | 8,18 | 4,9 |
| 18. | 700894 (15) to OCH 4735 (248) | 6 | 2,4,16,17 | 4,9 |
| 19. | 701882 (36) to HJT 6085 (167) | 3 | 14 | 7,11 |
| 20. | 700936 (17) to H/J 472 (218) | 10 | 13,14,16,17 | 3,4,5,9 |
| 21. | 701266 (27) to OCH 4985 (250) | 5 | 8,10,17 | 4,7,9 |
| 22. | 700427 (9) to OCH 5762 (282) | 8 | 4,17 | 1,2 |
| 23. | 701406 (28) to OCH 6471 (317) | 12 | 4,7,14,15,16 | 1,2,5,7,11 |
| 24. | 701165 (24) to OCH 6498 (319) | 6 | 15,16 | 1,2 |
| 25. | HAW 5564 (120) to OCH 6096 (298) | 5 | 3,16,17 | 1,2,9,11 |

| Cluster no. | Average linkage clusters | No.of individuals | Visual groups | "REGROUP" groups |
|---|---|---|---|---|
| 26. | 700348 (5) to HJT 5782 (140) | 2 | 3 | 10,11 |
| 27. | 703167 (90) to HJT 5848 (149) | 8 | 4,14,17 | 11 |
| 28. | 700320 (3) to HUA 868 (182) | 10 | 2,4 | 6,8 |
| 29. | 700690 (12) to HAW 6165 (123) | 5 | 3,17 | 6,10,11 |
| 30. | CUP 58 (93) to OCH 5405 (265) | 7 | 2,3 | 6 |
| 31. | 701948 (45) to OCH 3536 (239) | 8 | 3,4,7,17 | 4,6,9,11 |
| 32. | 702700 (72) to HUA 833 (178) | 5 | 2,3 | 6,8,9,10 |
| 33. | 700640 (11) to H/J 225 (208) | 6 | 3,16,17 | 10 |
| 34. | 702287 (55) to 702319 (57) | 5 | 3,18 | 6,10 |
| 35. | 700827 (14) to JAK 60 (227) | 8 | 5,17 | 10 |
| 36. | 702332 (58) to CUS 632 (114) | 4 | 3,17 | 3,6,10 |
| 37. | 700896 (16) to OCH 5678 (275) | 8 | 3,10,16,17,18 | 5,9,10,11 |
| 38. | 702223 (52) to OCH 6518 (324) | 7 | 13,16,17 | 1,5,10 |
| 39. | 702464 (64) to OCH 5162 (254) | 12 | 3,14,15,16,17,18 | 8 |
| 40. | CUS 277 (109) to OCH 5157 (252) | 2 | 1,18 | 8,10 |
| 41. | 700362 (6) to OCH 6506 (320) | 4 | 3,17 | 2,6 |
| 42. | 700403 (8) to HJT 6158 (172) | 11 | 3,4,17,18 | 1,2,3 |
| 43. | 701886 (37) to OCH 6538 (326) | 7 | 3,16,17 | 2,3 |
| 44. | 702234 (53) to JAK 56 (226) | 5 | 15,16,17 | 1,3,4,10 |
| 45. | 702151 (49) to OCH 5407 (266) | 5 | 1,3 | 2,4 |
| 46. | HUA 847 (179) to OCH 5907 (288) | 3 | 2,4 | 3,6,8 |
| 47. | 700791 (13) to OCH 6573 (327) | 4 | 17,18 | 5,9 |
| 48. | 702378 (60) to OCH 5997 (295) | 8 | 16,17 | 5 |
| 49. | HJT 5857 (150) to HJT 6008 (163) | 6 | 6 | 10 |

The results from the numerical analysis corresponded quite well with that of the visual grouping. The group number underlined in Table 4.18 column (4) indicates a concentration of the Visual Group (VG) in that cluster. It can be seen that Cluster-1 of the average linkage analysis had the concentration of VG-10, also, 3-VG3; 5-VG16; 6-VG9; 9-VG17; 10-VG11; 13-VG7; 16-VG8; 17-VG18; 19-VG14; 22-VG17; 24-VG15; 28-VG2, 29-VG3; 31-VG3; 32-VG2; 33-VG3; 34-VG18; 35-VG5; 36-VG3; 38-VG17; 41-VG3; 42-VG17; 45-VG1 and 49-VG 6.

The presence of visual groups in the clusters from average linkage analysis roughly followed a trend with VG2 and VG3 in a sequence and VG14, VG15, VG16 and VG17 in another. It appeared that VG2, VG3 and VG7 tended to be more concentrated in a cluster than VG15, VG16 and VG17. For example, many clusters had the VGs 15 to 17 together without any sign of being dominated by any one of the three visual groups. In several occasions, VGs 16 and 17 were clustered together with VGs 2, 3 and 4 or like in average linkage cluster 3 which was clustered in the midst of VGs 14, 15, 16 and 17. These together may indicate the more diverse nature of the three visual groups, VGs 15, 16 and 17, and the possible relationship between VGs 15, 16 and 17 to both VGs 3 and 4 and VGs 7, 8, 10, and 14. They were postulated during the process of visual grouping to be something equivalent to a "hybrid swarm". The occurrence of these three visual groups in the germplasm collection has the greatest number of accessions.

Another example of this nature is that of VG 4. It is intermediate between VGs 2 and 3, and VGs 14, 15, 16 and 17 because it

occurred in several cases with VGs 1, 2 and 3 only and also separately with VGs 14, 15, 16 and 17.

The distinctness of the two groups, VG2 and VG3, from the rest may be even more convincing if we consider cluster formation at a lower level of similarity between 52.5 to 55.0%. The two large characters, composed of Clusters (28) to (32) and Clusters (33) to (37), have high representation of VG2 and VG3. They are the most typical forms of S. stenotomum, especially VG2, and are found from Cuzco south to Potosi in Bolivia.

Visual groups 14, 15, 16 and 17 were dispersed in most of the clusters at level between 52.5 and 55.0% showing relationship with all other clones. Their centre of distribution is from Cuzco to the central highlands of Peru.

It is interesting to find that visual groups 1, 5, 6, 7, 8, 9 and to a lesser extent 10 and 11 tended to cluster only with members of the same visual group in average linkage analysis. Since in most cases only a small sample of 5 or less was available for study in each group no definite conclusion can be reached. However, there were strong indications of their individual uniqueness.

S. phureja, VG18, was found in many clusters, namely 15, 16, 17, 34, 37, 39, 40, 42 and 47, with concentration in 17 and 34. This points to the polymorphic nature of this species. The concentration of S. phureja in cluster 34 with VG3 (S. stenotomum) indicates a possible

link between S. phureja and S. stenotomum. On the other hand, its presence with VGs 8, 10, 14, 15, 16 and 17 shows its relationship with S. goniocalyx. From cluster (16) and cluster (17), it appeared that S. phureja is even related to the typical S. goniocalyx, "Papa Amarilla".

In conclusion, the analysis showed that the whole population may roughly be divided into two big divisions. They are firstly the southern form of S. stenotomum (cf. clusters (28) to (37)) and then all the northern forms, from Cuzco up to northern Peru. The relationship between the accessions of the latter is difficult to postulate but there is some indications that the visual groups 15, 16 and 17 were very close to each other and may then be grouped together as a single unit. The individual cluster formed for each of these VG 1, 5, 6, 7, 8, 9, 10 and 11 indicates that they may all be individual distinct forms.

No definite conclusions can thus be arrived at unless evidence from other types of study is furnished to qualify these results. Biochemical data from chromatography and electrophoresis will be presented in the next chapter. Unfortunately, no result was obtained from the crossing experiments between individuals from the verious groups and between individuals of the same group.

# 5. Biochemical taxonomic study of the diploid cultivars

## 5.1. Introduction

Chemical data are widely used at present to study the relationships between plant taxa. They have provided a vast number of new taxonomic characters which in many cases have been essential for correct taxonomic decisions and at other times have given rise to new ideas and concepts on the evolution of the groups under study. For example, the classical example of the study of betalain showed that the Cactaceae should be classified as a member of Centrospermae instead of being separated out as another order, because of the common occurrence of betalain in this order. Caryophyllaceae may have to be removed from Centrospermae because of the absence of betalain.

Many types of compounds are available for study. Smith (1976) classified them into amino acids, phenolics and betalains, oils, fats, and waxes, carbohydrates, alkaloids, terpenoids and steroids, proteins and DNA. Among these, phenolic compounds and proteins are the most widely used. The reason may be that they are usually more widely distributed in plants, and are also simple to extract, separate and handle.

Phenolic compounds in a broadest sense include "all natural substances with a free or masked phenolic function". (Harborne, 1964). They occur widely and in a great variety of forms in plants. It is postulated that similar pathways may have been involved in the derivation of these compounds for a wide range of plants. They may thus be used to evaluate possible relationships between taxa. However, these

compounds are all simple molecules and their functions in the plant mostly unknown. In addition, they are too greatly affected by environmental conditions.

The value of phenolic compounds as taxonomic characters lies in the discontinuous distribution of rare phenolics and the correlated occurrence of others. This is demonstrated by Bate-Smith (1958) in his study of the genus *Iris*. Using five phenolic compounds present in the seven sections he was able to transfer *Iris flavissima* from section *Pogoniris* to *Regelia*. This was later supported by chromosome counts. Also, Alston and Turner (1959), studying the genus *Baptisa*, were able to identify the hybrids as intermediate between the two parental species through the occurrence of phenolic compounds. There are many other examples of this sort where the distribution of rare compounds was studied and used for direct interpretation. A very convincing example in the study of potatoes is the case of *S.* x *ajanhuiri* (Huamán, 1975). He was able to identify a chromatographic spot that was unique to the'Yari' form of *S.* x *ajanhuiri* among all the cultivated diploids. This same spot was detected also in a wild species studied, *S. megistacrolobum*. In view of this and many other results he postulated the hybridogenic origin of *S.* x *ajanhuiri* as a cross between the cultivated diploid, *S. stenotomum* with the wild species, *S. megistacrolobum*.

However, in many cases, especially in intraspecific studies, most phenolics will be present in most of the accessions. This type of data is usually too complex to be sorted out by visual inspection. Normally, numerical analysis treating the presence and the absence of a spot as a binary character is carried out. This provides a complete

summary of the total variation.

Phenolic compounds can be easily separated by chromatography. Depending on the plant taxa under study and therefore the type of compounds present, paper chromatography (PC), thin-layer chromatography (TLC) or gas chromatography (GC) may be used. When the chromatographic spots are to be used as taxonomic characters without any further identification of the compounds, PC and TLC may be used. Gas chromatography is expensive to run but it has better resolution.

In the case of PC and TLC, spots may be identified under UV and UV + $NH_3$ gas or using a chemical developer. The colour reaction of the spots is taken and their Rfs recorded to characterise each individual spot. The comparison of Rf values from different chromatograms should be carried out with care since it is affected by so many factors. Some of these factors are:-

(1) dimension of the apparatus,

(2) grade of paper or thin-layer

(3) ascending or descending solvent flow and length of flow,

(4 )the volume of the solvent used and the composition of the solvent travelling along the paper,

(5) any other liquid or vapours incorporated for special purposes,

(6) equilibration time (if any),

(7) temperature

(8) nature of the mixture to be chromatographed and previous mode of treatment e.g. type of desalting, etc.

In most chromatographic study most of the above factors are kept uniform. In normal taxonomic study, the last factor may be the most important in causing the variation in Rf of a compound in different chromatograms. In a situation like this, the whole chromatogram should be taken into consideration at any single time in order to ascertain the relative position of a spot.

When chromatographic spots are used directly as taxonomic characters without first identifying the respective individual constituents there is a danger of an over-estimation of the actual number of characters really present and this will therefore certainly affect the resultant taxonomic relationship between the taxa. The over-estimation may be due to the assessment of "false" spots arising through the breakdown of the original compounds into their constitutent components during extraction, concentration or chromatography itself. For example, a flavonal di- or tri-glycoside can be partially broken down to intermediate glycosides and even to aglycone so that a single compound in the plant could give rise to three or more spots on a two-dimensional chromatogram.

Proteins are the most commonly studied plant molecules in chemotaxonomy. There are several advantages in the use of proteins. Among these, their direct relationship to the genetic materials RNA and thus DNA, their relatively greater environmental stability, as compared with other plant compounds, and their presence in all plant groups in reasonable amounts, which thus allows for their wider use, especially in comparative studies. The relatively simple, cheap and rapid methods available to study them is also of great importance.

Proteins can be studied by several analytical techniques. The most popular is electrophoresis which has the ability to separate out a mixture of different proteins into bands in a supporting medium, usually gel or paper, in an electric field. The process of separation depends on the interaction between the net charges of the individual protein with other proteins and the pore-size of the supporting medium. Since the electrical properties of a protein depend on the pH of the surrounding medium various modifications in the protein extract, the supporting medium, the running buffer, the electric field and the staining procedure can be effected to give the best results. Thus a whole range of electrophoretic techniques to cater for the different combination of different proteins and protein groups have been developed. Normally, the protein that is to be studied must first be defined and then the proper technique chosen and tried out. The proteins can be the albumins (associated with enzymes), globulins (associated with storage), glutelins, etc. or some isoenzyme systems. All these methods were reviewed extensively in several textbooks on this subject e.g. Smith (1976) and Gordan (1975). They can be performed in either of the two major types of apparatus as disc or slab electrophoresis.

The application of electrophoresis in plant systematics so far has been very encouraging. The most important fact that has to be appreciated here is the high repeatability of the result. Also, it was shown that grass seed proteins do not display random variation (Smith, 1976, p.143; Allard et al., in Smith (1976). If this is true for all the different plant groups storage proteins can then be used as an invaluable genetic marker to trace the relationships between taxa. The work on wheat (Johnson and Hall, 1965) showed quite convincingly the

quality of the taxonomic result that can be obtained using electrophoresis. Similar success was also found in the study on Brassica (Vaughan, 1968). More often, electrophoresis of the proteins is used to provide further evidence on an existing classification. Also because of its high resolution and consistent results electrophoresis is commonly used in varietal identification, e.g. wheat (Elton and Ewart, 1962), potato (Stegemann, and Loescheke, 1976, 1977), etc.

In potatoes, work on the tuber proteins is progressing very actively. The techniques used have been more or less standardised (Stegemann and Loescheke, 1976, Peloquin et al., 1975). The electrophoretic protein bands were found to be genetically controlled (Stegemann, 1975) and environmental factors like climate and soil, treatment with growth substances, size of mature tubers, fertilization regime or storage period of the mature tubers do not affect the electrophoretic pattern of a cultivar (Stegemann, 1975; Zacharius et al., 1971; Zwartz, 1967). Furthermore, specific banding patterns were found for each species (Desborough and Peloquin, 1966, 1969). Studies in Birmingham showed similar results (Huamán, 1975; Jackson, 1975; Schmiediche, 1977, etc.). Rickeman and Desborough (1978b) went further to postulate that when qualitative differences were few or non-existant, quantitative differences, or differences in the frequencies of proteins, might provide a means for delineating relationships.

More recently, the study of isoenzyme systems has become very popular, specially among taxonomists and evolutionists studying closely interrelated species complexes or at the infraspecific level. A series of isoenzyme systems provides a sample of defined loci for

study. The distribution and the correlation of these loci may then be used to assess any possible relationships that exist between the different groups in the complex.

Other than electrophoresis, serological techniques using the reaction of the antiserum and the antigens can also be used to study proteins. This method is more expensive and laborious because of the need to produce the required antisera. There are several serological techniques and usually the antiserum and the antibody are allowed to diffuse and to react in a supporting medium, frequently agar. Sometimes, the antigenic proteins may be separated out first using the electrophoretic technique before they are allowed to diffuse and react with the antiserum. This technique is known as immuno-electrophoresis. A successful case using this technique is the demonstration of the serological intermediary of the rye-wheat hybrid between its parents (Hall, 1959). The works of Gell et al., (1959), Lester (1965) and Hawkes and Lester (1966, 1968) on the tuber-bearing Solanum species of Latin America indicated the possibility of using this technique in wide taxa groupings.

Another less well-adapted technique to study proteins is the sequence analysis of proteins, using the "fingerprinting" technique. The proteins are subjected to the action of a selective peptide bond enzyme so that all the proteins are broken down into peptide units of a particular form which can then be separated by chromatography and electrophoresis.

In the present study, chromatography and electrophoresis on the leaf phenolic compounds and soluble tuber proteins respectively were carried out.

## 5.2. Chromatography

### 5.2.1. Materials and Methods

One hundred and two cultivars from the CIP potato collection were used. They represent the total variation of the cultivated diploids studied, based on the grouping made by visual inspection (cf. Sect. 4.7.).

Leaf materials were sampled from plants growing at Huancayo (3300m) in the 1977/78 season. They were all at the same age and in flower when the samples were taken. The fourth and fifth leaves from the apical buds of a main stem were taken and dried in an oven at 35°C for 48 hrs. The leaflets were then crushed in glass vials and stored at 5°C in the dark until they were used.

About 0.2 gm of the leaf powder was extracted with about 1ml of a solution of 1% conc. HCl in methanol in the dark at room temperature overnight. The extract was then spotted ten times on to a circle of 1.5cm diameter at 4.5 cm from two edges of a Whatman No. 1 chromatography paper (25cm x 25cm). They were then run in the first solvent (butan-1-ol: acetic acid : water = 3:1:1) for about 11 hrs. After drying at 35°C, they were run in the second direction in 10% acetic acid (v/v). Two replicates were carried out for each sample from two separated extractions.

5.2.2. Results

A total of 36 spots were detected from the chromatograms. They are presented in the master chromatogram (Fig. 5.1.). Only the colours of the spots under UV light with and without ammonia fumes were used to identify them (Table 5.1). Rf values were not taken and no attempt was made to identify the compounds present in each spot. The master chromatogram is very similar to that in Huamán (1975) and in Cribb (1972).

The spots present in each clone are shown in Table 5.2. No specific spots for each species or visual group (cf. Sect. 4.7) were detected. Thus the whole data set was subjected to numerical taxonomic analysis using CLASP. Jaccard's coefficient was used.

The dendrogram from the average linkage analysis is shown in Fig. 5.2. There were two big clusters at the 62.5% similarity level. These two clusters were also revealed in the scatter diagram from vector 1 and vector 2 plot resulting from the PCO analysis (Fig. 5.3). However, the first and second vectors with latent roots of 3.303 and 2.584 respectively accounted for only 20.1% of the total variance (Table 5.3). The vector scores are presented in Appendix XIII .

The two clusters formed from the average linkage analysis and the PCO analysis are supported by the results from "REGROUP" analysis. The ten groups formed from "REGROUP" analysis are shown in Table 5.4. One cluster is composed of Groups 1, 3, 4, 6 and 8, and the other of Groups 2, 5, 9 and 10.

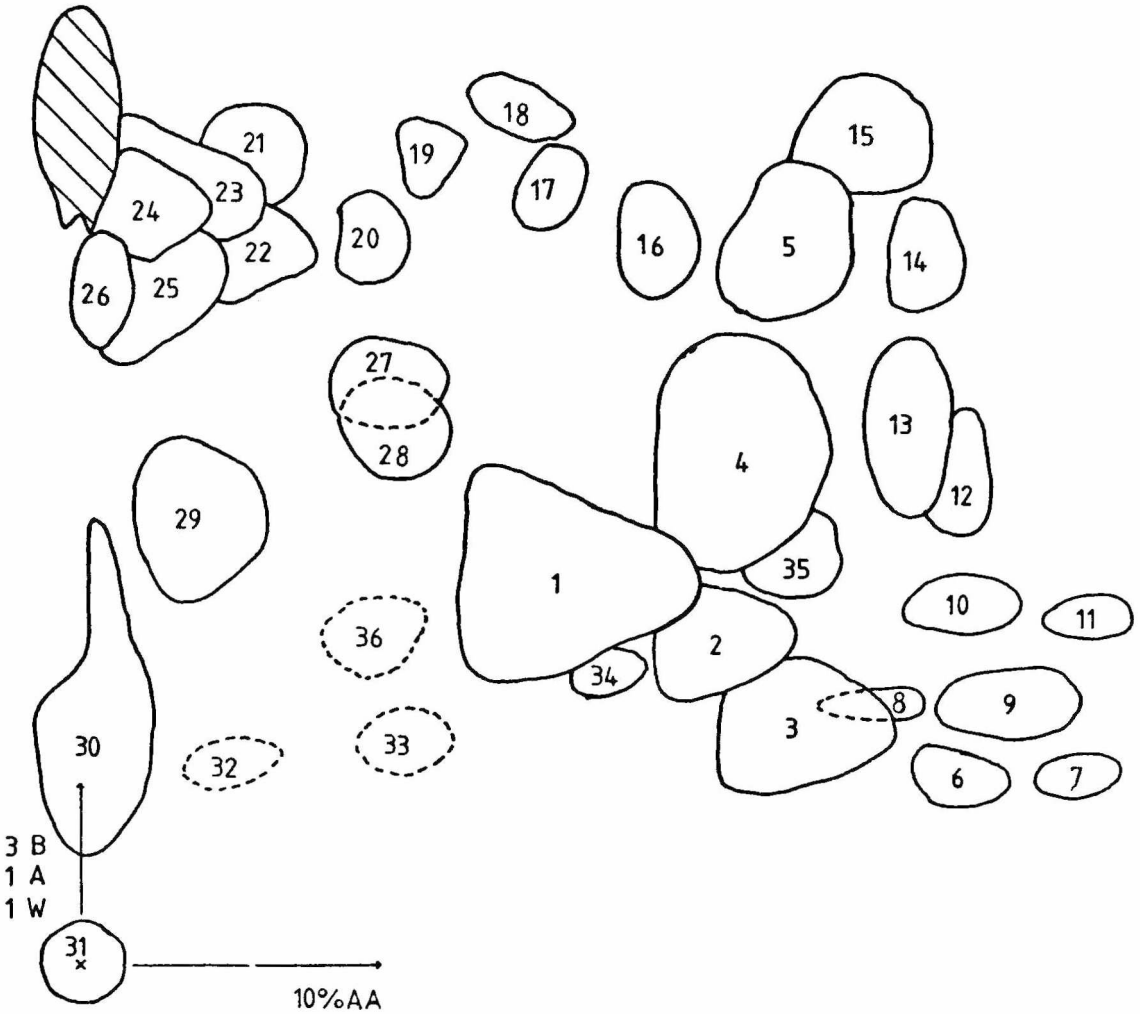



Fig. 5.1. Master chromatogram of leaf phenolics of the cultivated diploid potatoes.

TABLE 5.1: Colour reaction of the chromatographic spots in PC, obtained from leaf phenolic extracts.

| Spot No. | UV | UV + $NH_3$ |
|---|---|---|
| 1 | Dark brown | Dark yellow |
| 2 | Dark brown | Dark yellow |
| 3 | Dark brown | Dark yellow |
| 4 | Bright blue | Turquoise |
| 5 | Bright blue | Turquoise |
| 6 | - | Fluorescent green turquoise |
| 7 | Pale blue | pale blue |
| 8 | - | Fluorescent blue |
| 9 | - | Green turquoise |
| 10 | Blue | Fluorescent blue |
| 11 | Pale blue | Pale blue |
| 12 | - | Fluorescent blue |
| 13 | Bright blue | Blue turquoise |
| 14 | Light blue | Blue turquoise |
| 15 | - | Blue |
| 16 | - | White to pale blue |
| 17 | Dark blue | Fluorescent blue |
| 18 | Blue | Dark blue |
| 19 | Light blue | Fluorescent blue |
| 20 | Pale blue | Pale blue |
| 21 | Light orange yellow | Light orange yellow |
| 22 | - | Dark blue |
| 23 | - | Fluorescent dark blue |
| 24 | - | Fluorescent light blue |
| 25 | Greenish blue | Fluorescent green blue |

| Spot No. | UV | UV + $NH_3$ |
|---|---|---|
| 26 | Dark blue | Fluorescent dark blue |
| 27 | Pale blue | Pale blue |
| 28 | - | Pale yellow |
| 29 | Pale blue | Pale blue |
| 30 | Yellow | Orange Yellow |
| 31 | Pale blue | Fluorescent turquoise |
| 33 | - | Yellow orange |
| 34 | Pale yellow | Yellow |
| 35 | - | Turquoise |
| 36 | - | Pale blue |

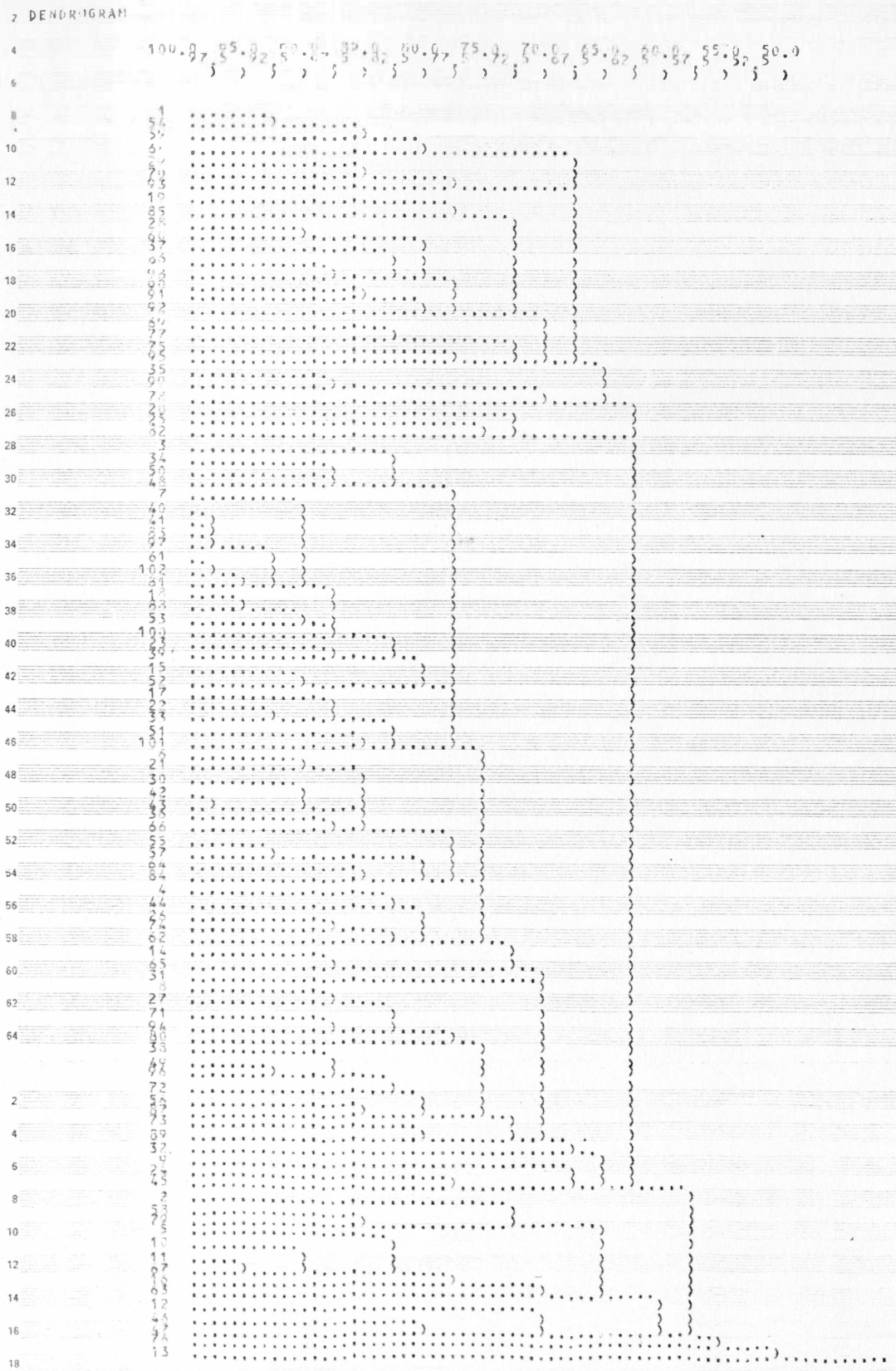
Table 5.2: Data of the chromatographic study on leaf phenolic compounds.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. CUP 72 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 26 |
| 2. CUS 100 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 27 |
| 3. CUS 158 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 23 |
| 4. CUS 277 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 29 |
| 5. CUS 241 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 27 |
| 6. CUS 549 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 24 |
| 7. JAK 7 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 28 |
| 8. JAK 11 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 24 |
| 9. JAK 62 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 24 |
| 10. JAK 188 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 28 |
| 11. JAK 190 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 29 |
| 12. H/J 33 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 20 |
| 13. H/J 50 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 18 |
| 14. H/J 103 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 24 |
| 15. H/J 179 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 27 |
| 16. H/J 417 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 26 |
| 17. H/J 501 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 25 |
| 18. H/J 660 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 31 |
| 19. HAW 5695 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 23 |
| 20. HAW 6165 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 24 |
| 21. HUA 818 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 24 |
| 22. HUA 864 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 25 |
| 23. HUA 867 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 26 |
| 24. HUA 870 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 25 |
| 25. HUA 895 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 27 |
| 26. HUA 915 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 27 |
| 27. HUA 962 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 25 |
| 28. HUA 979 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 25 |
| 29. HJT 5442 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 22 |
| 30. HJT 5457 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 24 |
| 31. HJT 5500 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 23 |
| 32. HJT 5515 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 22 |
| 33. HJT 5568 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 27 |
| 34. HJT 5625 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 27 |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35. HJT 5637 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 22 |
| 36. HJT 5734 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 28 |
| 37. HJT 5773 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 26 |
| 38. HJT 5783 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 26 |
| 39. HJT 5785 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 27 |
| 40. HJT 5787 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 28 |
| 41. HJT 5805 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 28 |
| 42. HJT 5857 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 26 |
| 43. HJT 6008 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 26 |
| 44. HJT 6106 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 26 |
| 45. 700390 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 23 |
| 46. 700670 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 22 |
| 47. 701137 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 25 |
| 48. 701266 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 26 |
| 49. 701518 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 26 |
| 50. 701739 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 26 |
| 51. 701893 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 26 |
| 52. 701905 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 30 |
| 53. 701970 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 32 |
| 54. 702219 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 26 |
| 55. 702288 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 26 |
| 56. 702472 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 28 |
| 57. 702547 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 26 |
| 58. 702856 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 27 |
| 59. 702941 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 27 |
| 60. 702998 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 25 |
| 61. 703027 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 30 |
| 62. 703129 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 27 |
| 63. OCH 2756 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 23 |
| 64. OCH 2764 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 24 |
| 65. OCH 2793 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 23 |
| 66. OCH 3486 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 27 |
| 67. OCH 3497 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 28 |
| 68. OCH 3518 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 23 |
| 69. OCH 3537 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 21 |
| 70. OCH 3552 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 22 |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71. OCH 4985 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 26 |
| 72. OCH 5131 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 27 |
| 73. OCH 5162 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 24 |
| 74. OCH 5193 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 28 |
| 75. OCH 5316 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 22 |
| 76. OCH 5364 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 22 |
| 77. OCH 5398 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 23 |
| 78. OCH 5407 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 23 |
| 79. OCH 5419 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 27 |
| 80. OCH 5460 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 24 |
| 81. OCH 5496 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 29 |
| 82. OCH 5525 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 26 |
| 83. OCH 5590 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 28 |
| 84. OCH 5648 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 26 |
| 85. OCH 5649 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 25 |
| 86. OCH 5679 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 27 |
| 87. OCH 5696 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 28 |
| 88. OCH 5697 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 32 |
| 89. OCH 5762 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 23 |
| 90. OCH 5833 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 26 |
| 91. OCH 5839 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 25 |
| 92. OCH 5859 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 25 |
| 93. OCH 6028 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 22 |
| 94. OCH 6148 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 25 |
| 95. OCH 6221 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 21 |
| 96. OCH 6232 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 28 |
| 97. OCH 6244 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 28 |
| 98. OCH 6326 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 26 |
| 99. OCH 6384 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 23 |
| 100. OCH 6401 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 29 |
| 101. OCH 6490 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 24 |
| 102. OCH 6573 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 30 |
| | 102 | 10 | 12 | 102 | 82 | 60 | 92 | 90 | 90 | 99 | 78 | 94 | 101 | 101 | 70 | 55 | 76 | 75 | 85 | 86 | 27 | 65 | 81 | 101 | 96 | 16 | 89 | 98 | 87 | 102 | 66 | 10 | 41 | 86 | 77 | 8 | |

Fig. 5.2 Dendrogram produced by average linkage clustering on the chromatographic data.



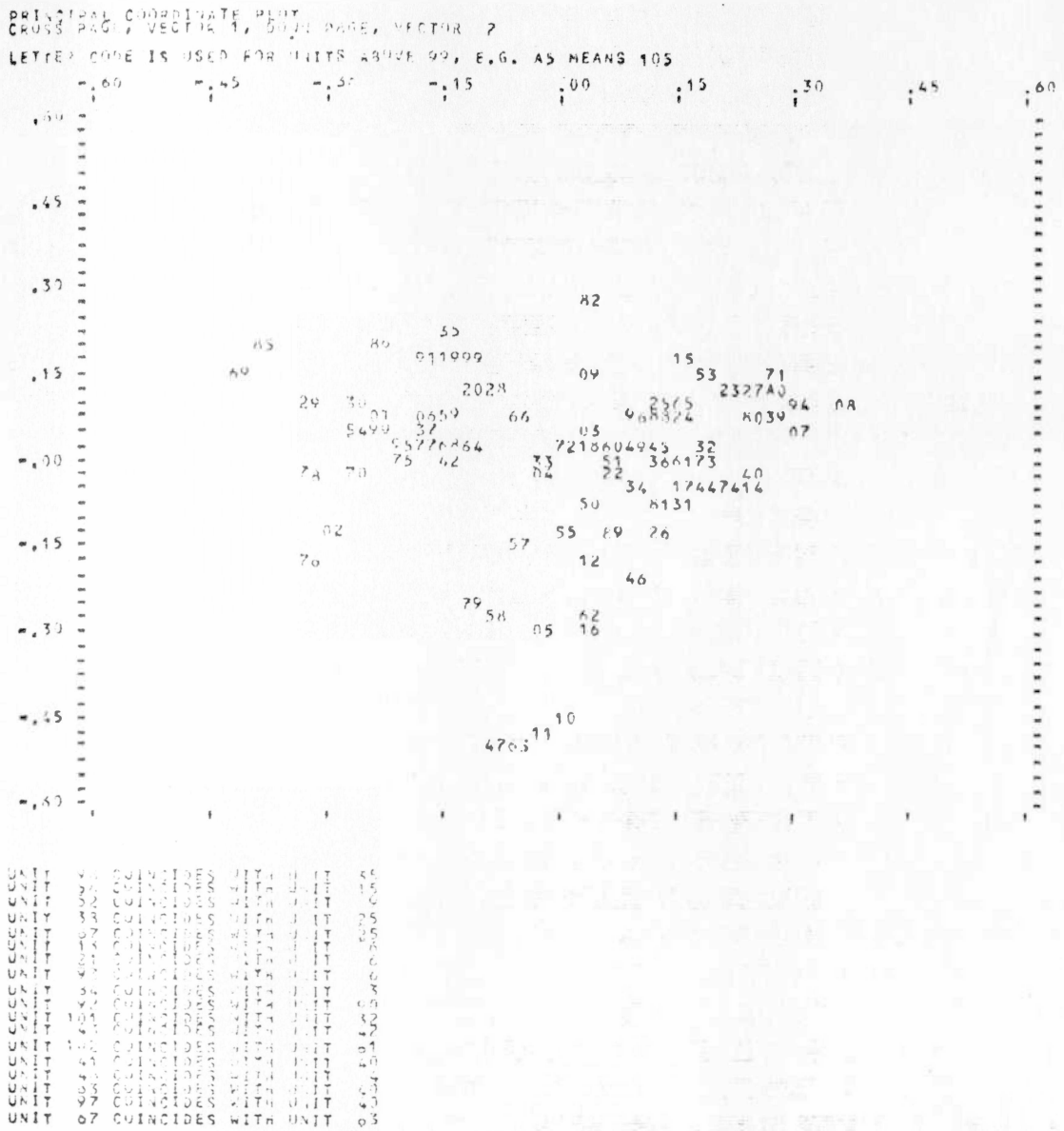



Fig. 5.3(a) Scatter diagram of PCO analysis on the chromatographic data.

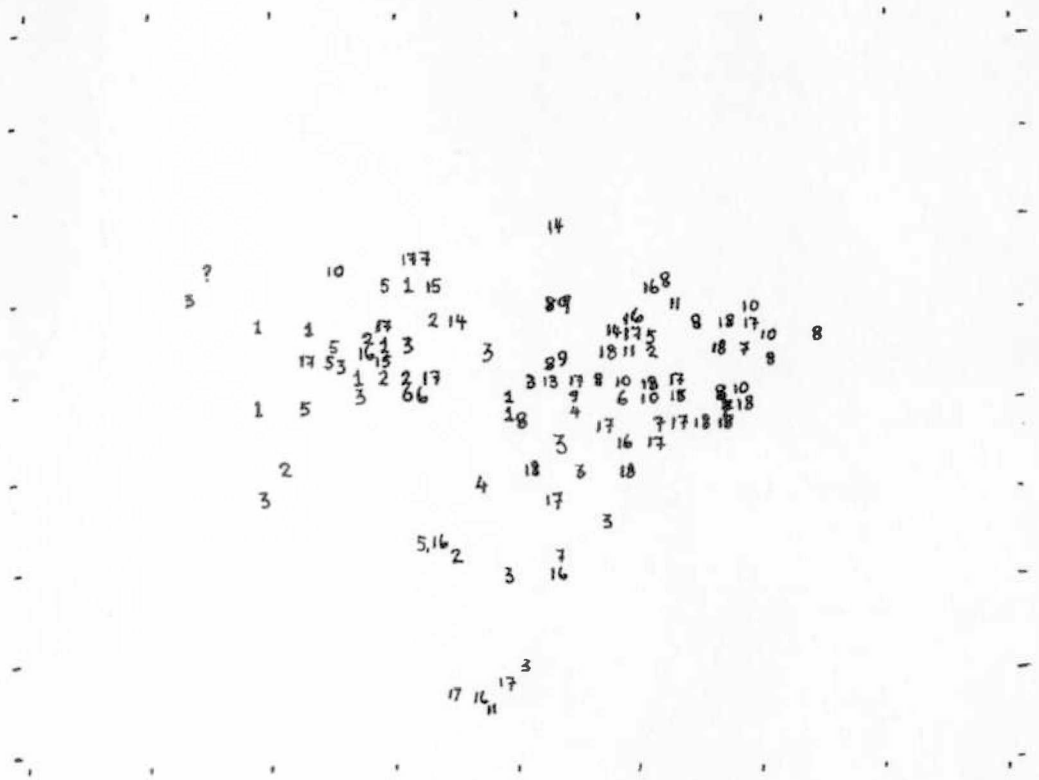


Fig. 5.3 (b) Replotting of Fig. 5.3 (a) with the Visual Group Nos.

Table 5.3: The latent roots and the percentage cumulative variance accounted for at each vector from the PCO analysis.

| Vectors | Latent roots | % cumulative variance accounted |
|---|---|---|
| 1 | 3.303 | 11.3 |
| 2 | 2.584 | 20.1 |
| 3 | 2.130 | 27.4 |
| 4 | 1.938 | 34.0 |
| 5 | 1.553 | 39.3 |
| 6 | 1.461 | 44.3 |
| 7 | 1.346 | 48.9 |
| 8 | 1.250 | 53.2 |
| 9 | 1.131 | 57.1 |
| 10 | 1.029 | 60.6 |
| Total | 29.249 | 100.0 |

Table 5.4: Result of "REGROUP" analysis

| Groups | Individuals | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 29 | 70 | 93 | | | | | | |
| 2 | 4 | 12 | 28 | 32 | 60 | 64 | 84 | | | |
| 3 | 6 | 21 | 30 | 33 | 35 | 38 | 42 | 43 | 66 | 99 |
| 4 | 1 | 54 | 59 | 68 | 85 | 86 | 90 | 91 | 98 | |
| 5 | 7 | 14 | 17 | 22 | 26 | 39 | 40 | 41 | 44 | 61 |
| | 65 | 74 | 81 | 83 | 97 | 102 | | | | |
| 6 | 2 | 20 | 58 | 76 | 78 | 79 | | | | |
| 7 | 5 | 10 | 11 | 16 | 47 | 62 | 63 | 67 | | |
| 8 | 19 | 37 | 69 | 75 | 77 | 92 | 95 | | | |
| 9 | 8 | 9 | 15 | 18 | 23 | 24 | 25 | 27 | 52 | 53 |
| | 56 | 71 | 80 | 82 | 87 | 88 | 94 | 96 | 100 | |
| 10 | 3 | 31 | 34 | 36 | 45 | 46 | 48 | 49 | 50 | 51 |
| | 55 | 57 | 72 | 73 | 89 | 101 | | | | |

There may be a third cluster which, although not well-defined, stood out in all the three analyses (Fig. 5.2, Fig. 5.3). It consists approximately of individuals from "REGROUP" Group 7.

The clusters formed from the above three analyses were compared (Table 5.5). It can be seen that their results were to a large extent consistent, with clusters from the different analyses roughly composed of the same individuals in any one single cluster.

Table 5.5: Comparison of the three clusters formed from the three analyses namely, Average linkage, PCO, and "REGROUP" among themselves and between the visual groups formed from Sect. 4.7.

| Case No. | Accession No. | Clustered together: Average linkage | REGROUP | PCO | Present classification | Vis. group | Locality |
|---|---|---|---|---|---|---|---|
| CLUSTER I | | | | | | | |
| 1 | CUP 72 | +* | + | + | S** | 5*** | may be Puno |
| 2 | CUS 100 | | + | + | S | 2 | may be Cuzco |
| 6 | CUS 549 | | + | + | S | 1 | may be Cuzco |
| 13 | H/J 50 | | + | + | S | 17 | Aguia, Ancash |
| 19 | HAW 5695 | + | + | + | S | 1 | Frias, Potosí |
| 20 | HAW 6165 | + | + | + | S | 2 | Sucre, Potosí |
| 21 | HUA 818 | | + | + | S | 2 | Corque, Oruro |
| 29 | HJT 5442 | + | + | + | S | 1 | Lircay, Huancavelica |
| 30 | HJT 5457 | | + | + | S | 1 | Lircay, Huancavelica |
| 33 | HJT 5568 | | + | | S | 1 | Acobamba, Huancavelica |
| 35 | HJT 5637 | + | + | + | S | 17 | Pampas, Huancavelica |
| 37 | HJT 5773 | + | + | + | S | 15 | Pariahuanca, Junín |
| 38 | HJT 5783 | | + | | GS | 16 | " " |
| 42 | HJT 5857 | | + | + | S | 6 | Ricran, Junín |
| 43 | HJT 6008 | | + | + | S | 6 | Ondores, Junín |
| 54 | 702219 | + | + | + | S | 17 | San Miguel, Ayacucho |
| 58 | 702886 | | + | | S | 2 | Cuzco, Cuzco |
| 59 | 702941 | + | + | + | S | 3 | San Pedro de Cajas, Junín |
| 66 | OCH 3486 | | + | + | S | 3 | Totorani, Cuzco |
| 68 | OCH 3518 | + | + | + | S | 2 | Yunguyo, Puno |
| 69 | OCH 3537 | + | + | + | S | 3 | La Paz, La Paz |
| 70 | OCH 3552 | + | + | + | S | 5 | Camacho, La Paz |
| 75 | OCH 5316 | + | + | + | S | 3 | Huancane, Puno |
| 76 | OCH 5364 | | + | + | S | 3 | Cuyo-Cuyo, Puno |
| 77 | OCH 5398 | + | + | + | S | 2 | Pisacoma, Puno |
| 78 | OCH 5407 | + | + | + | S | 1 | " " |
| 79 | OCH 5419 | | + | | S | 5,16 | Sandia, Puno |

| Case No. | Accession No. | Clustered together: Average linkage | REGROUP | PCO | Present classification | Vis. group | Locality |
|---|---|---|---|---|---|---|---|
| 85 | OCH 5649 | + | + | + | - | - | Tapuc, Pasco |
| 86 | OCH 5679 | + | + | + | G | 10 | Vilcabamba, Pasco |
| 90 | OCH 5833 | + | + | + | S | 5 | Yunguyo, Puno |
| 91 | OCH 5839 | + | + | + | S | 5 | " " |
| 92 | OCH 5859 | + | + | + | P | 3 | " " |
| 93 | OCH 6028 | + | + | + | S | 16 | Jacas Grande, Huánuco |
| 95 | OCH 6221 | + | + | + | - | 1 | - |
| 98 | OCH 6326 | + | + | + | G | 7 | - |
| 99 | OCH 6394 | + | + | + | PS | 15 | Chavinillo, Huánuco |
| CLUSTER II | | | | | | | |
| 3 | CUS 158 | + | + | + | G | 8 | may be Cusco |
| 4 | CUS 277 | + | + | + | S | 1 | " " " |
| 7 | JAK 7 | + | + | + | G | 8 | Encanada, Cajamarca |
| 8 | JAK 11 | + | + | + | G | 8 | Sucre, Cajamarca |
| 9 | JAK 62 | + | + | + | G | 8 | Jose Galvez, Cajamarca |
| 12 | H/J 33 | | + | + | G | 17 | Aquia, Ancash |
| 14 | H/J 103 | + | + | + | S | 18 | Aquia, Ancash |
| 15 | H/J 179 | + | + | + | G | 16 | Aczo, Ancash |
| 17 | H/J 501 | + | + | + | G | 7 | Sihuas, Ancash |
| 18 | H/J 660 | + | + | + | PG | 13 | Chugay, La Libertad |
| 22 | HUA 864 | + | + | + | S | 4 | Sica Sica, La Paz |
| 23 | HUA 867 | + | + | + | - | 8 | Calamarca, La Paz |
| 24 | HUA 870 | + | + | + | S | 2 | " " |
| 25 | HUA 899 | | + | + | S | 17 | " " |
| 26 | HUA 915 | + | + | + | P | 18 | Incahuasi, Lambayeque |
| 27 | HUA 962 | + | + | + | P | 18 | Huancabamba, Piura |
| 28 | HUA 979 | | + | | S | 14 | Oncay, Ancash |
| 31 | HJT 5500 | + | + | + | S | 17 | Huancavelica, Huancavelica |
| 32 | HJT 5515 | + | + | + | S | 17 | " " |
| 34 | HJT 5626 | + | + | + | S | 17 | Pampas, Huancavelica |
| 36 | HJT 5734 | + | + | + | - | 6 | Jarpa, Junín |
| 39 | HJT 5785 | + | + | + | SG | 7 | Pariahuanca, Junín |

| Case No. | Accession No. | Clustered together: Average Linkage | REGROUP | PCO | Present classification | Vis. group | Locality |
|---|---|---|---|---|---|---|---|
| 40 | HJT 5787 | + | + | + | GS | 7 | Pariahuanca, Junín |
| 41 | HJT 5806 | + | + | + | GS | 18 | Comas, Junín |
| 44 | HJT 6106 | + | + | + | S | 17 | Huasahuasi, Junín |
| 45 | 700390 | + | + | + | G | 10 | Peru |
| 46 | 700670 | | + | + | S | 3 | Peru |
| 48 | 701266 | + | + | + | S | 8 | Cachicadan, La Libertad |
| 49 | 701518 | + | + | + | G | 8 | Ulcumayo, Junín |
| 50 | 701739 | + | + | + | GS | 3 | Tambo, Ayacucho |
| 51 | 701893 | + | + | + | G | 9 | Chavinillo, Huánuco |
| 52 | 701905 | + | + | + | G | 9 | " " |
| 53 | 701970 | + | + | + | GS | 11 | " " |
| 55 | 702288 | + | + | + | P | 18 | Murillo, La Paz |
| 56 | 702472 | + | + | + | G | 8 | Paccha, Huánuco |
| 57 | 702547 | + | + | + | S | 4 | Frias, Potosí |
| 60 | 702998 | | + | + | G | 17 | Ulcumayo, Junín |
| 61 | 703027 | + | + | + | GS | 10 | San Pedro de Coyas, Junín |
| 64 | OCH 2764 | + | + | | - | 17 | Huancavelica, Huancavelica |
| 65 | OCH 2793 | + | + | + | S | 5 | Pucarani, La Päz |
| 71 | OCH 4985 | + | + | + | S | 10 | Locococha, Lima |
| 72 | OCH 5131 | + | + | + | S | 3 | Ollachea, Puno |
| 73 | OCH 5162 | + | + | + | P | 18 | Sandia, Puno |
| 74 | OCH 5193 | + | + | + | P | 18 | " " |
| 80 | OCH 5460 | + | + | + | P | 18 | Granada, Amazonas |
| 81 | OCH 5496 | + | + | + | - | 16 | Paka, Pasco |
| 82 | OCH 5525 | | + | + | S | 14 | Yanahuanca, Pasco |
| 83 | OCH 5590 | + | + | + | G | 8 | San Pedro de Pillas, Pasco |
| 84 | OCH 5648 | + | + | + | S | 9 | Tapuc, Pasco |
| 87 | OCH 5686 | + | + | + | - | 14 | Vilcabamba, Pasco |
| 88 | OCH 5697 | + | + | + | G | 11 | " " |
| 89 | OCH 5762 | + | + | + | S | 3 | Huachan, Pasco |
| 94 | OCH 6148 | + | + | + | S | 10 | Punos, Huánuco |
| 96 | OCH 6232 | + | + | + | S | 18 | Huachon, Pasco |
| 97 | OCH 6244 | + | + | + | S | 10 | " " |
| 100 | OCH 6401 | + | + | + | G | 17 | La Union, Huánuco |

| Case No. | Accession No. | Clustered together: Average linkage | REGROUP | PCO | Present classification | Vis. group | Locality |
|---|---|---|---|---|---|---|---|
| 101 | OCH 6490 | + | + | + | - | - | Rondos, Huánuco |
| 102 | OCH 6573 | + | + | + | S | 18 | Chaglla, Huánuco |
| **CLUSTER III** | | | | | | | |
| 5 | CUS 241 | + | + | + | S | 3 | may be Cuzco |
| 10 | JAK 188 | + | + | + | P | 3 | Bambamarca, Cajamarca |
| 11 | JAK 190 | + | + | + | S | 17 | " " |
| 16 | H/J 417 | + | + | + | SG | 16 | Fidel Olivas, Ancash |
| 47 | 701137 | + | + | + | G | 17 | Otuzco, La Libertad |
| 62 | 703129 | | + | + | - | 7 | Huasahuasi, Junín |
| 63 | OCH 2756 | + | + | + | - | 16 | La Union, Huánuco |
| 67 | OCH 3497 | + | + | + | - | 11 | Huamanguilla, Ayacucho |

* + indicated that the accession was clustered together with the rest in the cluster.

** S - S. stenotomum SG - S. stenotomum x S. goniocalyx
G- S. goniocalyx GS - S. goniocalyx x S. stenotomum
P - S. phureja PS - S. phureja x S. stenotomum
PG - S. phureja x S. goniocalyx

*** Visual groups 1, 2, 3, 4 and 5 were underlined to indicate their frequency of occurrence in the three clusters.

It is interesting to find that individuals of visual groups 1, 2, 3 and 5 tended to cluster together (Table 5.5, Cluster I). VGs 1, 2 and 3 are the more typical forms of S. stenotomum (cf. Sect. 4.7). VG 5 is another distinct form by itself from South Peru and North Bolivia. On the whole, Cluster I is composed mainly of typical S. stenotomum forms which are distributed from South Junin and Huancavelica southwards to Potosi in Bolivia.

Cluster II consisted of the various forms of S. goniocalyx which included "Papa Amarilla", and S. phureja. S. phureja from Lambayeque in north Peru (Case No. 26) clustered with its southern form (Case No. 74) from Sandia, Puno. This may point to the close relationship between them even though they are separated by so great a distance.

VGs 16 and 17 occurred in all three clusters. Does this therefore indicate their close relationship to all the others as shown in the morphological analyses?

The results thus correlated well with analyses done in the morphological study. S. stenotomum forms from south Peru (region south of Junin) tend to be separated from the S. goniocalyx forms which occur mostly in the Central Peruvian highlands. The intermediate nature of VGs 16 and 17 was revealed again. In several cases, as for example, nos 40 and 41, and nos. 8 and 27 (Fig. 5.2), S. goniocalyx was clustered immediately with S. phureja. This may indicate the possibility of a close relationship between the two taxa. It therefore seems that there

is a general pattern in the distribution of the leaf phenolic compounds. The pattern of distribution can be species-specific or due to a geographical and latitudinal cline.

## 5.3. Electrophoresis

### 5.3.1. Materials and Method

Two tubers per accession (excluding the duplicates) were collected in the 1977/78 season harvesting of the germplasm collection in Huancayo (3300 M). A total of about 500 accessions were obtained. They were kept in the cold store at 5-8°C in the dark for about two months. All the tubers were still fresh during the extraction of the proteins.

The tubers of each accession were washed and then frozen at -20°C for at least 24 hours. They were then thawed completely at room temperature. The thawed tubers were peeled and the sap extracted with a hand press. To prevent browning due to oxidation, 0.5 ml of the solution of 1.0 g $Na_2 SO_4$ and 0.75 g $Na_2 S_2O_5$ in 20 ml of distilled water was added. It was then centrifuged at 4500 rpm for 45 mins. (15,000 rpm is recommended but the centrifuges at CIP were out of order during that period). The supernatant containing the soluble proteins were kept at -20°C until used.

Stegemann's apparatus (slab electrophoresis - using the technique of Stegemann and Loeschike - 1976) was used. The gel was prepared by mixing the chemicals in the following sequence:-

145 ml of the monomeric solution.

7.1 g acrylamide
375 mg BIS ($N,N^{11}$ Methylenebis-acrylamide)
150 ml diluted buffer (300 ml of the buffer stock (see below) to 2,100 ml of distilled water).

50 mg sodium sulphite (anhydrous)

0.1 ml Temed (= N,N,N$^{11}$, N$^{11}$ Tetramethylethylene diamine) - as catalyst

2.8 ml ammonium persulphate (2% w/v solution freshly prepared)

This volume was enough to form a gel of 3 mm thick which was found to be most suitable for potato work (Schmiediche, 1977). The gel was found to set best when poured at a plate temperature of 20$^{o}$C and then cooled down to 5$^{o}$C. A constant power of 600 V was applied for about two hours, until the tracking dye was at the bottom of the slab.

The 0.25 M TRIS/Boric acid buffer of pH 7.9 was used. It was composed of 60.5 g TRIS (2-Amino-2 (hydroxymethyl)-1, 3 propanediol) and 73.2 g Boric acid in 2 l solution of distilled water.

The tracking dye was incorporated into the sample by mixing 0.8 ml of the thawed sap with 0.2 ml of the following solution:-

15 mg Buffalo black (amidoschwarz) (dye)

25 g sucrose (to increase the density of the sample)

50 ml distilled water.

The gel was stained overnight using the following recipe:-

5 ml of 1% Conmassie brilliant blue R mixed in 200 ml of the following solution:-

60 g trichloroacetic acid

200 ml methanol

70 ml glacial acetic acid

800 ml distilled water

It was destained, four to five times using the following solution:-

600 ml methanol

100 ml glacial acetic acid

1400 ml water

Cultivar, "Ticahuasi" (4x) was included in all the runs as a reference in order to ascertain the different in mobility of the same band due to different runs.

5.3.2. Results and discussion

A total of 382 accessions were studied. Unfortunately, even with the reference sample, cv. "Ticahuasi", which was incorporated in all the runs it was still not possible to score the bands objectively, taking each band as a character. The resolution was good but the difference in mobility of the same band as the result of different runs confused the scoring process. During electrophoresis all the varying factors were kept as uniform as possible but it was just impossible to make extracts migrate at the same rate. This may be due to the nature of the protein mixtures in the samples and their interaction with all the other factors during electrophoresis. It should be noted that the protein extracts were not properly separated because instead of centrifuging at 15,000 rpm for 30 mins they were done at only 4,500 rpm for 45 mins. (Reason in Sect. 5.3.1.).

It was therefore decided to use the major bands at the top half of the gels as a reference to group them. Based on this, 13 groups (patterns) were formed. Each group was then further divided into subgroups whenever possible according to the electrophoretic pattern at the lower half of the gels. As a result, 20 distinct groups were formed. There was a considerable amount of variation within each group considering that as many as 20 bands could be found in each gel. The general electrophoretic pattern of these groups are shown in Fig. 5.4 and a few representatives of each group are presented in Fig. 5.5. Members of each group are given in Table 5.6 with the corresponding visual group (cf. Sect. 4.7) and the site where they were collected.

It can be seen that cultivars of VG 1, the typical S. stenotomum with white flowers, all have the similar and unique protein pattern (Pattern A, Fig. 5.4). The number of bands were relatively fewer than other patterns. However, it was noted that many other cultivars from other groups have the lower half of the gels similar to that of this group.

Similarly, cultivars belong to VG 7, a distinct form of S. goniocalyx, all share a single electrophoretic pattern (Pattern B) with relatively more bands than many other groups. Pattern C which appeared to be different from B (Fig. 5.4) is closely related to it when the total variation of the electrophoretic pattern of the two groups were compared. C is composed of the various forms of S. goniocalyx, VGs 8, 9 and 10, where VG8 is "Papa Amarilla". We may assume that S. goniocalyx tends to have quite a similar electrophoretic

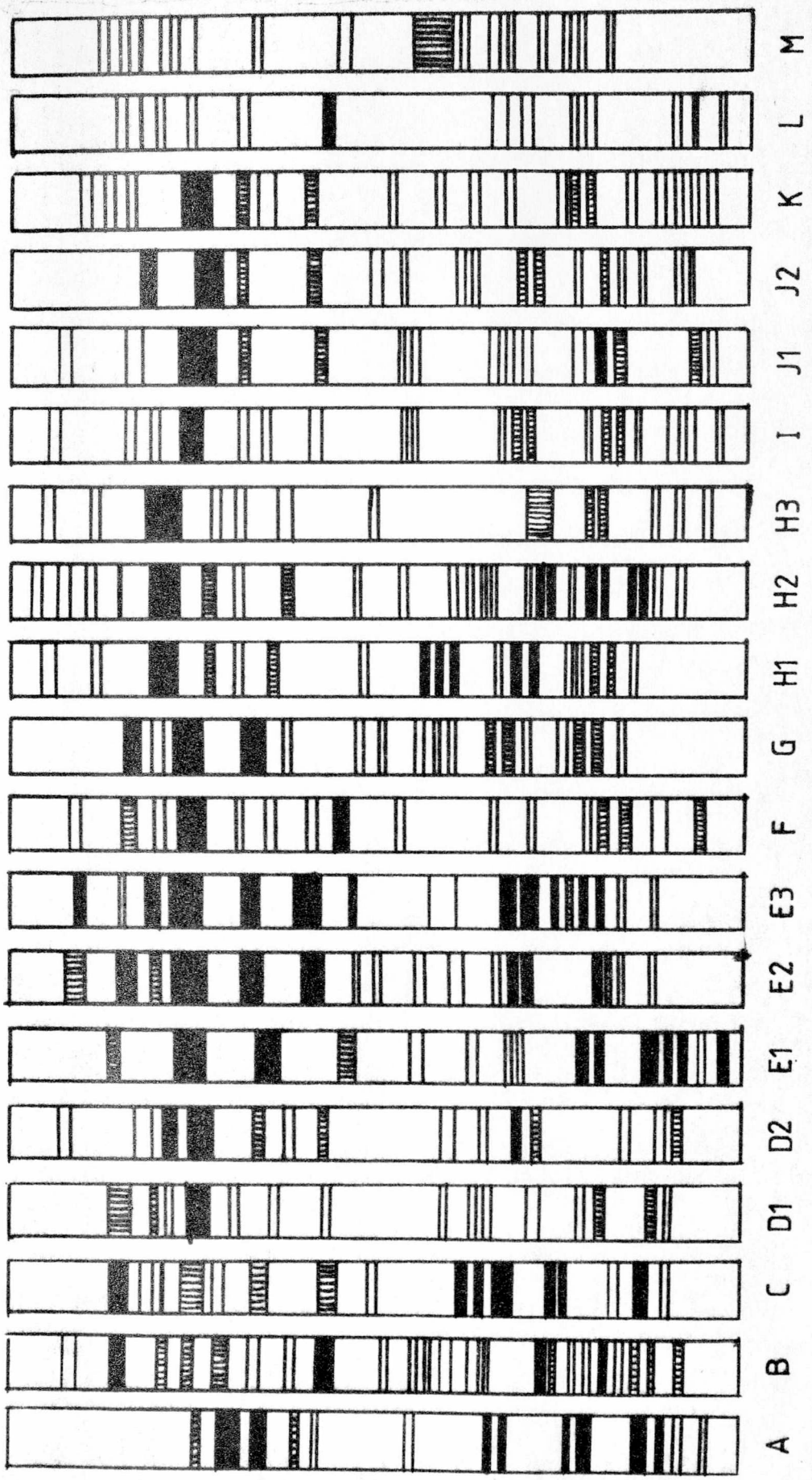
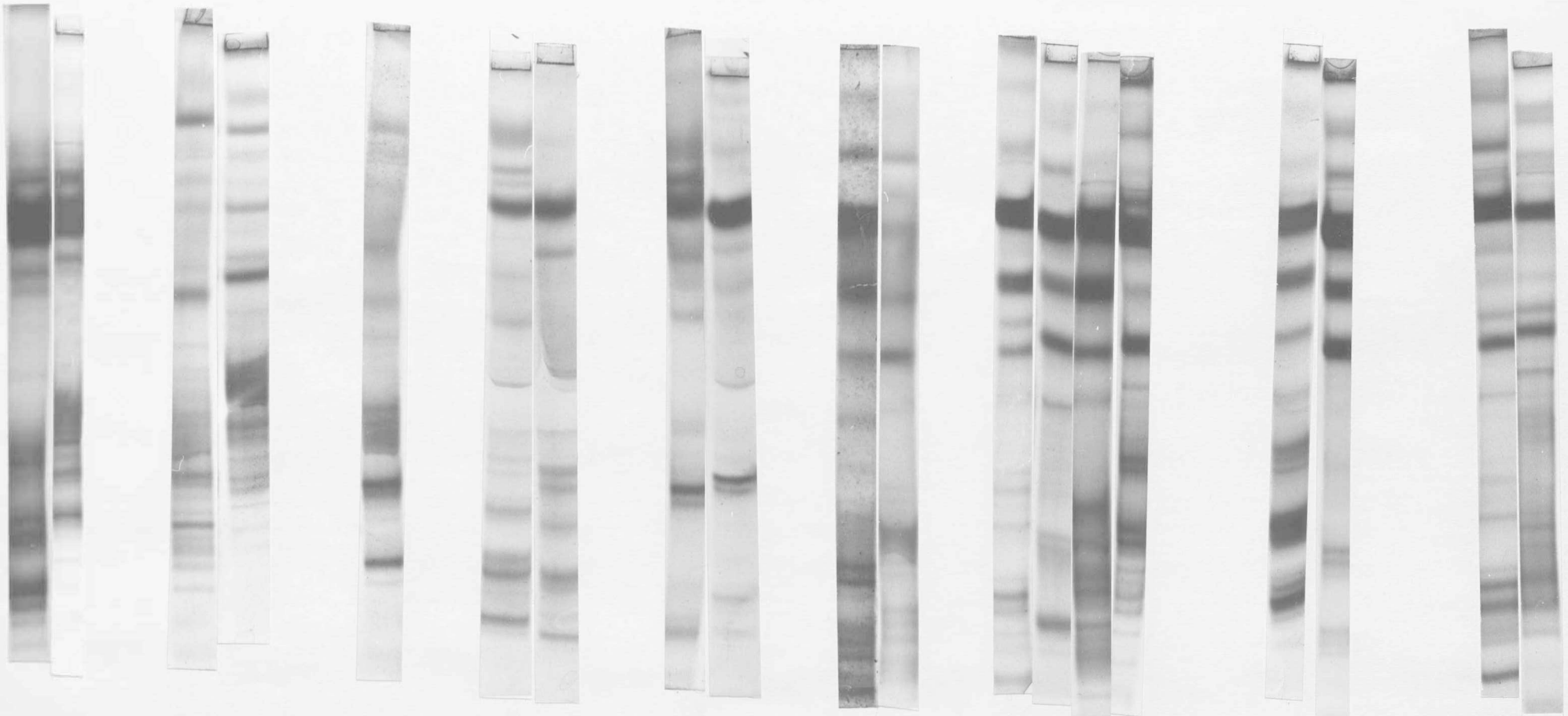



Fig. 5.4 Electrophoregrams of soluble tuber proteins of cultivated diploid potatoes.

Fig. 5.5 Representative gels of each of the electrophoretic patterns.



A B C D1 D2 E1 E2 E3 F

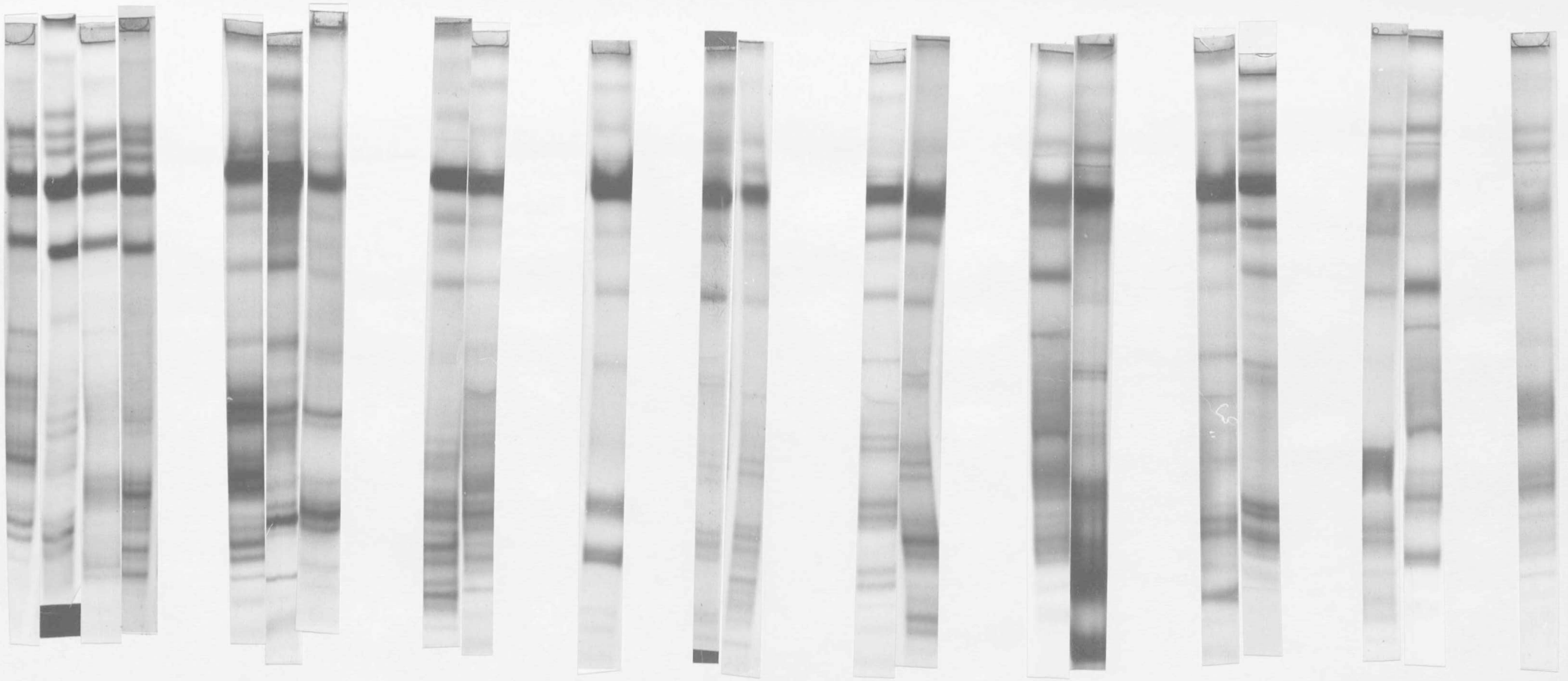

G
H1
H2
H3
I
J1
J2
K
L
M

Table 5.6: Composition of each of the electrophoretic patterns

Pattern A

| | | | |
|---|---|---|---|
| 702172[a*] | S** | 1*** | Canas y Canchis, Cuzco |
| CUP 13 | S | 1 | may be Puno |
| CUS 36 | S | 1 | may be Cuzco |
| CUS 549[a] | S | 1 | may be Cuzco |
| HAW 5695 | S | 1 | Frias, Potosí |
| HJT 5442 | S | 1 | Lircay, Huancavelica |

Pattern B

| | | | |
|---|---|---|---|
| 700469 | SG | 7 | Peru |
| 703078 | S | 7 | Ulcumayo, Junín |
| 703096 | SG | 7 | " " |
| 703129[a] | - | 7 | Huasahuasi, Junín |
| HJT 5663 | GS | 7 | Pampas, Huancavelica |
| HJT 5835 | GS | 17 | Concepcion, Junín |
| OCH 3496[a] | - | 7 | Huamanquilla, Ayacucho |
| OCH 5585[a] | - | 7 | San Pedro de Pillao, Pasco |
| OCH 6338 | S | 7 | Huachon, Pasco |

Pattern C

| | | | |
|---|---|---|---|
| 700390 | G | 10 | Peru |
| 701633 | S | 17 | Cuzco, Cuzco |
| 701905 | G | 9 | Chavinillo, Huánuco |
| 702991 | GS | 17 | Huasahuasi, Junín |
| JAK 11 | - | 8 | Celendin, Cajamarca |
| OCH 5590 | G | 8 | San Pedro de Pillao, Pasco |
| OCH 5941[a] | S | 9 | Tantamayo, Huánuco |
| OCH 6441 | - | - | - |
| OCH 6563[a] | S | 9 | Obas, Huánuco |

Pattern D1

| | | | |
|---|---|---|---|
| 702887 | P | 18 | - |
| CCC 4499[a] | P | 18 | Ipiales, Nariño |
| CCC 4513 | P | 18 | - |
| CCC 4531[a] | P | 18 | Tuquerres, Nariño |
| CCC 4558 | P | 18 | Pasto, Nariño |
| HJT 5806 | GS | 18 | Concepcion, Junín |
| HUA 915[b] | P | 18 | Incahuasi, Lambayequa |
| HUA 932[b] | P | 18 | Ayabaca, Piura |
| JAK 84[b] | P | 18 | Cajamarca, Cajamarca |
| JAK 130 | P | 18 | Chota, Cajamarca |
| JAK 203[b] | P | 18 | Bambamarca, Cajamarca |
| OCH 5154 | P | 18 | Inincolla, Puno |
| OCH 5157 | P | 18 | " " |
| OCH 5159 | P | 18 | " " |
| OCH 5162 | P | 18 | " " |
| OCH 5188A | P | 18 | Ckali, Puno |
| OCH 5189 | P | 18 | " " |
| OCH 5192A | P | 18 | " " |
| OCH 5196 | P | 18 | Turpani, Puno |
| OCH 5439 | - | 18 | Conila, Amazonas |
| OCH 5460 | - | 18 | Granada, Amazonas |
| OCH 5677 | - | 18 | Vilcabamba, Pasco |
| OCH 6232 | S | 18 | Huachon, Pasco |

Pattern D2

| | | | |
|---|---|---|---|
| 701570 | P | 18 | Ancohuayllo, Apurímac |
| 702311 | P | 18 | - |
| HUA 956 | P | 18 | Huancabamba, Piura |
| HUA 962 | P | 18 | " " |
| OCH 5182 | P | 18 | Phara, Puno |
| OCH 6573 | P | 18 | Chaglla, Huánuco |

Pattern D3 (not clear)

| | | | |
|---|---|---|---|
| 701954 | P | 18 | Chaupimarca, Pasco |
| 702888 | P | 18 | - |
| JAK 32 | P | 18 | Celendin, Cajamarca |
| JAK 75 | - | 18 | Asuncion, Cajamarca |
| JAK 83 | - | 18 | Cajamarca, Cajamarca |
| JAK 165 A | P | 18 | Chota, Cajamarca |

Pattern E 1

| | | | |
|---|---|---|---|
| 700827 | S | 5 | Peru |
| 702283[a] | S | 5 | Toralapa, Bolivia |
| 702624 | S | 5 | Aroma, La Paz |
| OCH 2793 | S | 5 | Pucarani, La Paz |
| OCH 5309 | S | 5 | Conima, Puno |
| OCH 5419 | S | 5 | Sandia, Puno |
| OCH 5839[a] | S | 5 | Yunguyo, Puno |

Pattern E 2

| | | | |
|---|---|---|---|
| 700407 | S | 17 | Peru |
| 700700[a] | S | 10 | Peru |
| 702379 | GS | 16 | Paucartambo, Cuzco |
| 702961 | G | 10 | Ulcumayo, Junín |
| 702970[a] | S | 10 | Bellavista, Junín |
| 703167 | G | 14 | Rondos, Huánuco |
| CUS 312 | S | 17 | may be Cuzco |
| HJT 5653 | SG | 3 | Pampas, Huancavelica |
| HJT 5915 | S | 10 | Paucartambo, Pasco |
| HJT 6033 | GS | 10 | Ulcumayo, Junín |
| HUA 979 | S | 14 | Ocros, Ancash |
| HUA 1009 | GS | 14 | Cajamarquilla, Ancash |
| H/J 609 | G | 10 | Conchucos, Ancash |
| OCH 3408 | G | 14 | Llata, Huánuco |
| OCH 3411 | - | 16 | Pasco, Pasco |
| OCH 3413 | G | 17 | La Union, Pasco |
| OCH 4823 | S | 10 | Yauyos, Lima |

| | | | |
|---|---|---|---|
| OCH 4985[a] | S | 10 | Canta, Lima |
| OCH 6421 | GS | 16 | Chavinillo, Huánuco |
| OCH 6469[a] | S | 10 | Rondos, Huánuco |
| OCH 6498 | S | 15 | Pachas, Huánuco |

Pattern E 3

| | | | |
|---|---|---|---|
| 700403 | S | 17 | Peru |
| 700791 | S | 17 | Peru |
| 702332 | S | 3 | Pomata, Puno |
| 702834 | S | 3 | - |
| CUP 149 | S | 3 | may be Puno |
| HAW 5593 | S | 3 | Aroma, La Paz |
| HJT 5773 | S | 15 | Pariahuanca, Junín |
| HJT 5816 | S | 4 (17) | Concepcion, Junín |
| HJT 5998 | S | 10 | Ondores, Junín |
| HUA 1022 | G | 8 | Cajamarquilla, Ancash |
| H/J 113 | G | 17 | Chiquian, Ancash |
| JAK 12 | G | 17 | Sucre, Cajamarca |
| OCH 6333 | G | 17 | Huachon, Pasco |
| OCH 6388 | GS | 14 | Chavinillo, Huánuco |
| OCH 6534 | - | 16 | Chupan, Huánuco |
| OCH 6572 | - | 15 | Chaglla, Huánuco |

Pattern F

| | | | |
|---|---|---|---|
| 700304 | G | 17 | Peru |
| 700896 | GS | 16 | Peru |
| 701611 | - | 11 | Taujapata, Abancay |
| 701739 | GS | 3 | Tambo, Ayacucho |
| 701863 | S | 16 | La Union, Huánuco |
| 701970 | GS | 11 | Chavinillo, Huánuco |
| 702421 | S | 4 | Pancartambo, Cuzco |
| 702472 | G | 8 | Paccha, Huánuco |
| 702505 | S | 15 | Cuzco, Cuzco |
| 702951 | GS | 11 | Huasahuasi, Junín |

| | | | |
|---|---|---|---|
| 703042 | S | 4 | San Pedro de Cajas, Junín |
| CUP 173 | S | 3 | may be Puno |
| HJT 5647 | S | 15 | Pampas, Huancavelica |
| HJT 5711 | S | 15 | " " |
| HJT 5785 | SG | 7 | Pariahuanca, Junín |
| HJT 5826 | S | 8 | Concepcion, Junín |
| HJT 6000 | - | 3 | Ondores, Junín |
| HJT 6022[a] | G | 17 | Ulcumayo, Junín |
| HJT 6142 | SG | 7 | Tapo, Junín |
| HJT 6164 | GS | 17 | " " |
| HJT 6184 | S | 6 | Ricran, Junín |
| HJT 6189 | S | 6 | " " |
| HUA 864 | S | 4 | Aroma, La Paz |
| H/J 225 | S | 16 | Acso, Ancash |
| H/J 301 | SG | 17 | Marcara, Ancash |
| H/J 302 | S | 17 | Cusca, Ancash |
| H/J 572 | S | 3 | Otuzco, La Libertad |
| OCH 4769 | S | 10 | Yanyos, Lima |
| OCH 5364 | S | 3 | Cuyo-Cuyo, Puno |
| OCH 5664[a] | G | 16 | Tapuc, Pasco |
| OCH 5687 | G | 17 | Vilcabamba, Pasco |
| OCH 5995 | G | 16 | Jacas Grande, Huánuco |
| OCH 6014 | S | 17 | " " " |
| OCH 6186 | GS | 17 | Punos, Huánuco |
| OCH 6357 | GS | 16 | Ticlacayan, Pasco |
| OCH 6471 | GS | 16 | Rondos, Huánuco |
| OCH 6534 | - | 16 | Chupan, Huánuco |
| OCH 6540 | G | 17 | " " |

Pattern G

| | | | |
|---|---|---|---|
| 700736 | S | 17 | Peru |
| 700939 | G | 17 | Peru |
| 701137 | G | 17 | Otuzco, La Libertad |
| 701915 | S | 16 | La Union, Huánuco |
| 701947 | GS | 17 | Chaglla, Huánuco |

| | | | |
|---|---|---|---|
| 702585 | - | 15 | Saavedra, Potosí |
| 702742 | - | 15 | San Miguel, Ayacucho |
| CUS 277 | S | 1 | may be Cuzco |
| HJT 6158 | S | 17 | Tapo, Junín |
| H/J 3 | S | 17 | Chiquian, Ancash |
| H/J 472 | G | 17 | Fidel Olivas, Ancash |
| H/J 591 | G | 17 | Mache, La Libertad |
| JAK 60 | S | 17 | Jose Galvez, Cajamarca |
| OCH 2795 | - | 8 | Pucarani, La Paz |
| OCH 3499 | PG | 13 | Huamanquilla, Ayacucho |
| OCH 5953 | S | 15 | Tantamayo, Huánuco |
| OCH 5957 | S | 16 | " " |
| OCH 6122 | G | 15 | Punos, Huánuco |

Pattern H 1

| | | | |
|---|---|---|---|
| 700362 | S | 3 | Peru |
| 702450 | S | 2 | Ilave, Puno |
| 702515 | S | 3 | Frias, Potosí |
| 702533 | S | 3 | " " |
| 703089 | S | 3 | Bellavista, Junín |
| CUS 241 | S | 3 | may be Cuzco |
| CUS 473 | S | 17 | " " " |
| CUS 656 | S | 3 | " " " |
| HAW 5560 | S | 4 | La Paz, La Paz |
| HAW 5564 | S | 3 | " " " " |
| HAW 5698 | S | 3 | Frias, La Paz |
| HJT 5919 | S | 17 | Paucartambo, Pasco |
| HUA 833 | S | 3 | Carangas, Oruro |
| HUA 847 | S | 2 | Saucari, Oruro |
| HUA 884 | S | 3 | Aroma, La Paz |
| HUA 899 | S | 17 | " " |
| H/J 206 | S | 4 | Aczo, Ancash |
| JAK 56 | P | 17 | Sorochuco, Cajamarca |
| OCH 3537 | S | 3 | La Paz, La Paz |
| OCH 4793 | S | 17 | Yanyos, Lima |

| | | | |
|---|---|---|---|
| OCH 5648 | S | 9 | Tapuc, Pasco |
| OCH 5715 | - | 10 | Santa Ana de Tusi, Pasco |
| OCH 5815 | GS | 16 | Huachon, Pasco |
| OCH 6511 | S | 10 | Quivilla, Huánuco |
| OCH 6547 | G | 10 | Chupan, Huánuco |

Pattern H 2

| | | | |
|---|---|---|---|
| 700343 | S | 2 | Peru |
| 702014 | S | 2 | Canas y Canchis, Cuzco |
| 702832[a] | S | 2 | Puno, Puno |
| CUP 84[a] | S | 2 | may be Puno |
| CUP 155 | S | 2 | " " " |
| CUS 234 | S | 2 | " " Cuzco |
| CUS 484 | S | 2 | " " " |
| HAW 5529 | S | 2 | Puno, Puno |
| HJT 5922 | S | 3 | Paucartambo, Pasco |
| HUA 781 | - | 2 | Pacajes, La Paz |
| HUA 822 | S | 2 | Carangas, Oruro |
| HUA 868 | S | 2 | Cadamarca, La Paz |
| OCH 5251 | S | 2 | San Ramon, Puno |
| OCH 5398 | S | 2 | Pisacoma, Puno |
| OCH 6323 | S | 16 | Huacho, Pasco |

Pattern H 3

| | | | |
|---|---|---|---|
| 700640 | S | 3 | Peru |
| 702353 | S | 3 | Paucartambo, Cuzco |
| CUS 632 | S | 17 | may be Cuzco |
| OCH 3538 | - | 4 | Azangaro, Puno |
| OCH 5131 | S | 3 | Ollachea, Puno |
| OCH 5348 | G | 3 | Cuyo-Cuyo, Puno |
| OCH 5686 | - | 14 | Vilcabamba, Pasco |

Pattern I

| | | | |
|---|---|---|---|
| 700894 | S | 17 | Peru |
| 701153 | S | 4 | Tarma, Junín |
| 701207 | GS | 10 | Tarma, Junín |
| 701629 | S | 8 | Cuzco, Cuzco |
| 702941 | S | 3 | San Pedro de Cajas, Junín |
| 702998 | G | 17 | Ulcumayo, Junín |
| 703117 | G | 16 | Paucartambo, Pasco |
| CUP 198 | S | 16 | may be Puno |
| CUS 672 | S | 3 | " " Cuzco |
| HJT 5500 | S | 17 | Huancavelica, Huancavelica |
| HJT 5859 | S | 16 | Tarma, Junín |
| HJT 5863 | - | 11 | " " |
| HJT 6085 | G | 17 | San Pedro de Cajas, Junín |
| H/J 348 | - | 16 | Sihuas, Ancash |
| OCH 5409 | P | 3 | Pisacoma, Puno |
| OCH 5623 | GS | 8 | Pancar, Pasco |
| OCH 5826 | P | 3 | Yunguyo, Puno |
| OCH 5859 | P | 3 | " " |
| OCH 5951 | - | 7 | Tantamayo, Huánuco |
| OCH 6518 | G | 17 | Chupan, Huánuco |

Pattern J 1

| | | | |
|---|---|---|---|
| 701052 | GS | 17 | Santus Cacha, Bolivia |
| 701205 | GS | 11 | Huasahuasi, Junín |
| 701300 | S | 17 | Tarma, Junín |
| 701406 | GS | 7 | Chaupimarca, Pasco |
| 701592 | S | 17 | Abancay, Apurímac |
| 701840 | GS | 16 | Huanuco, Huánuco |
| 701882 | GS | 14 | Jacas Chico, Huánuco |
| 701886 | S | 17 | " " " |
| 702430 | - | 17 | Yarus yacan, Pasco |
| 702547 | S | 4 | Frias, Potosí |
| 702815 | S | 3 | Puno, Puno |
| CUP 192 | S | 3 | may be Puno |

| | | | |
|---|---|---|---|
| CUS 271 | GS | 17 | may be Cuzco |
| CUS 672 | S | 17 | " " " |
| HJT 5500 | S | 17 | Huancavelica, Huancavelica |
| HJT 5777 | S | 15 | Pariahuanca, Junín |
| HJT 5846 | S | 17 | Concepcion, Junín |
| H/J 100 | G | 16 | Aquia, Ancash |
| H/J 306 | G | 16 | Cusca, Ancash |
| JAK 247 | G | 3 | Cuyo-Cuyo, Puno |
| OCH 5226 | S | 11 | Santa Ana de Tusi, Pasco |
| OCH 5410 | S | 3 | Pisacoma, Puno |
| OCH 6013 | G | 17 | Jacas Grande, Huánuco |
| OCH 6328 | G | 3 | Huachon, Pasco |

Pattern J 2

| | | | |
|---|---|---|---|
| 701640 | S | 17 | Huancayo, Junín |
| 702234 | S | 15 | San Miguel, Ayacucho |
| 702467 | G | 17 | Paccha, Huánuco |
| 702556 | S | 3 | Frias, Potosí |
| CUP 198 | S | 17 | may be Puno |
| HAW 3558 | S | 16 | La Paz, La Paz |
| HJT 5848 | S | 4 | Concepcion, Junín |
| HJT 5865 | S | 17 | Tarma, Junín |
| HJT 5892 | - | 3 | Huasahuasi, Junín |
| HJT 5964 | - | 10 | Ondores, Junín |
| HJT 6065 | G | 16 | Ulcumayo, Junín |
| OCH 3517 | S | 4 | Yunguyo, Puno |
| OCJ 3571 | S | 3 | Junín |
| OCH 5392 | S | 2 | Pomata, Puno |
| OCH 5888 | S | 16 | Miraflores, Huánuco |
| OCH 5907 | S | 4 | Chavin de Pariarca, Huánuco |
| OCH 5933 | G | 16 | " " " " |
| OCH 5997 | GS | 17 | Jacas Grande, Huánuco |
| OCH 6271 | S | 11 | Huachon, Pasco |
| OCH 6293 | S | 16 | " " |

Pattern K

| | | | |
|---|---|---|---|
| 700313 | S | 3 | Peru |
| 700320 | S | 4 | Peru |
| 702142 | S | 3 | Canas y Canchis, Cuzco |
| 702586 | S | 3 | Saavedra, Potosí |
| 702588 | S | 3 | Pacajes, La Paz |
| CUP 188 | S | 3 | may be Puno |
| CUS 14 | S | 3 | " " Cuzco |
| CUS 103 | S | 3 | " " " |
| CUS 669 | - | 2 | " " " |
| HJT 5783 | GS | 16 | Pariahuanca, Junín |
| HJT 5787 | GS | 7 | " " |
| HJT 5863 | - | 11 | Tarma, Junín |
| OCH 3427 | - | 17 | Ticlacayan, Pasco |
| OCH 3477 | S | 17 | Huancaca, Cuzco |
| OCH 5356 | P | 16 | Cuyo-Cuyo, Puno |
| OCH 5421 | - | 3 | Sandia, Puno |
| OCH 5805 | - | 17 | Huachon, Pasco |
| OCH 5975 | G | 17 | Jacas Grande, Huánuco |
| OCH 6028 | S | 16 | " " " |

Pattern L

| | | | |
|---|---|---|---|
| 700394 | S | 10 | Peru |
| 701912 | - | 17 | La Union, Huánuco |
| 702464 | S | 16 | Paccha, Huánuco |
| 702736 | S | 17 | Peru |
| 703088 | S | 17 | Huasahuasi, Junín |
| CUP 127 | - | 16 | may be Puno |
| HAW 5642 | - | 3 | Cochabamba, Cochabamba |
| HAW 6164 | S | 3 | Chayanta, Potosí |
| HJT 5517 | GS | 17 | Huancavelica, Huancavelica |
| HJT 5864 | GS | 16 | Tarma, Junín |
| HUA 863 | S | 2 | Sica Sica, La Paz |
| HUA 869 | S | 4 | " " " " |
| HUA 892 | - | 3 | Calamarca, La Paz |

| | | | |
|---|---|---|---|
| H/J 70 | - | 17 | Aquia, Ancash |
| H/J 265 | - | 16 | Aczo, Ancash |
| OCH 3518 | S | 2 | Pajana, Puno |
| OCH 5370 | - | 17 | Cuyo-Cuyo, Puno |
| OCH 5375 | S | 2 | Pomata, Puno |
| OCH 5405 | S | 2 | Pisacoma, Puno |
| OCH 5665 | - | 17 | Tapuc, Pasco |
| OCH 5697 | G | 11 | Vilcabamba, Pasco |
| OCH 5755 | - | 17 | Huachon, Pasco |
| OCH 6110 | - | 17 | Punos, Huánuco |
| OCH 6147 | GS | 16 | Punos, Huánuco |
| OCH 6186 | GS | 17 | " " |
| OCH 6270 | S | 14 | Huachon, Pasco |
| OCH 6332 | G | 17 | " " |
| OCH 6506 | S | 17 | Quivilla, Huánuco |
| OCH 6524 | GS | 17 | Chupan, Huánuco |

Pattern M

| | | | |
|---|---|---|---|
| 702222 | S | 17 | San Miguel, Ayacucho |
| 702342 | - | 8 | Sicuani, Cuzco |
| 702610 | S | 3 | Aroma, La Paz |
| HJT 5668 | S | 4 | Pampas, Huancavelica |
| HJT 6173 | S | 17 | Ricran, Junín |
| HJT 6353 | - | 10 | - |
| H/J 238 | S | 15 | Aczo, Ancash |
| OCH 5644 | S | 17 | Paucar, Pasco |
| OCH 5685 | SG | 11 | Vilcabamba, Pasco |
| OCH 5721 | GS | 11 | Santa Ana de Tusi, Pasco |
| OCH 5805 | - | 12 | Huachon, Pasco |
| OCH 6136 | G | 14 | Punos, Huánuco |
| OCH 6319 | S | 17 | Huachon, Pasco |

* suffix within a pattern indicates that the clones are duplicates.

** S - *S. stenotomum* G - *S. goniocalyx* P - *S. phureja*
SG - *S. stenotomum* x *S. goniocalyx*
GS - *S. goniocalyx* x *S. stenotomum*
PG - *S. phureja* x *S. goniocalyx*

*** Number of visual group.

pattern. However, this is not necessarily a clear-cut species-specific pattern because VG 8 which was supposed to be morphologically very unique was found to be associated with patterns E3, F, G, I and M, plus another two accessions that could not be classified into any of the existing patterns. (Actually, from observations in the field one clone of "Papa Amarilla" appeared to be related to VG 13, a S. phureja x S. goniocalyx hybrid form, and there are others that appeared to be other forms of intermediates). This was also true for VG10 which occurred in patterns E2, E3, F, H1, I, J2, L and M. The relationship between VG10 and VG14 in E2 should be taken into consideration also.

It is extremely interesting to see that all the phurejas were grouped together under two very similar electrophoretic patterns, Pattern D1 and D2. They included accessions found as far north as Nariño in Colombia and as far south as Puno in Peru. This is contrary to what was found in the morphological and chromatographic studies. S. phureja is renowned for its polymorphic nature and wide distribution. From morphological analysis (cf. Sect. 4.6), forms of S. phureja were found to occur in groups in different clusters. This may be as expected from field observation where the small southern form is very different in plant habit from the typical type described by Juzepczuk and Bukasov in 1929, also from the south. Both of these southern forms are different from the northern forms in northern Peru and Colombia. The leaf phenolics study put them together with S. goniocalyx in one big cluster (Cluster II, Table 5.5) but was unable to separate them into a separate cluster for S. phureja. Based on its electrophoretic patterns S. phureja may be considered as a good species. In some ways this correlates with characters such as non-dormancy, earliness, and leaf

glossiness in helping to define it as a species. However, can it be that the general electrophoretic patterns were selected for along with selection for non-dormancy, earliness, etc. If this is true the value of protein characters may be treated as any other form of character in promoting taxonomic decisions. Furthermore, it was found that the inheritance of three of the wide and intense (major) bands in cultivated potatoes can be explained by simple genetic actions as dominant, duplicate dominant and complementary gene action (Rickeman and Desborough, 1978a). This may have led Huamán (1975) to deny the use of these major bands in hybrid analysis and as genetic markers. On the other hand, if the total general electrophoretic pattern is considered as a whole some taxonomic information may be revealed. No proof on this is available in potatoes until hybrids from a set of well organised crosses are studied electrophoretically. There are some indications that some hybrid families may give a more consistent electrophoretic pattern than others. An example of this is the work of Schmiediche on bitter potatoes (1977) where the 28 hybrids of the Family 476.1.59 (76000.1 "S. acaule" x HJT 5886 "S. stenotomum") gave very similar protein patterns but with quite a reasonable amount of variation in the presence and absence of bands within this general pattern.

Pattern E has three 'major' bands at the top half of the gel. E1 is composed of all the VGS, a unique form from the southern distribution of the diploids. Its occurrence with that of VGs 10, 14, 15, 16 and 17 and a few of VG 3 in E 2 and E 3 may suggest some relationships between them. Can it be that VG 5 is the southern counterpart of what are VGs 15, 16 and 17 in the central region? E 2 and E 3 were differentiated by the difference in the pattern of the lower half of the

gels, but both consisted mostly of VGs 10, 14, 15, 16 and 17. If the three 'major' bands are taken as equivalent to the lighter band in C, E bears a considerable amount of resemblance to C and therefore B also.

Pattern F has the lighter middle band of the three 'major' bands in E. It was not possible to subdivide them according to the pattern at the lower half of the gel. It is a very heterogenous group and includes VGs 3, 4, 6, 7, 8, 10, 11, 15, 16 and 17. The distribution may be from central to south central Peru.

Pattern G has the lower band of the three 'major' bands in E missing. It is therefore in a way related to E and is composed mainly of VGs 15, 16 and 17.

Pattern H has only one 'major' band and below the 'major' band there are three lighter equally spaced bands. It is composed mostly of VG 3, the southern form of S. stenotomum. According to the lower half of the gel it can be subdivided into three subgroups. H 1 consists mostly of VGs 2 and 3 but with a number of VGs 10 and 17. H 2 consists almost totally of VG 2 and H 3 again a mixture of VG 3, 4, 14 and 17. The general pattern on the whole bears some resemblance to D and F. With D, it may indicate some relationships between S. stenotomum (H) and S. phureja (D).

Pattern I has quite a similar upper half of the gel to that of H but the bands were very light and the lower half of the gel was not clear. It is composed of a mixture of VG 3, 4, 7, 8, 10, 11, 16 and 17.

Pattern J resembles H closely except for the middle band of the three lighter bands below the 'major' band was missing. As in H, it was subdivided into two subgroups by the lower pattern of the gels. J 1 is composed of VGs 3, 4, 7, 11, 14, 15, 16 and 17, and J 2 is composed mainly of VGs 2, 3, and 4, and 16 and 17.

Pattern K has the general pattern of H but the middle band of the three lighter bands below the 'major' band is much more closer to the upper band than in H. It comprises both the southern forms (VGs 2 and 3) and the central forms (VGs 16 and 17).

Pattern L has no major band. It has some similarity to A and is represented by a mixture of the southern and central forms, mostly VGs 2 and 3, and VGs 16 and 17.

Pattern M appeared to be similar to L with no 'major' band but a close look relates it to J if the major bands were ignored. It is interesting to find that the two have quite similar VG make-ups.

In conclusion, electrophoresis provides a very useful tool to confirm the similarity within each of the very closely resemblance morphotypes (cf. Pattern A (VG 1), Patter B (VG 7), and Pattern E 1 (VG 5)). Also, S. phureja, which is extremely polymorphic, appeared to have species-specific protein pattern (Pattern D). The significance of protein characters in this case had been discussed above. The close resemblance of electrophoretic patterns for S. phureja and the southern forms of S. stenotomum (Pattern (H)) indicates some possible

relationships between the two species. In addition, it showed that there may be some group-specific patterns e.g. H is composed mostly of VGs 2 and 3 whereas the rest, excluding A, B, C, D and part of E, is mostly of the S. goniocalyx forms and VGs 15, 16 and 17. The occurrence of the southern forms, (VGs 2 and 3) with the central form (VGs 15, 16 and 17) may indicate some close relationships between the two groups. This is in accordance with the morphological and chromatographic study. At the moment, it is not possible to draw any firm conclusions about this until more objective comparisons of the protein bands is done. There is enough variability existing in the electrophoretic banding to do this. The lack of variation detected by Rickeman and Desborough (1978b) may possibly be due to the narrow base of the materials used or the incorrect classification of the two groups, or both.

## 5.4 Comparing the results of morphological, chromatographic and electrophoretic studies

The results of the chromatographic study (Sect. 5.2.2) and the electrophoretic study (Sect. 5.3.2) were superimposed on to the dendrogram produced from the computer-aided morphological analysis (Fig. 4.13).

### Chromatography

Only 80 of the 102 accessions analysed for the leaf phenolic compounds were represented in the morphological study. These 102 accessions were chosen systematically from the visual groups which were supposed to give a wide coverage of the whole diploid variability. It was found that the 80 accessions were distributed more or less uniformly in the whole dendrogram produced from the morphological study. This pointed to the usefulness of the visual grouping.

Since the 80 accessions are scattered sparsely over the whole dendrogram (Fig. 4.13) it is very difficult to see any definite trend of coincidence between the two studies. However, as was noted in Sect. 5.2.2, most of Cluster I is composed of VGs 2 and 3, *S. stenotomum*. This shows up again where a proportionally large number of members of Cluster I (9 out of 27) fell into the two big clusters, from C700320 (Case No. 3) to CUS 672 (Case No. 116). In addition, another four members of Cluster I from the chromatographic study were concentrated in a small cluster of the dendrogram derived from the computerised morphological analysis. Three of these, HJT 5442, CUS 549 and OCH 5407, were members of VG 1. Members of Cluster II from the chromatographic

study were found to be distributed along the whole dendrogram (Fig. 4.13).

The most important finding is that when we look at the small clusters at 57.5 to 60.0% similarity level, either members of chromatographic Cluster I or members of Cluster II but not both, tended to occur in any one single cluster. This therefore supports the clustering carried out in the morphological study i.e. individuals that are morphologically similar also have a similar set of leaf phenolic compounds. The small clusters at the 57.5 to 60.0% similarity level can therefore be said to be genuine or "natural". We can then tentatively conclude that the two studies coincide on the basis of the materials examined.

However, the chromatographic study does not give any further information to qualify the relationships between those small clusters in Fig. 4.13. At the moment, nothing can be said about their true relationships, from the very nature of the method. Furthermore, they all appear to link together at similarity level between 50 to 52.5%.

Electrophoresis

The result of electrophoresis should be compared with more caution because the protein extracts could not be prepared as recommended due to the breakdown of the centrifuge at CIP. The electrophoretic patterns of the accessions studied can best be grouped visually without any objective scoring and analysis.

Again as in the chromatographic study, Pattern H and to a lesser extent Pattern E seemed to concentrate in the two big clusters, from C700320 (Case no. 3) to CUS 672 (Case No. 116). Also, a pattern tends to have a close neighbour of its kind in the small clusters at 57.5 to 60.0% similarity. This is however not as clear-cut as for the chromatographic result. It therefore indicates some trends in the distribution of protein banding pattern. Electrophoresis can thus be used to study the relationship between the diploid cultivars.

## 6. Segregation Studies

### 6.1. Introduction

Genetic theory has shown that the degree of $F_1$ uniformity depends directly on the heterozygosity of the two parents used. When both the parents are very homozygous, e.g. pure lines, all the progeny should possess the same genotype and the variation will then be due entirely to environmental effects. However, at the other extreme, when both the parents are very heterozygous e.g. the $F_1$ individuals of a cross between two dissimilar pure lines, the variation will be very wide. If the parents are from two different $F_1$ families where all the four distinct homozygous parents were all unrelated, i.e. a double cross, the degree of segregation will be of an even higher order and so on. In between, we have a whole series of intermediate degrees of segregation. However, in real situations, segregation is very much dependent on the genetic make-up of the species as a whole. This involves the interaction of the various genetic factors like linkage, maternal effect, cytoplasmic inheritance, epistasis, etc. This can be very complicated. There is then a series of all possible higher generations crosses which give rise to different degrees of segregation. In nature, this is often known as a 'hybrid swarm'.

These phenomena can then be applied to study the genetic status of the different morphotypes and the relationships between them. Univariate analysis may be used here but the over-all segregation can be taken into account when multivariate analysis is used. In addition, the similarity between segregates of different families can even be

identified and this information can then be used to assess the relationships between the different morphotypes. This is therefore a very useful tool for the study of relationship within a species-complex.

## 6.2. Materials and method

As has already been seen in the previous chapters the cultivated diploids are very polymorphic and the majority of the clones may be intermediate between a few extreme forms. Thus random sampling of the parents may not yield the greatest amount of information because it is very likely that most of the parents will be composed of the intermediate forms only.

In this study, a control sampling according to the morphotypes was adapted. (Actually, it was due to this need that the visual grouping was done as indicated in Sect. 4.7).

Two sets of crosses were made. Set I was a half 8 x 8 diallel cross between some of the most typical morphotypes of the three entities, S. stenotomum, S. goniocalyx and S. phureja. VG 2 (cf. Sect. 4.7) was not included because no flower was available during the course of the crossing. The crossing table is shown in Table 6.1.

Set II was a series of 24 within-morphotype crosses and one 'self'. They are shown in Table 6.3.

Pollination was done in an insectproof plastic house at 'La Victoria', ancayo in the 1977/78 main season. The standard cut-stem technique was used. None of the crosses failed to be pollinated and to produce viable seeds.

Table 6.1: Set I crosses, a half 8 x 8 diallel cross between some of the different distinct morphotypes.

| | OCH 5407 VG 1 | CUP 72 VG 5 | HJT 5857 VG 6 | OCH 6326 VG 7 | 701358 VG 8 | 701893 VG 9 | OCH 5193 VG 18 | CCC 4448 VG 18 |
|---|---|---|---|---|---|---|---|---|
| OCH 5407 VG 1 | | F | F | F | F | M | M | M |
| CUP 72 VG 5 | | | F | M | F | M | M | F |
| HJT 5857 VG 6 | | | | M | M | M | M | F |
| OCH 6326 VG 7 | | | | | F | M | M | M |
| 701358 VG 8 | | | | | | M | F | M |
| 701893 VG 9 | | | | | | | M | F |
| OCH 5193 VG 18 | | | | | | | | M |
| CCC 4448 VG 18 | | | | | | | | |

Key: (Reading down the columns)

F - indicates that the clone was used as a female parent in the cross.

M - indicates that the clone was used as a male parent in the cross.

They were selected randomly.

Both sets of crosses were grown in the field at 'El Acesor', Lima in the 1978 southern winter in a randomised complete block design (RCBD) in separate experiment. Set I was divided into four blocks of 28 plots. Each plot had three rows of ten individuals each from the same family. Thus 120 individuals from each family were grown. It was planned to take records only on the ten individuals of the middle row of each plot. This would give a sample size of 40 individuals per family. Set II was divided into eight blocks of 25 plants each whenever enough seedlings were available. A plot was a row.

However, due to some unforseen circumstances (and not due to lack of time) I was prevented from taking any data on both sets of crosses.

A second planting was done for both sets of crosses in 'La Victoria', Huancayo in the 1978/79 season. Unfortunately, they were all badly damaged by a very strong hailstorm on 19.1.79.

## 6.3. Results and discussion

The results of the pollinations are shown in Table 6.2 for Set I crosses and Table 6.3 for Set II crosses. The germination data are given in Table 6.4 and Table 6.5 for Set I and Set II respectively. In Set I, all the possible combinations of the eight

Table 6.2: Pollination and fertility data of Set I crosses.

| Pedigree | No. of Pollinations | No. of big Fruits | No. of small Fruits | Total no. of Fruits | Total No. of Seeds | Av. no. of seeds/fruit |
|---|---|---|---|---|---|---|
| OCH 5407 x | | | | | | |
| CUP 72 | 7 | 4 | 0 | 4 | 187 | 47 |
| HJT 5857 | 7 | 5 | 0 | 5 | 1182 | 236 |
| OCH 6326 | 7 | 2 | 2 | 4 | 550 | 138 |
| 701358 | 8 | 4 | 2 | 6 | 366 | 61 |
| 701893 | 5 | 5 | 0 | 5 | 221 | 44 |
| OCH 5193 | 8 | 7 | 1 | 8 | 1180 | 148 |
| CCC 4448 | 13 | 9 | 1 | 10 | 625 | 63 |
| CUP 72 x | | | | | | |
| HJT 5857 | 7 | 5 | 1 | 6 | 1346 | 235 |
| OCH 6326 | 8 | 7 | 0 | 7 | 1170 | 201 |
| 701358 | 11 | 8 | 2 | 10 | 953 | 95 |
| 701893 | 5 | 3 | 2 | 5 | 530 | 125 |
| OCH 5193 | 6 | 4 | 2 | 6 | 1184 | 218 |
| CCC 4448 | 7 | 2 | 3 | 5 | 476 | 95 |
| HJT 5857 x | | | | | | |
| OCH 6326 | 7 | 6 | 0 | 6 | 1729 | 304 |
| 701358 | 7 | 6 | 1 | 7 | 1070 | 196 |
| 701893 | 7 | 6 | 1 | 7 | 1217 | 174 |
| OCH 5193 | 8 | 4 | 1 | 5 | 1155 | 231 |
| CCC 4448 | 8 | 6 | 1 | 7 | 1502 | 215 |
| OCH 6326 x | | | | | | |
| 701358 | 12 | 6 | 5 | 11 | 415 | 38 |
| 701893 | 6 | 4 | 2 | 6 | 498 | 83 |
| OCH 5193 | 8 | 7 | 0 | 7 | 700 | 100 |
| CCC 4448 | 8 | 4 | 2 | 6 | 700 | 117 |
| 701358 x | | | | | | |
| 701893 | 8 | 4 | 1 | 5 | 335 | 67 |
| OCH 5193 | 8 | 5 | 3 | 8 | 460 | 58 |
| CCC 4448 | 9 | 4 | 5 * | 9 | 175 | 44 |
| 701893 x | | | | | | |
| OCH 5193 | 9 | 7 | 2 | 9 | 1033 | 115 |
| CCC 4448 | 10 | 8 | 2 | 10 | 1335 | 134 |
| OCH 5193 x | | | | | | |
| CCC 4448 | 11 | 10 | 1 | 11 | 1220 | 111 |

* berries with no seed.

Table 6.3: Pollination and fertility data of Set II crosses

| Pedigree | No. of Pollinations | No. of big Fruits | No. of small Fruits | Total no. of fruits | Total no. of Seeds | Av. no. of seeds/fruit |
|---|---|---|---|---|---|---|
| 1. HUA 886 × HJT 5704(VG1) | 13 | 8 | 2 | 10 | 319 | 32 |
| 2. CUS 392 × 700670 (VG3) | 7 | 5 | 2 | 7 | 482 | 69 |
| 3. OCH 8220 × OCH 7821(VG3) | 13 | 4 | 0 | 4 | 34 | 9 |
| 4. CUP 184 × CUP 72 (VG5) | 4 | 3 | 1 | 4 | 183 | 46 |
| 5. HJT 5694 × HJT 6094 (VG6) | 10 | 3 | 0 | 3 | 41 | 14 |
| 6. OCH 5537 × OCH 6326 (VG7) | 11 | 6 | 3 | 9 | 135 | 15 |
| 7. 702472 × 701358 (VG8) | 6 | 5 | 0 | 5 | 103 | 21 |
| 8. OCH 5497 × 701358 (VG8) | 18 | 13 | 2 | 15 | 382 | 26 |
| 9. 701906 × 701893 (VG9) | 21 | 9 | 1 | 10 | 119 | 12 |
| 10. OCH 6096 × H/J 591 (VG14) | 14 | 10 | 3 | 13 | 2252 | 173 |
| 11. HUA 979 × OCH 5919 (VG14) | 14 | 10 | 2 | 12 | 2769 | 231 |
| 12. OCH 5525 × OCH 5679 (VG14) | 16 | 10 | 0 | 10 | 1204 | 120 |
| 13. OCH 6244 × OCH 4789 (VG10) | 10 | 6 | 1 | 7 | 597 | 85 |
| 14. HJT 6010 × HJT 5626 (VG17) | 9 | 8 | 0 | 8 | 96 | 12 |
| 15. HJT 5473 × HJT 5515 (VG17) | 15 | 13 | 1 | 14 | 13 | 1 |
| 16. OCH 3437 × HUA 978 (VG11) | 15 | 10 | 1 | 11 | 1103 | 100 |
| 17. HJT 5637 × OCH 5772 (VG 17) | 13 | 9 | 1 | 10 | 1757 | 176 |
| 18. HJT 5873 × HJT 6106 (VG11) | 13 | 5 | 2 | 7 | 310 | 44 |
| 19. CUS 234 × 702014 (VG2) | 6 | 6 | 0 | 6 | 121 | 20 |

| Pedigree | No. of Pollinations | No. of big Fruits | No. of small Fruits | Total no. of Fruits | Total no. of Seeds | Av. no. of Seeds/fruit |
|---|---|---|---|---|---|---|
| 20. OCH 5187 x OCH 5195 (VG18) | 7 | 6 | 0 | 6 | 232 | 39 |
| 21. OCH 5942 x OCH 6478 (VG18) | 19 | 11 | 2 | 13 | 261 | 20 |
| 22. OCH 5155 x OCH 5156 (VG18) | 8 | 5 | 2 | 7 | 715 | 102 |
| 23. OCH 6384 x H/J 97 (VG15) | 8 | 8 | 0 | 8 | 664 | 83 |
| 24. HUA 915 x JAK 84 (VG18) | 12 | 7 | 3 | 10 | 385 | 39 |
| 25. 701893 (selfed) (VG9) | 12 | 3 | 2 | 5 | 40 | 8 |

Table 6.4: Germination data for Set I crosses

| Pedigree | No. of Seeds Sown | No. of seeds germ-inated | No. of small seed-lings | No. of med. seed-lings | No. of large seed-lings | No. with chloro-phyll deficiency | No. of 2-leaf seed-lings | Vigour |
|---|---|---|---|---|---|---|---|---|
| OCH 5407 x | | | | | | | | |
| CUP 72 | 187 | 168 | 0 | 40 | 128 | 0 | 0 | V* |
| HJT 5857 | 250 | 229 | 4 | 52 | 193 | 0 | 0 | V |
| OCH 6326 | 250 | 250 | 27 | 102 | 121 | 0 | 0 | F |
| 701358 | 250 | 181 | 83 | 38 | 60 | 0 | 0 | P |
| 701893 | 221 | 179 | 3 | 46 | 130 | 0 | 0 | F |
| OCH 5193 | 250 | 243 | 25 | 74 | 144 | 0 | 1 | V |
| CCC 4448 | 250 | 230 | 14 | 85 | 131 | 0 | 0 | F |
| CUP 72 x | | | | | | | | |
| HJT 5857 | 250 | 236 | 27 | 122 | 87 | 0 | 6 | F |
| OCH 6326 | 250 | 156 | 62 | 66 | 28 | 0 | 0 | P |
| 701358 | 250 | 212 | 94 | 95 | 23 | 0 | 9 | P |
| 701893 | 250 | 158 | 45 | 36 | 77 | 0 | 0 | F |
| OCH 5193 | 250 | 208 | 114 | 74 | 20 | 0 | 1 | P |
| CCC 4448 | 250 | 230 | 172 | 39 | 19 | 0 | 2 | P |
| HJT 5857 x | | | | | | | | |
| OCH 6326 | 250 | 244 | 43 | 126 | 75 | 0 | 5 | F |
| 701358 | 250 | 245 | 13 | 118 | 114 | 0 | 1 | F |
| 701893 | 250 | 250 | 4 | 97 | 149 | 0 | 2 | V |
| OCH 5193 | 250 | 250 | 14 | 87 | 149 | 0 | 1 | V |
| CCC 4448 | 250 | 243 | 10 | 114 | 127 | 0 | 0 | F |
| OCH 6326 x | | | | | | | | |
| 701358 | 250 | 229 | 92 | 92 | 45 | 0 | 6 | P |
| 701893 | 250 | 224 | 17 | 70 | 137 | 0 | 3 | V |
| OCH 5193 | 250 | 204 | 49 | 68 | 87 | 0 | 16 | V |
| CCC 4448 | 250 | 240 | 35 | 94 | 111 | 0 | 3 | F |
| 701358 x | | | | | | | | |
| 701893 | 248 | 196 | 39 | 103 | 54 | 55 | 5 | F |
| OCH 5193 | 250 | 235 | 35 | 99 | 101 | 0 | 1 | F |
| CCC 4448 | 175 | 150 | 39 | 81 | 30 | 0 | 1 | P |
| 701893 x | | | | | | | | |
| OCH 5193 | 250 | 248 | 30 | 71 | 147 | 0 | 21 | V |
| CCC 4448 | 250 | 246 | 12 | 78 | 156 | 0 | 1 | V |
| OCH 5193 x | | | | | | | | |
| CCC 4448 | 250 | 247 | 36 | 84 | 127 | 0 | 7 | F |

*Keys: V - vigorous
F - Fair
P - Poor

Table 6.5: Germination data for Set II crosses

| Pedigree | Group (VG) | No. of seeds sown | No. of seeds germ-inated | No. of small seed-lings | No. of medium seed-lings | No. of big seed-lings | No. of seed-lings without chloro-phyll | No. of 2-leaf seedl-ings | No. of seedlings without cotyle-dons |
|---|---|---|---|---|---|---|---|---|---|
| 1. HUA 886 × HJT 5704 | 1 | 150 | 126 | 49 | 77 | 0 | 1 | 0 | 3 |
| 2. CUS 392 × 700670 | 3 | 150 | 141 | 6 | 27 | 108 | 0 | 2 | 0 |
| 3. OCH 8220 × OCH 7821 | 3 | 34 | 29 | 6 | 14 | 9 | 6 | 0 | 1 |
| 4. CUP 184 × CUP 72 | 5 | 184 | 77 | 43 | 26 | 8 | 0 | 2 | 4 |
| 5. HJT 5694 × HJT 6094 | 6 | 41 | 32 | 3 | 8 | 21 | 0 | 0 | 3 |
| 6. OCH 5537 × OCH 6326 | 7 | 135 | 113 | 22 | 64 | 27 | 0 | 0 | 1 |
| 7. 702472 × 701358 | 8 | 103 | 79 | 36 | 29 | 14 | 15 | 1 | 3 |
| 8. OCH 5497 × 701358 | 8 | 150 | 116 | 45 | 58 | 13 | 20 | 0 | 0 |
| 9. 701906 × 701893 | 9 | 119 | 74 | 20 | 33 | 21 | 35 | 0 | 5 |
| 10. OCH 6096 × H/J 591 | 14 | 149 | 126 | 10 | 67 | 49 | 0 | 0 | 3 |
| 11. HUA 979 × OCH 5919 | 14 | 150 | 134 | 26 | 58 | 50 | 17 | 0 | 1 |
| 12. OCH 5525 × OCH 5679 | 14 | 150 | 86 | 12 | 39 | 35 | 18 | 0 | 2 |
| 13. OCH 6244 × OCH 4789 | 10 | 150 | 134 | 3 | 15 | 116 | 1 | 0 | 13 |
| 14. HJT 6010 × HJT 5626 | 17 | 96 | 90 | 6 | 12 | 72 | 0 | 0 | 2 |
| 15. HJT 5473 × HJT 5515 | 17 | 13 | 8 | 2 | 0 | 6 | 0 | 1 | 1 |
| 16. OCH 3437 × HUA 978 | 11 | 150 | 119 | 7 | 25 | 87 | 16 | 0 | 2 |
| 17. HJT 5637 × OCH 5772 | 17 | 150 | 123 | 35 | 55 | 33 | 38 | 0 | 3 |
| 18. HJT 5873 × HJT 6106 | 11 | 150 | 78 | 15 | 32 | 31 | 21 | 1 | 7 |
| 19. CUS 243 × 702014 | 2 | 121 | 72 | 38 | 29 | 5 | 6 | 0 | 5 |

| Pedigree | Group (VG) | No. of seeds sown | No. of seeds germ-inated | No. of small seed-lings | No. of med. seed-lings | No. of big seed-lings | No. of seed-lings without chloro-phyll | No. of 2-leaf seed-lings | No. of seedlings without cotyle-dons |
|---|---|---|---|---|---|---|---|---|---|
| 20. OCH 5187 × OCH 5195 | 18 | 150 | 130 | 12 | 37 | 81 | 0 | 0 | 3 |
| 21. OCH 5942 × OCH 6478 | 18 | 150 | 115 | 1 | 12 | 102 | 0 | 0 | 2 |
| 22. OCH 5155 × OCH 5156 | 18 | 150 | 107 | 25 | 61 | 21 | 0 | 0 | 20 |
| 23. OCH 6384 × H/J 97 | 15 | 150 | 129 | 10 | 45 | 74 | 0 | 0 | 9 |
| 24. HUA 915 × JAK 84 | 18 | 150 | 103 | 21 | 52 | 30 | 0 | 0 | 9 |
| 25. 701893 (selfed) | 9 | 40 | 32 | 12 | 7 | 13 | 9 | 0 | 0 |

parents excluding the reciprocals were possible. There were also possible for crosses in Set II but the average number of seeds per fruit dropped very significantly (Table 6.2 and Table 6.3). This is probably due to inbreeding in Set II crosses because the crosses were between pairs of very similar morphotype. The number of seedlings suffering from chlorophyll deficiency increased drastically and the cross between 701906 x 701893 had nearly half of the progenies without chlorophyll (Table 6.5). Also, the number of seedlings without cotyledons increased significantly (this character was included in the 2-leaf seedling character in Set I crosses).

Since the amount of inbreeding depression may be judged from the degree of occurrence of such characters as acotyledonons or 2-leaved seedlings or chlorophyll deficiency, these features may be used as a quick screening method to assess the degree of genetic similarity between morphotype groups or clones.

## 7. General discussion and Conclusion

Cultivated potatoes, like many other major ancient crops, have evolved into a series of related species linked together in a complex manner. In addition, potatoes have formed a polyploid series ranging from 2x to 5x. Most of the taxonomic and evolutionary relationships between the higher ploidies and the diploids have already been established: S. tuberosum ssp. andigena (Cribb, 1972), S. x chaucha (Jackson, 1975) and S. x juzepczukii and S. x curtilobum (Schmiediche, 1977). The findings all point to the importance of the diploids in their formation. However, it was rather surprising to find that so little was known about the diploids, apart from S. x ajanhuiri (Huamán, 1975). Nothing was known of their variation pattern and population structure, and the present study was therefore designed to establish whether any discontinuities existed in the variation, both morphologically and biochemically. It was thus hoped to use these findings to confirm or reject the existance of the three diploids, S. stenotomum, S. goniocalyx and S. phureja, and to propose alternative taxa if this was considered necessary.

It is generally agreed by all potato taxonomists that great variability exists in the cultivated diploids. This has created much confusion about their taxonomic structure. Depending on the species concept used, they had been divided into as many as twelve species, as in the earliest classifications attempted by Juzepczuk and Bukasov (1929), Bukasov (1937) and Hawkes (1944). These were later reduced by Hawkes (1956) to the four major species, namely, S. stenotomum, S. goniocalyx, S. phureja and S. x ajanhuiri, in his revision of the tuber-

bearing Solanums. This reduction was considered necessary after he made an extensive breeding study on this material. In his second revision of the tuber-bearing Solanums (1963), S. goniocalyx was included as a subspecies of S. stenotomum. Due to the incomplete agreement with this classification by some potato workers an alternate scheme was put forward by Dodds (in Correll, 1962) where the whole variability of diploids, triploids and tetraploids was amalgamated into a single cultivated species, S. tuberosum, except for the two hybridogenic species S. x juzepczukii and S. x curtilobum. The former diploid species were reduced to Group Stenotomum and Group Phureja. The most recent classification by Hawkes (in Harris, 1978) consists of the four species as in Hawkes (1956). The problem here is therefore not only concerned with the construction of species boundaries but also with the species concept in the tuber-bearing potatoes as a whole.

The species concept is a topic that has caused much controversy among taxonomists and evolutionists. To date, there is not a single satisfactory system that can accommodate all kinds of situation. In the classification of cultivated potatoes the two major species concepts, the morphological concept and the biological concept, in a broad sense, have been tried out. The earliest classification mentioned above followed strictly the morphological concept. Its major weakness was immediately revealed when the vast amount of variability was presented for classification. Each unique variant was named as a Linnean species, variety or form. Thus the very purpose of classification was defeated. Instead of bringing order it created more confusion. It is therefore obvious that the morphological concept by itself is inadequate.

Fortunately, potato taxonomists quickly realised the serious pitfalls inherent in the purely morphological concept. Hawkes (1956) used the biological species concept in part, and at the same time kept to the general framework of the original classification, thus attempting a major reduction in the number of species, as indicated above. Breeding experiments were carried out to delimit species. However, the cultivated potatoes are almost all interfertile. They appear to share a common gene pool (Dodds and Paxman, 1962) and even to some extent for the different ploidy levels. These might have led Dodds (in Correll, 1962) to put all of them together under one species except for the hybridogenic bitter potatoes. It can be seen that Dodds' scheme at first glance appeared to adopt the biological species concept by grouping all the interfertile populations into one single taxon. However, if one were to take the strictest sense of the many definitions of the biological concept into consideration it falls short of satisfying the criteria. Mayr (1940) defined a biological species as "groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups". It was rephrased by Dobzhansky (1950) as "the largest and most inclusive reproductive community of sexual and cross-fertilizing individuals which share a common gene pool". According to these definitions many of the wild and cultivated potatoes should also be classified together under one Linnean name because they are all interfertile, but they perhaps do not completely share a common gene pool. As Harlan (1970) put it - "It could, ...., result in lumping all the one hundred or more tuber-bearing forms of Solanums into one giant biological species". Thus Dodds is incorrect in drawing a sharp line between wild and cultivated materials if he wishes to follow rigidly

the biological species concept. It is also worth noting that many wild species, e.g. S. canasense, which are morphologically more similar to some of the cultivated forms than the cultivated forms among themselves, are classified as distinct species. After all they are all potentially interfertile and wildness and alkaloid content of the tuber may represent a few genes differences only. Lumping of many species together in this case will cause a serious oversimplification and therefore negate the purpose of classification. The biological species concept is therefore not completely applicable for potatoes.

It should also be appreciated that the idea of the objectiveness of the biological concept is not shared by all plant taxonomists, for various reasons. Some would rather see taxonomy separated from evolutionary considerations (Sokal and Crovello, 1970) and think of species as "utilitarian mental constructs and that species in practice do not comply with sets of prescribed rules" (Levin, 1979). They are therefore empirical. This may even result in a more "natural" or phenetic classification.

Hawkes' 1956 classification attempts to steer a middle course between the extremes of both systems. As can be seen, Dodds' classification is not as "biological" as it seems to be; instead it is rather a rephrasing of Hawkes 1956 classification where the species names have merely been changed into Groups.

In order to pursue a further understanding of potato taxonomy, the breeding system and the eco-geographical distribution should also be studied. Most potato species reproduce sexually except

for some of the odd ploidies where fertility is low. Vegetative propagation provides clones adapted to particular environmental conditions but the plasticity of a clone to withstand different environmental conditions should not be underestimated. The diploids are self-incompatible and therefore cross-pollination is obligatory. Intrinsic sterility barriers between breeding populations are poor but they are usually kept apart by physical barriers due to their preferences for different ecological niches, by geographical separation or by the difference in flowering period. An example of the latter type is between S. microdontum and S. vernei from north-west Argentina (Hawkes and Hjerting, 1969). A knowledge of their eco-geographical distribution is therefore important for taxonomic decisions. When distributions of two species meet hybridisation is inevitable. An example is the introgression between S. chacoense and S. microdontum (Hawkes, 1962a) in northwest Argentina which results in an invasion of S. chacoense into new areas. However, sometimes the hybrids formed will be less well adapted than the parents and will disappear in time, leaving the two parents in a more or less pure state (see Hawkes and Hjerting, 1969, Appendix III).

In cultivation, all species and ploidy levels are traditionally grown together by the Andean Indians in mixed fields. They are sometimes accompanied by weedy species such as S. leptophyes, S. sparsipilum, S. megistacrolobum, S. acaule, etc. in the poorly weeded fields. Hybridization take place between them and the nature of these fields allows for new seedlings to become established and enter into the population.

In some crosses the $F_2$ generation will suffer from some genetic breakdown and loss of fertility. This was postulated as the result of cryptic genome differences between the two parents (Hawkes, 1972). This phenomena provides him with a good ground to set the boundary of many potato species.

In conclusion, an acceptable system for classifying potatoes may be one that will reflect the natural variation and the eco-geographical distribution. It should, also , be simple to use and flexible enough for any modification if called for. It may have to be separated strictly from the evolutionary viewpoint only until the definite evolutionary path is worked out for that particular taxon. It will thus contain information on existing natural variation as well as evolutionary information when available. The system will then be ever evolving with new information being added as it is discovered.

I maintain that Hawkes' and Dodds' classifications are the same except that at the moment a section of Group Stenotomum should be promoted to species level as S. x ajanhuiri, since it was shown to be a hybrid between S. stenotomum and S. megistacrolobum (Huamán, 1975). Furthermore, S. x ajanhuiri has developed a distributional, morphological and to a certain extent genetical set of characteristics which is no longer similar to that of S. stenotomum and S. megistacrolobum.

The present study was based on 938 accessions, with a very wide range of the total variability of diploids, including S.

stenotomum, S. goniocalyx and S. phureja. After identifying the duplicates about 500 accessions were left. The three species are all very polymorphic. Species boundaries are not clear and diagnostic characters of one species overlap those of another. This may have led Ochoa to group many of them as hybrids between one and another. It was therefore not possible to divide them up into the three-species for comparison, and sampling was not possible either.

The problem can be considered as one of pure phenetics, and on this basis each individual was regarded as of equal value in estimating the total variation. From this point, by using numerical methods, the whole collection was assessed for the presence of discontinuities and clusterings, in an attempt to provide a more objective classification than had hitherto been possible.

Before beginning the discussion of the numerical results we should be aware of the fact that these numerical results should be treated as provisional since the techniques are still relatively new. At population level, even less is known. As Sneath and Sokal (1973) put it - "There is some doubt even about whether meaningful hierarchic structures can be obtained below a given categorical level. Whether this level is below that of the species, (whatever its exact definition may be), or whether non-hierarchic phenetic relations begin at a higher level needs further investigation". However, Janoria et al., (1976), using correlation coefficients and the unweighted pair-group method using arithmetic averages (UPGMA), were able to cluster 18 dwarf rice cultivars according to their pedigree. Bird and Goodman (1977) showed the usefulness of principal component analysis in the study of maize

"races". Moreno and Cubero (1978) again used PCA successfully in the study of Cicer arietinum. Martin and Rhodes (1978) used a combination of different multivariate analyses to study Dioscorea species, also with success. In the present study, the numerical techniques used were somewhat proven, using a test population (Sect. 4.4.4). They were shown to be sensitive enough to cluster morphologically similar individuals together and to detect some genetic relationships between them depending on the complexity of the population under study (Sect. 4.5).

The results from the morphological study (Sect. 4.6.4) indicate the very close relationship between all the cultivars under study. There were no distinct major clusters. This is therefore in accordance with previous experience when classical taxonomic methods were used, and many problems were encountered in trying to draw the species boundaries. Numerical taxonomy therefore appears to share a similar problem to the classical approach. Distinct forms like the typical S. stenotomum, S. goniocalyx and S. phureja are not difficult to identify. It is the "intermediate" forms that have created this taxonomic problem. The term "intermediate" refers to forms that do not have a set of well correlated morphological characters that allows them to be recognised as such. These "intermediate" forms possess very wide variation in morphological features where characteristics of different distinct forms may be present or completely new characters are found, e.g. very deep red corolla. Sometimes, these "intermediate" forms include all those clones that could not possibly be allotted to any of the existing distinct classical taxa. If this is the case classification becomes a matter of convenience. It should also be noted

that these "intermediates" are different from the clear-cut "hybrid" forms e.g. S. stenotomum x S. goniocalyx, S. stenotomum x S. phureja, etc. Thus as shown in Fig. 4.1, the particular clone, OCH 11208 has the typical flowers of S. stenotomum but the typical leaves of S. phureja. However, it is not suggested that these hybrids are simple $F_1$s, though they might be $F_2$ segregates with blocks of linked gene complexes.

The whole variation may be seen as a continuum under a single taxon. However, we must not deny the existence of certain distinct forms. Some of them may possibly be the progenitors, e.g. the narrow leaved S. stenotomum, and others may be newly created forms resulting from hybridization, introgression and selection. These distinct forms were all revealed in the dendrogram produced from the morphological analysis, (cf. Table 4.18 in Sect. 4.8).

Are these small distinct clusters genuine and therefore "natural"? This seems to be so for the following reasons:-

(1) Numerical techniques have been tried out and found to work well. They were able to cluster all the similar morphotypes together (Sect. 4.4.4).

(2) Results from biochemical studies, both chromatography and electrophoresis, coincided fairly well with those of the morphological study (cf. Fig. 4.13 and Sect. 5.4)

(3) The small distinct clusters coincided with groupings made visually in the field (Sect. 4.7). A list of matches between the numerical analysis clusters and

the visual groups was given in Sect. 4.8.

We are therefore left with a series of distinct morphotype groups (clusters). To examine them further, it is best to follow the visual groups (VGs) in Sect. 4.7. These VGs may have been formed subjectively but their close coincidence with the more objective clusters of numerical analysis allows them to be considered as though they are reasonably objective.

The most obvious part of the analysis in relation to the VGs is the clustering of most of the individuals of VGs 2, 3 and 5 into two big clusters (Cluster No. 28 to Cluster no. 37, Fig. 4.13). These two clusters comprise the southern forms of S. stenotomum, those with the narrower leaf types, which occur mainly from Cuzco southwards to Potosi in Bolivia. Actually, VG 2 consists of forms that were first described by Juzepcuk and Bukasov in 1929. The variability within VGs 2 and 3 is reasonably high, and they consist of about 20% of the total number of distinct clones studied (Table 4.17). These three VGs, 2, 3 and 5, occurred mainly in groups 6 and 10 of "REGROUP" analysis (Sect. 4.6.4). They stood out even more clearly in the PCO scatter diagrams (Fig. 4.12(c)-(h)). From chromatographic study, these three, together with VG 1, tended to group together again in a cluster, cluster I (Fig. 5.2). Also, VGs 2 and 3 have a more or less similar electrophoretic pattern, pattern H (Table 5.6). However, VG 5 has a set of different patterns (E1). Here, it should be added that all VG 5 were grouped together in Cluster No. 35 in the dendrogram from the morphological study. It might then be a unique form within the big southern "complex". The term "complex" here refers to a collection of different unique forms which are linked together morpho-

logically and geographically and even biochemically.

Considering all the evidence given above, the distinctness of the southern "complex", and its equation with S. stenotomum (VGs 2 and 3, and possibly 5), is beyond doubt.

The only discrepancy in the concept of 'S. stenotomum" is VG 1. It is the white flowered, narrow leafleted "Poccoya" form, which occurs mainly in Cuzco and northwards to Huancavelica and disappears in southern Junín. This group is usually considered by experienced potato taxonomists as one of the most typical forms of S. stenotomum. However, from morphological studies, it is separated from the main clusters of S. stenotomum (the two big clusters mentioned above). Instead, clones of this form clustered tightly together in Cluster No. 45. It fused with Cluster No. 46, which consists of VGs 2 and 4, at 52.5 to 55.0% similarity level. This level is the same as that forming the 2 clusters above. VG 1 has therefore in its immediate neighbours clones of the southern S. stenotomum "complex". Furthermore, observations on the progeny of a cross between two clones of this group, HUA 886 x HJT 5407, detected almost no segregation at all. It therefore breeds true. Also, when it was crossed to S. goniocalyx, "Papa Amarilla", 702151 x 700042, there was lack of clustering as compared with some other crosses (Sect. 4.4.4.1). This may thus be seen as a cross between two good species, giving rise to a single homogeneous $F_1$ generation. A similar result was obtained in another cross between VG 1 and another S. goniocalyx (VG 14), HJT 5457 x OCH 6401 (Sect. 4.4.4.1). Based on leaf phenolic study, VG 1 clustered consistently with the rest of the southern forms. However, it has its own electrophoretic pattern (A) which is one of the simplest patterns in

this study. On the whole VG 1 should therefore be included as a member of the S. stenotomum "complex".

The southern S. stenotomum "complex" should therefore include VGs 1, 2, 3, 4 and 5. The case of VG 4 will be argued below.

The rest of the dendrogram (Fig. 4.13) may be roughly divided into another two sections. One consists of Cluster No. 1 to Cluster No. 25 and the other, Cluster No. 41 to Cluster No. 49 (Table 4.18). This division may be artificial because we have very little knowledge about the genuineness of the linkage at this low level of similarity (52.5 to 55%). The PCO plots with the mean coordinates of "REGROUP" groups (Fig. 4.12 (c) - (h)) show that all the other groups except for 6 and 10 did not form any cluster. However, there is an indication that group 1, 4 and 7 may have been the opposite "pole" of groups 6 and 10. Group 4 contains the typical S. goniocalyx of Juzepcuk and Bukasov, "Papa Amarilla" (VG 8). Unlike the southern S. stenotomum (VGs 2 and 3) it has only a few variants. Its relationship with other forms therefore cannot be ascertained. However, other forms like VGs 7, 10, 11, 14, 15, 16 and 17 occurred together with "Papa Amarilla" in a cluster at 52.5 to 55.0% similarity level (Cluster No. 12 to Cluster No. 19, Table 4.18).

Perhaps it would be more realistic to consider the whole section of the dendrogram from Cluster No. 1 to Cluster No. 25 as a single unit, a "complex". We then have a "complex" with many different forms, VGs 7, 8, 9, 10, 11, 14, 15, 16, 17 and 18. This lumping is

justified because the different VGs were concentrated individually into different smaller clusters, at 57.5 - 60.0% similarity level, within the big cluster of this "complex". VGs 7, 8, 9 and to a lesser extent 10 are morphologically distinct. From field observations, the segregation of crosses between clones of the same group was narrow and each family could easily be related to the parental group. The occurrence of abnormal seedlings was high in each case (Table 6.5). These four VGs have very few variants each (Table 4.17).

The bulk of this "complex" is composed of the "intermediate" forms, VGs 15, 16 and 17. In addition, a broad-leaved form of S. goniocalyx (VG14), the southern S. stenotomum forms (VGs 2, 3 and 4) and S. phureja forms (VG 18) were also present. The "intermediate" nature of VGs 15, 16 and 17 was revealed in the morphological study. These three groups occurred in most of the clusters at a level between 52.5 to 55.0% similarity and therefore seemed to be related to many other groups such as VGs 3 and 4 on the one hand and VGs 7, 8, 10 and 14 on the other. From chromatographic and electrophoretic studies a similar trend was obtained (Sect. 5.2.2 and 5.3.2). In addition, crosses between members of similar visual groups segregated more widely than many other distinct forms. Their "intermediate" nature is therefore confirmed and they may best be considered together as a single unit. Together, they make up to 40% of the total variability in the cultivated diploids and occur mostly in the central Peruvian Andes, southwards to Cuzco and northwards to northern Peru. The presence of southern S. stenotomum forms in this " complex" and, similarly, the occurrence of these "intermediate" forms in the southern "complex" (Cluster No. 28 to Cluster No. 37) may thus be an indication of gene flow between the two "complexes".

We have now a situation where we can see:

(1) a large number of "intermediate" forms (VGs 15, 16 and 17) and a very few "hybrid" forms (VGs 11, 12 and 13).

(2) several unique forms with few variants each (VGs 5, 6, 7, 8, 9, and 10)

(3) evidence of "gene flow" between the two major "complexes"

(4) presence of S. phureja (see later)

(5) a distinct geographical distribution of the two "complexes".

Here, I will first try to construct a scheme to simulate the above situation. Evidence to support this postulation will be presented later.

The situation may best be explained by postulating a certain cultivated taxon in the central Peruvian highlands. It must have been quite distinct from the southern taxon because the present central Peruvian highlands "complex" is so different from that of the southern one. It might have been widespread and its origin could have been a parallel domestication of wild forms from the central Peruvian highlands with no direct connection with the southern form. More likely, it could have been an establishment from the earlier introduction of the southern form with or without introgression and hybridization with wild relatives or even semi-domesticated forms. The central forms became stabilised and gave rise to some distinct forms like that of "Papa Amarilla" or related ones. There is no evidence to support any of these hypotheses except that we have not yet come across any similar wild relatives that can possibly be the wild progenitors of the central forms.

When the southern forms came into contact with the central forms in the central Peruvian Andes interbreeding took place. The hybrids might have had some advantages over the parental types, thus providing a range of "intermediate" forms (VGs 15, 16 and 17). This process may still be going on at the present time with selection continuing constantly to give more stable forms (VGs 6, 7, 9 and 10 and also S. phureja). Equally possible is that these distinct forms could be the remnants of the ancient central Peruvian highlands taxon which has now mostly been overwhelmed by the hybrids. Therefore, "Papa Amarilla" and all the other distinct forms such as VGs 6, 7, 9 and 10, and even S. phureja could have been the stabilised forms of some of the segregates. They were being selected for adaptation to special environmental conditions, such as those required by S. phureja, or even through human preference as for example, with "Papa Amarilla". Here, we should also not forget that these might have been introgression from endemic wild species in the central highlands of Peru.

To complete the picture gene flow should be in both directions, from central to southern Peru and vice versa. It seems that it was, and may still be going on. VGs 3 and 4 are possibly the remains of introgression of the southern forms by the central Peruvian forms since they have so wide a variability (Table 4.17). Their geographical distributions support this claim also. They may then be seen as the counterparts of the northern "intermediate" forms. In the south, the parental types, possibly VGs 1 and 2, may have some special advantages over their hybrids thus preventing them from being overwhelmed by the "intermediate" forms. VG 1 may even be the result of the introgression of the southern forms by the central forms. Observations in the field

at Huancayo (3,300m) indicate that they (VGs 1 and 2) flower sparsely, especially VG 2.

Since two distinct forms of southern S. stenotomum (VG 1 and VG 2) have been identified, the immediate questions are - which of the two were involved in the creation of this "intermediate" complex? Did it involve both of them? According to distributional evidence VG 1 is more likely to be the one that intruded into the central region. However, gene flow more probably has involved both VGs 1 and 2.

The whole postulated scheme is summed up in Fig. 7.1. Let me now try to put forward the available evidence to support what have been postulated above.

As was postulated, VG 1 was the form of S. stenotomum that intruded into the central region. This is obvious if we examine the geographical distribution of VG 1 forms. VGs 2 and 3 are found mainly in northern Bolivia and Puno. They occur relatively less frequently in Cuzco and Apurimac. However, VG 1 has its major occurrence in Cuzco and is also found in Huancavelica and even southern Junin in the north, and Puno and northern Bolivia in the south. We can therefore see that VG 1 is in direct contact with the central "complex", even to this day. However, morphological study indicates a relationship between VGs 2, 3 and 4 with VGs 15, 16 and 17. A more obvious case is Cluster No. 3 where four accessions of VG 3 were clustered among the central "complex" forms. We should therefore consider both VGs 1 and 2 as

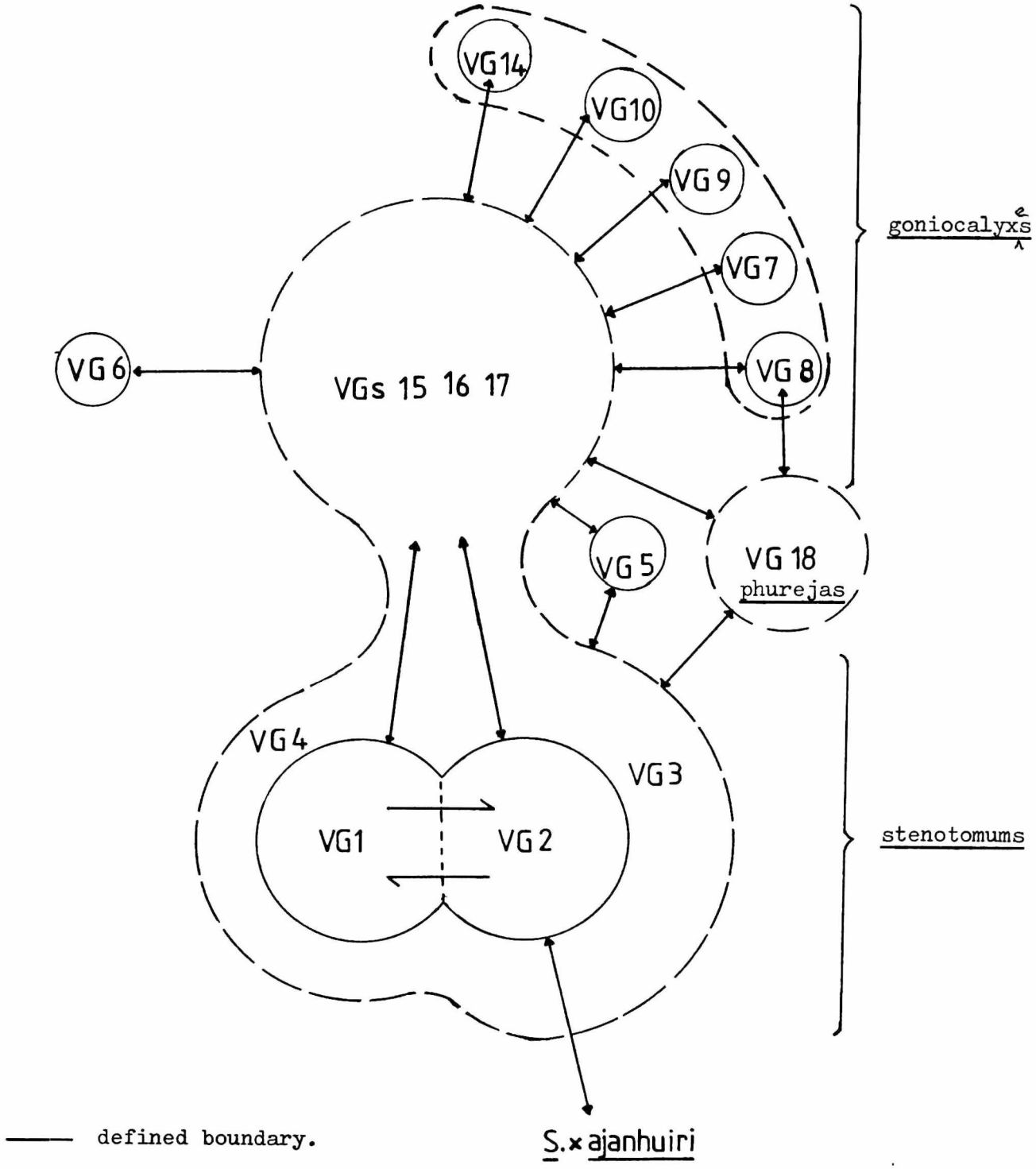
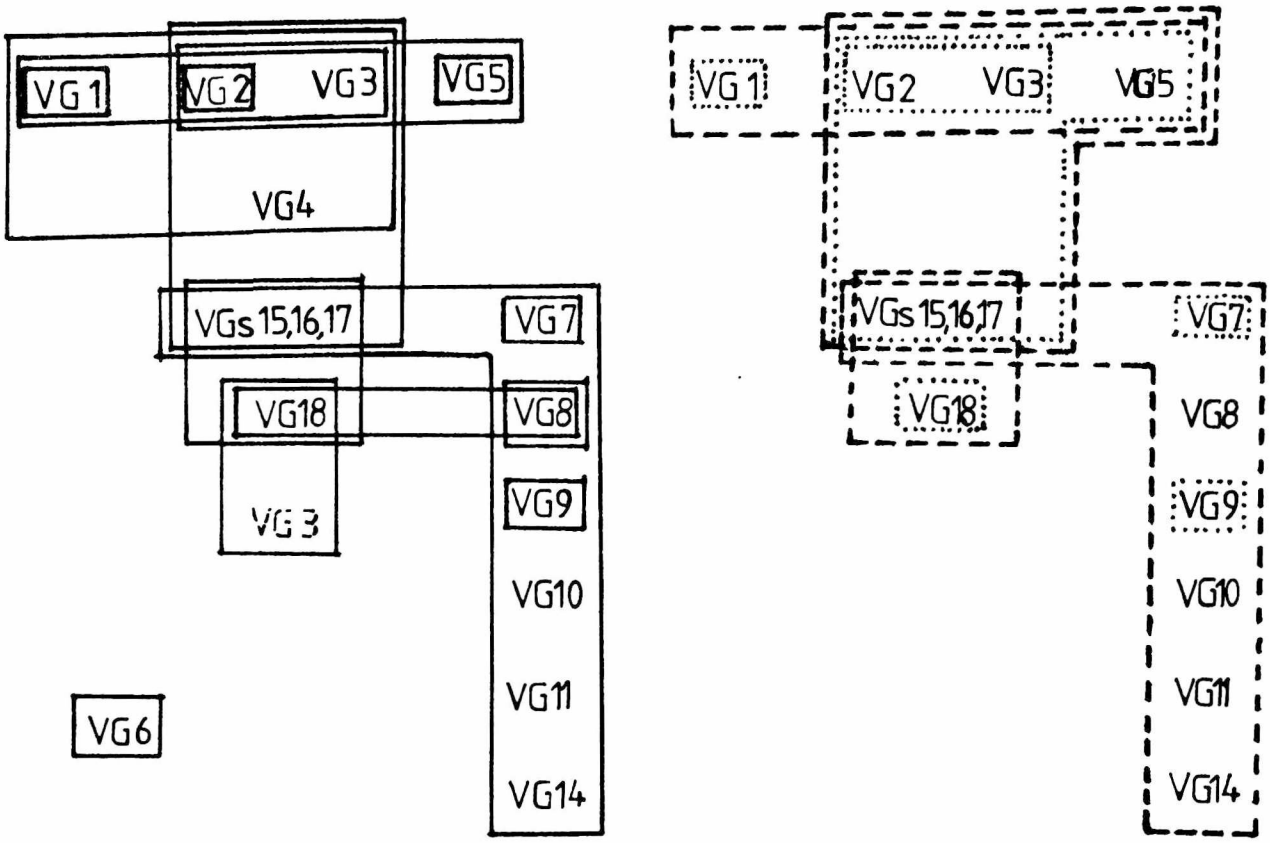



Fig. 7.1 Summary of the postulated evolutionary scheme for the cultivated diploid potatoes.




morphological similarity.

chromatographical similarity.

electrophoretical similarity.

Fig. 7.1(b) Key for linkage in Fig. 7.1(Page 293).

equally active in contributing to gene flow to the north. Alternately, we can think of them as a single unit where VG 1 is the product of VG 2 through introgression from the northern forms.

At the same time, VGs 3, 4 and 5 may be seen as the southern counterpart of the central "intermediate" forms (VGs 15, 16 and 17). Similar results were obtained in chromatographic and electrophoretic studies (Sect. 5.2.2 and Sect. 5.3.2) and even more convincing is the fact that VG 5 has a unique pattern of its own, E 1, which is closely related to the "intermediate" form of the central "complex", Patterns E 2 and E 3.

As mentioned already, individuals of VGs 5, 6, 7, 8, 9 and to a lesser extent 10 and 14 tend to cluster only with their respective group. These VGs can therefore be thought of as distinct clusters each with its own similar forms. Each of them has only a few variants (Table 4.17).

VGs 7, 8, 9 and part of 10 and 14 were clustered together in the big central "intermediate" "complex". They were also clustered together according to the leaf phenolic content (Cluster II). Electrophoretically, VGs 7 and 9 were shown to have their own unique patterns, B and C respectively. However, "Papa Amarilla" (VG 8) exhibited a variety of patterns, as also VG 10. These might have been the fault in the electrophoresis itself (Sect. 5.3.1). As mentioned above, the cross, 702151 x 700042, between S. stenotomum (VG 1) and "Papa Amarilla" (VG 8) did not show any significant amount of segregation and therefore

is an indication of two good species (Sect. 4.4.4.1). From the crossing study there is an indication of very close relationship between members of their own visual groups because of the high occurrence of abnormal seedlings which is assumed to be due to inbreeding depression (Table 6.5). They may then be seen as some stabilised forms of the segregates from the "intermediate" forms or possibly the sister remnants of the lost central taxon, because they are all interrelated, as stated above. Some of these groups might be made up of siblings of a cross or progeny of very related crosses, preserved vegetatively till now.

The formation of S. phureja (VG 18) can have taken place through the combination of three evolutionary pathways. This is because:-

(1) S. phureja from the north clusters immediately with "Papa Amarilla", except for OCH 5193, which is from Sandia, Puno, in the south (Cluster Nos. 16 and 17).

(2) A group of southern S. phureja clustered with the "intermediate" complex of the central Peruvian highlands (Cluster No. 38 and 39).

(3) The group from Bolivia clustered among the two big clusters of the southern " complex" (Cluster No. 34).

Its polymorphic nature is thus revealed in the analysis. S. phureja may thus have to be divided up into different forms. However, if we take the biochemical and segregation studies into consideration all these three forms bear a close similarity to one another. All of

them have a similar electrophoretic pattern D. They all have a set of correlated leaf phenolic compounds since they clustered together (Cluster II, Table 5.5). Furthermore, HUA 915 from Lambayeque in northern Peru clustered immediately with its southern forms, OCH 5193 from Sandia, Puno, in southern Peru. It is therefore justified to group the different morphotypes together under one name. This is therefore an interesting taxonomic case of "correlation weighting" or "a posteriori weighting" of characters in classifying the potato where the value of using some "good" correlated characters e.g. earliness, no dormancy, leaf glossiness, etc., is revealed (Davis and Heywood, 1963). These same characters are used for diagnosis in the existing classification keys. ("Good" characters are those that have low phenotypic plasticity and which tend to stay together in the whole taxon as other characters vary).

The facts revealed from the study of S. phureja can be used further to support the postulated evolutionary scheme. No doubt some of the northern S. phureja forms are morphologically dissimilar from some of the southern ones. However, biochemically and genetically they are very similar and observation of the segregating families of within morpho-group crosses indicated an overlap in segregates from different families. This evidence shows that they must have the same genetic background. The general morphological differences may be due to the differences of their immediates progenitors. The genetic study by Dodds and Paxman (1962) supports this claim. A situation like this fits well in the postulation of relationships between VGs 3 and 4 in the south and VGs 15, 16 and 17 in the north. These two complexes are morphologically distinct but postulated to be genetically linked. In a way therefore

S. phureja confirms the link between VGs 3 and 4 with VGs 15, 16 and 17.

The "hybrid" forms (VGs 11, 12 and 13) between the three 'main' taxa could be recognised with ease using the concept of "a posteriori weighting". A flower of VG 1 if it appears in a plant of VG 18 can easily be recognised. Here, we are talking about whole character set transfer. The coherence of some particular set of characters together was detected in the analysis of the hybrid families where some families gave quite well-defined clusters and others had no clustering at all (Sect. 4.4.4.1). In this study very few clones of VGs 11, 12, 13 were available for study and therefore their relationship with the rest is difficult to predict.

VG 5 is close to the southern " complex" as mentioned above but its similar electrophoretic pattern (E 1) to the central "complex" may further support the interaction of the two "complexes" and indicate that VG 5 may have been a stabilised form from this interaction.

VG 6 was clustered singly from the morphological study (Cluster No. 49). Biochemically, it is not so certain but there is an indication of its uniqueness. From its geographic distribution, it may be considered as part of the central "complex". It might have been the remnant of the ancient central Peruvian Andean taxon, or a stabilised form of the "intermediate" forms or even the result of introgression from some related wild species.

Like many of the small units of distinct forms described above there are in existence among the "intermediates" small units of not so distinct forms. They are usually very localised in their distribution and they tend to be confined to their own valleys or townships only (Sect. 3.2). They are possibly the result of hybridisation between the endemic cultivars with those introduced from outside. Many of them from the same valley may be the progeny of a single cross or very related crosses because crosses between very similar individuals from the same region e.g. HJT 5473 x HJT 6106 produced very few seeds, possibly due to inbreeding. The above phenomenon is therefore equivalent to that of the differentiation - hybridization cycles of Harlan (1970).

In the evolution of cultivated potatoes these cycles must be very prominant because of the geographical situation of the Andean highlands. The mountain ranges act as a sort of physical and ethnological barrier against the free communication between inhabitants of different valleys. This in turn creates a partial isolation of the potato gene pool. Sometimes even within the same valley, altitude differences may help to isolate them. In these ways potatoes were able to evolve independently in each valley. At any time, when a new wave of introduction is realised hybridization takes place and there will be an outburst of new recombinations for selection to work on.

The very diverse nature of the diploids found in the central Peruvian highlands at present could be the results of crosses through the new wave of introduction of some well differentiated populations from the Cuzco area during the Inca reign. During that period agriculture was supposed to be well organised and intensive.

Unfortunately in the potato, unlike its counterpart maize (Grobman et al., 1961), there are few well-preserved archeological materials. We cannot therefore possibly trace its evolutionary path on a time sequence.

In conclusion, it is suggested that the cultivated diploids studied can be classified into three distinct subspecies - subsp. stenotomum, subsp. goniocalyx, and subsp. phureja under one name S. stenotomum.

(1) subsp. stenotomum. This includes VGs 1, 2, 3, 4 and 5. They occur in the region from south Junín southwards to Potosí in Bolivia with major variability in Cuzco and the Lake Titicaca basin. VG1 and VG2 may be the original forms of this complex. The differences between them may even deserve further division. VGs 3, 4 and 5 may be the "intermediate" forms of the complex.

(2) subsp. goniocalyx. This includes VGs 6, 7, 8, 9, 10, 14, 15, 16 and 17. They form the central Peruvian highlands "complex". The "remnant" or "stabilized" forms may be VGs 6, 7, 8, 9, 10 and 14, and the "intermediate" forms are VGs 15, 16 and 17. VG 8 is "Papa Amarilla", the type of the Russian S. goniocalyx.

(3) subsp. phureja. This includes VG 18 only. The existing classification is agreed with. It may be a newly created subspecies with close relationships to both the southern and the central "complexes" through their "intermediate" forms. Its distinct ecological specialisation provides it with a new set of geographical conditions and thus allows the already differentiated genotypes to evolve further with less introgression from the other two "complexes". It occurs in Colombia, extending southwards to Puno in Peru and northern Bolivia.

The above scheme is tentative. More segregation experiments like that in Chapter 6 will have to be carried out to confirm this finding. When assessing the progeny of the crosses objective scoring of characters may not be necessary. An experienced potato taxonomist can see any existing similarity and relationship between families. In addition, gene frequencies eg. isoenzyme systems may be used to study the evolutionary relationships between the various diploid units. However, a greater number of genes should be sampled and the total variability of the population used before any true relationship can be reached, since the diploids are all very closely related to each other. It is also true that they are all very closely related to the other ploidies and to many of the wild species. It will therefore be important for both the cultivated and the wild species to be studied together at the same time. This may give us a clearer picture of the evolution of the cultivated potatoes.

In order to use the existing cultivated diploids gene pool efficiently, more detailed breeding studies may be done using these preliminary findings as a working hypothesis. The genetic background of each group can then be ascertained and at the same time this result can be applied directly for practical breeding. After all, it is always the breeders that are most directly confronted with the problem of taxonomic classification.

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APPENDIX: I

Solanum ajanhuiri Juz. et Buk.

(S.W. Juzepczuk and S. M. Bukasov, Proc. U.S.S.R. Cong. Genet. Plant and Animal Breed. 1929: 3: 605).

Tubérs: Subterranean, oblong, yellow or violet.

Leaves: 7-jugate, with distinctly acute leaflets, strongly decurrent on the basiscopic side, on both surfaces densely hairy with fairly rigid hairs.

Inflorescence: Peduncle bifurcate; inflorescence about 10-flowered; pedicels 14-36 mm long below articulation, 4-6 mm long above, thickly covered with horizontally petent many-celled substrigose hairs.

Calyx: Often irregular, small, about 6 mm long, lobes gradually ending in a shortish acute acumen.

Corolla: Blue, rotate, 23-35 mm diameter, lobes 5-10 mm long, ending gradually in a broadly triangular acumen.

Androecium: Filaments slender, 0.5-1.0 mm broad, free part about 2 mm long; anthers small, 4-5.5 mm long, about 2 mm wide at the base, 1 mm wide near the apex, base cordate.

Gynoecium: Style 7-8 mm long, thick, in lower 1/2-1/3 covered with very short papillae; stigma large, up to 1.5 mm long, bifid and compressed at the apex, with cordate approximate lobes.

Habitat: Cultivated on the Bolivian altiplano above La Paz (S. M. Juzepczuk, Nos. 1518, 1661, 1699, 1744, 1800).

Vernacular name: "Ajanhuiri".

Affinities: Differs from S. phureja in the form of the suberect leaflets, the pedicels articulated higher up, in the pubescence, smaller calyx with lobes more shortly acuminate, blue corolla with longer lobes, anthers narrowed towards the apex, thick style and form of stigma lobes.

Bukasov (1937): Leaf lobes narrow, calyx small, 6 mm long, with small acumens, corolla blue, filaments thin, style thick with cordate stigma.

Communicated verbally: Stem when young with short internodes, semirosulate; leaves with primary segments often widely decurrent for a short distance; leaflets narrow, with spreading hairs; long interjected leaflets compared with S. phureja. Distinguished from S. andigena by small anthers, thin filaments and small calyx with short triangular mucros. Leaflets much more acuminate than in S. x chaucha and the internodes only half as long. Corolla quite well dissected, that of S. x chaucha is almost demissiform.

S. ascasabii Hawkes sp.nov.

(Hawkes J. G., Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 130, 1944).

Herbaceous, tuberiferous, with ovoid curved tubers.

Tubers — With long rather deep eyes and dark purple skin, white flesh outside, blue purple flesh inside the vascular ring; sprouts bluish purple.

Stem — spreading, much branched, about 30-40 cm. long, bearing leaves 12-15 cm. long.

Leaves — 5-jugate, the basal two jugae very small, the others very broadly ovate with obtuse or acute apex 23 x 27 mm., 27 x 35 mm, 21 x 37 mm. etc., with about 5 mm. long petiolules; terminal leaflet the same size as or slightly larger than the laterals much more acute or somewhat acuminate apically; interjected leaflets few, generally 1-2 pairs of ovate sessile secondaries up to 10 mm. long between the upper 2 pairs of primary lateral leaflets; all leaves bright green above, shining, sparsely covered with short hairs, rather lighter below.

Inflorescence — few (4-5-) flowered, the peduncle 4-6 cm. long.

Pedicels — 15-25 mm. long, about 6-9 mm. long above the articulation, covered with very short hairs.

Calyx — large, often bilabiate, about 10-12 mm. long (recalling that of certain varieties of S. stenotomum) the free part of the lobes about 6-7mm. long x 2.25 mm. wide at the base and narrowing into a parallel sided mucro which is from 2-4 mm. long, calyx rather dark purple especially

on the nerve, externally glabrescent.

Corolla — rotate, large, ± 30 mm. diam., purple with white petal acumens, with bright green star, lobes 16-17 mm. broad x 7-10 mm. long in the free part of which ± 3mm is the triangular acumen.

Filaments — 1.5-2 mm. long

Anthers — bright orange-yellow, 5.5 mm. long.

Style — 7-8 mm. long, covered in the lower half with extremely minute mamillae only visible under a microscope.

Stigma — larger than the style apex, capitate.

Berry — ovoido-cordate, pale green flushed and streaked with purple, about 2 cm. long. V . v . c.

Chromosome no. — 2n = 24.

Affinities — Distinguished from S. rybinii Juz. et Buk. in the broader leaflets with 1-2 pairs of interjected leaflets per series, terminal leaflet hardly larger than the laterals, larger calyx, corolla colour, longer style and larger stigma. It differs from S. kesselbrenneri Buk. in the larger leaves and in all the floral features. From S. stenotomum Juz. et Buk. to which it bears some resemblance it differs in the large wide shining leaves, short and sparse pubescence, large corolla.

Solanum boyacense Juz. et Buk.

(S. M. Bukasov: Suppl. 47, Bull. Appl. Bot. Genet. & Pl. Breed. 1930. Chapt. 14, p.214).

(Juzepczuk & Bukasov, Proc. Cong. Genet. Pl. & An. Breed. 1929: 3: 609).

Apparently related to S. rybinii Juz. et Buk.; differs in the more numerous leaflets (with simple leaves entirely absent on secondary stems), the pubescence of the whole plant consisting in longer hairs, in the larger more long acuminate calyx lobes, the broader corolla lobes, the shorter anthers.

Habitat: Grown in Colombia, Department Boyaca, Choconta, near Tunja (No. 20).

Solanum caniarense Juz. and Buk. ad int.

(Bukasov in Vavilov: Theoretical Bases of Plant Breeding. 1937: 3 : 17).

Chromosome number 2n = 24 as in other new species from Ecuador, e.g. S. erlansonii. The leaf differs from that of S. goniocalyx in being much wrinkled as in S. boyacense with narrowish acute segments; degree of dissection slight; 5 pairs of primary segments and 1-2 pairs per series of secondaries.

Inflorescence: Pedicels with short pubescence; length above articulation 8 mm., thickened at top. Articulation pigmented.

Calyx: like that of S. goniocalyx, very sharply ribbed, green, large, with short mucros.

Corolla: at first white with slight anthocyanin near the star, later pale mauve, strongly dissected; radius of corolla 21 mm., width of lobe 12 mm., length 11 mm., acumen 3 mm., pubescence on upper surface.

Androecium: Filaments thin, rather long, about 2 mm.; anthers small narrow, 6 x 1.75 mm. in an oval loose column.

Gynoecium: Style thinnish, thinner than in S. cuencanum, length 9 mm. (not much or only slightly exserted), glabrous; stigma of medium dimensions, capitate; ovary small pyriform-oval, attenuated.

(Communicated verbally): Leaves well dissected. Base of calyx slightly like that of S. goniocalyx. Corolla white or tinged with lilac. Anthers small. Intermediate between S. goniocalyx and S. kesselbrenneri.

S. cardenasii Hawkes sp.nov.

(Hawkes J. G., Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 129-30, 1944).

Herbaceous, bearing long oval tubers.

Tubers — about 5.5 x 2.5 cm. with rather long eyes of medium depth and yellow skin.

Stem — 40 cm. high, about 6 springing from one tuber, diam. half way up 3.5-4 mm., angled and with rather wide wings dilated at the slightly swollen nodes; internodes 2.5-5 cm. long, the whole stem entirely without pigment, provided with not frequent scattered hairs chiefly on the edges of the wings.

Leaves — about 18 x 11.5 cm., petiole and rachis very sparsely pubescent, more so on the upper surface, imparipinnate (3-) 4-jugate, the 3rd and 4th leaflets (nearest to the stem) generally minute; upper lateral primary leaflets 4-6.5 cm. long x 2-3 cm. broad, ovato-lanceolate or elliptic, the apex acute or obtuse, asymmetrical at the base, larger on the basiscopic side and very slightly decurrent, petiolules 1-6 mm. long on the basiscopic, 4-10 mm. long on the acroscopic side; terminal leaflets 5.5-8.5 cm. long x 3.2-5.5 cm. broad, much larger than the laterals, broadly ovate, acute at the apex, base slightly asymmetrical, a little auricled and decurrent, its petiolule up to 2.3 cm. long; secondary leaflets minute, absent in the upper and 3-jugate leaves, not more than one pair between each two

pairs of primary leaflets, sessile orbicular, to 4 mm. diam., slightly basiscopically decurrent; all leaflets bright green above, slightly paler below, clothed above with frequent acute short hairs, shorter below; pseudo-stipular leaves lanceolate very small.

Inflorescence — terminal 1 on each stem with about 2-6 flowers per inflorescence.

Peduncle — common peduncle 3.5-8.5 cm. long, forked, the furcase up to 2.5 cm., green pubescent in a similar manner to the leaf but with slightly more delicate hairs.

Pedicels — rather thick, swollen at the apex, up to 2.5 cm. long, articulated more or less in the centre, below the articulation 1.2-1.5 cm., above 9-10 mm., articulation distinct, colourless, green as the peduncle;

Calyx — spreading, irregular, 9-10 mm. long, the lobes 3-4 mm. wide, rather sharply contracted into an obtuse acumen 3-4 mm. long x 1-1.5 mm. wide, green, covered with short dense pubescence.

Corolla — pentagonal, reflexed large, 30-40 mm. diam., white, with triangular acumens 4 x 4 mm. minutely pubescent on the edges and exterior surface.

Filaments — 2.3 mm. long x 0.7 mm. wide in the free part.

Anthers — column ovoid curved, often irregular owing to the curved anthers, oblique at apex.

6 mm. x 2 mm. at the base, narrowing to 1.2 mm. above, somewhat emarginate at base and apex, yellow, with abundant pollen.

Style — very short, only 7 mm. long x 0.5 mm. broad at the base, widening to 1 mm. at the apex, not exserted above the anthers, in the lower half covered with dense very minute papillae.

Stigma — short green capitate, rather large, somewhat thicker than the style apex.

Ovary — ovoid.

Chromosome no. — 2n = 24.

Affinities — Although named "phureja" (= early) and maturing in 3 months in the original habitat the plant differs completely from S. phureja from similar localities further north. Probably nearer to S. goniocalyx Juz. et Buk. and S. rybinii Juz. et Buk., agreeing with the latter species in the swollen pedicel apex, short style, poor leaf dissection etc.; it can have no close relationship with this species however since it is separated from it by a very large distance in which no intermediate types occur. It agrees with S. goniocalyx in the white flowers, swollen pedicle apex and short style but differs in the less dissected leaves and shorter calyx lobes.

S. churuspi Hawkes sp.nov.

(Hawkes J. G., Bull. Imp. Bur. Plant Breed. & Genet, Cambridge, 129, 1944).

| | |
|---|---|
| Leaves | 4-5 jugate; primary leaflets broadly oblong-ovate, up to about 18 x 30 mm., slightly apically acuminate, 2-4 mm. petiolulate; terminal leaflet similar to laterals; leaflets of second order very sparse, 0-2 pairs per series. |
| Pedicel | articulation rather high, 6-9 mm. below the calyx, the pedicels themselves 20-30 mm. long; |
| Calyx | bilabiate (3+2 or 2+2+1), pale green, 10-12 mm. long the free parts of the sepals ± 10 mm. long or fused together completely (except for the mucros), mucro about 2.5 mm. long; |
| Corolla | lilac ± 30 mm. diam., when spread out flat almost truly circular in outline (with the exception of the acumens), the lobes about 17-18 mm. wide x 5-6 mm. long in the free part, of which 3-4 mm. is the triangular acumen. |
| Filaments | about 1.5-2 mm. long, with mamillae between their bases. |
| Anthers | 5-6 mm. long. |
| Style | slender, about 8 mm. long. |
| Chromosome no. | 2n = 24. |

Solanum goniocalyx Juz. et Buk.

(S. W. Juzepczuk and S. M. Bukasov. Proc. U.S.S.R. Cong. Genet. Plant and Animal Breed. 1929: 3 : 605-606).

Tubers: subterranean, oblong or rotund, red or yellow.

Leaves: Long, up to 30 cm. long, petiole 3-4 cm. long, strongly dissected, 6-8-jugate; interjected leaflets of first order 3-4-jugate, of second order and acroscopics 6-9-jugate (interjected leaflets in all up to 100), leaflets about 4 cm long, narrow, more than twice as long as broad, oblong ovate, gradually narrowing towards the apex, acute and not acuminate, covered on both sides with rather small scattered hairs, (or rather densely below); terminal leaflet almost equalling the laterals.

Inflorescnece: Common peduncle rather long, bifurcate, about 12-flowered; pedicels 9-22 mm long below, 7-12 mm long above articulation, the whole length rather densely clothed with two- too many celled spreading hairs.

Calyx: irregular, 8-13 (-15) mm long, with ovate lobes gradually drawn out into a long acumen equal to 1/3 the calyx length; calyx at the base conspicuously delimited from the pedicel, 5-angled, covered with many-celled hairs.

Corolla: violet or white, large (22-) 25-37 mm diam., rotate, with lobes ending at the apex in a triangular moderate sized mucro, glabrescent above.

Androecium: Filaments thickish to fairly thick, not rarely more than 1 mm broad, free part above 2 mm long; anthers large, 6-8 mm long, base emarginate.

Gynoecium: Style 7.5-10 mm long clothed on lower half with distinct frequent papillae; stigma not large, thicker than style apex, capitate, 0.6-0.9 mm long and broad, lobes cordate at base.

Ovary: pear shaped; berries elongated.

Habitat: Cultivated in Central Peru Department Junin, Tarma (S. Juzepczuk Nos. 157, 302, 316) Cerro de Pasco (the same Nos. 571, 572, 587 (type) ) Huamantango (669) Jauja (738) etc.

Vernacular name: Runtu Papa, Papa Amarilla.

Affinities: Differs very distinctly from S. tuberosum s. str., in pubescence, very numerous interjected leaflets, form of calyx, slightly narrower filaments, and form of ovary and fruit. Differs from S. multiinterruptum Bitt. (a wild species) to which it is probably related, in longer petiole, smaller and more numerous leaflets as also are the interjected leaflets, distinctly petiolulate, not decurrent, in the pedicels also covered with many-celled hairs beside the short hairs and in the distinct style papillae.

Bukasov (1937): Resembles S. stenotomum inthe form of the calyx and its ribbed base. The leaf segments are wider and the filaments somewhat thicker. Corolla white.

Communicated verbally: Leaves very dissected; primary segments very far apart on very long petiolules; first pair of secondary segments very large; 60-100 leaf segments in all. Calyx bilabiate with ribbed base. Corolla smaller than S. andigena.

Solanum kesselbrenneri Juz. and Buk. ad int.

(Bukasov in Vavilov: Theoretical Bases of Plant Breeding, 1937; 3 : 18).

Leaf: shiny, dissection slight, up to 4 pairs of segments with one pair of secondary segments per series.

Inflorescence: Flowering abundant as a result of the proximity of the tiers of pedicels and early onset of flowering. Pedicels thinner than in S. boyacense, less than 5 mm. long above the articulation, the latter being situated above the middle of the pedicel. Flower bud narrower than in S. boyacense with clearly ribbed calyx but less so and less clearly demarked from the pedicel than in S. boyacense.

Calyx: Symmetrical with narrow lobes 1.5 mm wide, tapering or parallel sided, smaller than in S. boyacense.

Corolla: mauve without white tips, more dissected than in S. boyacense, with abruptly descending lobes of the type of S. rybinii; radius 11-15 mm., width of lobes 15 mm., length 8 mm., length of acumen 2 mm.

Androecium: Anthers small narrow, 4.5 x 1.5 mm., in a conico-oval column.

Gynoecium: Style very short, 5 mm., glabrous. Stigma thinner and smaller than that of S. boyacense. Ovary large, long narrow, oval as in some forms of S. stenotomum which this resembles in certain other characters.

The species resembles also S. boyacense in its extreme susceptibility to degeneration diseases.

Solanum phureja Juz. and Buk.

(S. W. Juzepczuk & S. M. Bukasov. Proc. U.S.S.R. Cong. Genet. Plant & Animal Breed. 1929: 3 : 604-5).

Tubers: subterranean, elongate, violet or variegated.

Leaves: rather small, 5 or 7-jugate; leaflets small, narrow elliptic, almost twice as long as broad, with acute apex, somewhat decurrent on basiscopic side, covered above with very sparse and below with scattered hairs; interjected leaflets between two pairs of larger leaflets up to 3 or 4-jugate.

Inflorescence: Peduncle 6-10 mm. cm? long, bifurcate with up to 4 flowers on each fork. Pedicels 10-20 mm. long below articulation, 8-14 mm. long above, rather densely clothed with many-celled patent crisp hairs, admixed with minute shortly stalked glands.

Calyx: up to 7-8 mm. long, irregularly partite, zygomorphic; lobes 2 or 4 (2+2) joined to each other laterally for a long way, suddenly acuminate, about half the length of the calyx, linear acutish.

Corolla: rich violet, rotate, 20-31 mm. diam.; lobes short 5-8 mm. long, shortly arched, ending in a large triangular mucro equalling half the lobe.

Androecium: Filaments slender, up to 1 mm. broad, long free part about 2 mm.; anthers small 4-5 mm. long, 2 mm. broad, base cordate.

Gynoecium: Style long, about 1 cm., covered with very short papillae on the lower 1/3-3/8 of its length; stigma not large,

thicker than style apex, about 1 mm. long and broad, capitate. V.v.

Habitat: Cultivated in Bolivia, dept. La Paz, prov. Larecaja, Sorata etc.

Vernacular name: "Phureja".

Affinities: From S. tuberosum s. str. it differs in smaller calyx, narrow filaments, smaller anthers, minutely papillose style; from S. tenuifilamentum in the narrower leaflets, corolla colour, and shorter corolla lobes, thicker filaments, longer style and form of stigma; from S. stenotomum in the smaller calyx, the suddenly acuminate lobes, the shorter lobes of the more deeply violet corolla.

Bukasov (1937): Plant tall, leaf lobes narrow but less acute than those of S. ajanhuiri. Bilabiate calyx with characteristic anthocyanin pigmentation. Corolla intensely bluish purple of characteristic shade and almost entire.

(Communicated verbally:) Stem pigmented. Leaves narrower and with less dissection than in S. chaucha, fairly dissected, though not erect as in S. ajanhuiri and more obtuse; leaf segments narrow; basiscopics absent; interjected leaflets rounded; leaflets very remote, 7 pairs of primaries, 3 pairs of secondaries and 2 of tertiaries, two pairs in the uppermost series but elsewhere only one; quarternaries very rarely present. Calyx bilabiate, large, dark. Corolla dark, very large, with pubescence on the edge of the acumen; star always dark. Stamens short; filaments thin; anthers rather small. Tubers with short dormancy period, long,

with deep eyes; skin pigment pale or absent.

S. phureja Juz. et Buk. v. pujeri Hawkes var.nov.

(Hawkes, J. G., Bull Imp. Bur. Plant Breed. & Genet. Cambridge, 130, 1944).

Differs from the type in the slightly longer calyx lobes and longer corolla lobes which are more similar to those of S. chaucha, the floral parts as in the typical S. phureja are often hexamerous or even heptamerous. Although growing at much higher altitudes (± 12,500 ft.) than the true S. phureja the tubers are nevertheless very similar in shape, coloration short dormancy period and high protein content.

Solanum rybinii Juz. et Buk.

(S. M. Bukasov: Suppl. 47. Bull. Appl. Bot. Genet. & Pl. Breed. 1930. Chapt. 14. p.213-14).

(Juz. & Buk. Proc. USSR. Cong. Genet. Pl. & Anim. Br. 1929: 3 : 606).

Tubers: spherical, yellow.

Leaves: short, hardly interrupted, 2-4-jugate, leaflets about 5 cm. long, 2 cm. broad, terminal leaflets much larger than the laterals up to 8.5 cm long and 4.8 cm. broad, interjected leaflets generally 1-jugate, leaflets of the lateral branches often entire, covered on both surfaces with densish short hairs.

Stem: much branched, up to 25 times.

Inflorescence: Peduncles short, 4-5 cm. long, few- (4-8) flowered; pedicels short, 6-15 mm. long below articulation, (4-)5-6(-9) mm. long above articulation, rather densely clothed with short hairs (generally 2-3-celled) intermixed with very minute gland-bearing ones.

Calyx: short, 5-8 mm. long, lobes acuminate, the acumens equal in length to ½ of calyx, endowed with short sparse hairs.

Corolla: white or intense lilac, rotate, not large, 2-3 cm. diam., lobes fairly long, 5-7 mm. long, semirotund, gradually ending in a triangular acumen.

Androecium: Filaments thick, more than 1 mm. broad, short, free part about 1.5 mm. long; anthers 4.5-6 mm. long, 1.7-2 mm. broad, slightly emarginate at base.

Gynoecium: Style short, 5.5-7.5 mm. long, not protruding over the anthers, endowed in the lower half with very minute sparse

papillae. Stigma not large, about 0.6 mm. long, 0.7 mm. broad, slightly thicker than style apex, subconical, laterally compressed, lobes broadly emarginate at the base.

Habitat: Grown in Colombia, Department Cundinamarca near Bogota. S. Bukasov (No. 46).

Affinities: Very distinct from S. tuberosum s. str. in the branching of the stem, the shape and pubescence of the leaves, the small calyx with short lobe acumens, the pubescence of the pedicels, the sparse short papillae of the style and the form of the stigma.

Bukasov (1937): Stem with multiple branching. Leaf dissection slight. Some leaves entire. Corolla white, rather strongly dissected; filaments thickish, style short; papillae very small and few in number.

(Communicated verbally): Very little leaf dissection (but depends on nutrition). Basal leaves simple, leaflets bluntish. Short pubescence. Very long stem with many inflorescences at different levels on the stem (7 in the plant seen). This is the only cultivated species with this character. Calyx small. Dissection great. No hairs on upper surface of acumen. Flowers small white. Corolla well dissected. It would be of interest to find the exact locality.

The group of S. rybinii, S. boyacense and S. kesselbrenneri has a spreading habit and broad leaves distinct from all other species but S. tuberosum

S. rybinii Juz. et Buk. var. popayanum Hawkes var. nov.

(Hawkes, J. G., Bull. Imp. Bur. Plant Breed. & Genet., Cambridge, 130-131, 1944).

Affinities: Agrees with v. bogotense in tuber shape and size, sprout colour and short dormancy period, leaf type, anther size etc. Differs in the pink skinned tubers, bright orange-yellow at the eyes, with bright orange yellow flesh, deeper in colour than v. bogotense, leaves shining, 2-3 jugate, terminal much larger than laterals, up to 6.5 x 4.2 cm., with no (or rarely one) interjected leaflets (but these are also absent on v. bogotense grown at Cambridge), no entire simple leaves on the side branches though occasional unijugate ones occur, longer calyx, about 10 mm. long, sometimes rather irregular.

Corolla: intense lilac-purple with the lobes not so steep, though much more than those of v. bogotense.

Style: longer, 8 mm. long, exserted 1.5 mm.

Stigma: almost 1 mm. broad, therefore larger than that of v. bogotense.

Chromosome no. 2n = 24.

S. rybinii Juz. et Buk. v. pastoense Hawkes var. nov.

(Hawkes, J. G., Bull. Imp. Bur. Plant. Breed. & Genet., Cambridge, 131, 1944).

Differs from v. bogotense in the ovoid tubers with black-purple skin and deep straight eyes, more dissected leaf with 1-3 pairs of secondary leaflets per series and very dark purple corolla which is fairly large.

Chromosome no. 2n = 24.

Solanum stenotomum Juz. and Buk.

(S. W. Juzepczuk & S. M. Bukasov, Proc. U.S.S.R. Cong. Genet. Plant & Animal Breed. 1929: 3 : 604).

Tubers: subterranean, oblong, curved, pink.

Leaves: 6-8-jugate, leaflets 3-4 cm. long, 1.5-1.8 cm. broad, narrow, obovate, at first decurrent on the basiscopic side, sparsely hairy above, more densely below with very minute hairs, terminal leaflet at first hardly larger than the laterals; interjected leaflets often 3-10-jugate.

Inflorescence: Pedicels 5-12 mm. below articulation, 6-8 mm. above, shortly hairy.

Calyx: irregular, almost zygomorphic (7-)10-11 mm. long, lobes almost half as long as calyx, broadish asymmetric (with unequal sides) obtusish at the apex.

Corolla: pale violet, subrotate 2-2.3 cm. diam. (when dry) lobes half as long as tube, about 7 mm. long, semirotund or angulato-semirotund, ending at the apex in a quite large whitish mucro.

Androecium: Filaments very slender, mostly 0.5 mm. broad, short free part 1-1.3 mm. long; anthers small, 4.5-5 mm. long, 1.75 mm. broad, base scarcely emarginate (almost rotund).

Gynoecium: Style short 7-8 mm., in the lower ½-⅜ covered with distinct papillae; stigma somewhat large, not tall, distinctly thicker than style apex, 0.6-0.8 x 0.8-1 mm. - V.v.

Habitat: Cultivated on the altiplano of Bolivia: La Paz, (Juzepczuk Nos. 1681 (type) and 1743), also in Peru.

Vernacular name: phinu (Peru).

Affinities: Differs from S. tuberosum s. str. in the very slender habit of the whole plant, narrow, more numerous leaflets, very narrow filaments, small anthers; from S. juzepczukii described above in the larger leaves more numerous leaflets, the conspicuous articulation of the pedicels which is placed lower down, the longer calyx and corolla lobes, the anthers almost rotund at base, and the form of the stigma.

Bukasov (1937): Leaves very dissected with small narrow segments. Calyx with rather long acumens, asymmetric. Corolla light purple; filaments very thin.

(Communicated verbally); Leaf is more dissected than that of S. phureja; basiscopics present. Calyx with long wide mucors not distinguished easily from the lobes, dissected far down. Flowers smaller than S. phureja, corolla not so dark, but better dissected. Not many flowers produced.

One form from Urubamba with white large flowers but leaves of same type - "Ppispinco".

Bolivian types often very small.

Peruvian types are large plants like the Peruvian S. andigena.

Two triploid types (one of S. stenotomum - native name "pitikalla") (one of S. goniocalyx) were collected by Juzepczuk but perished at Krasnyi Pakhar, near Leningrad.

S. yabari Hawkes sp.nov.

(Hawkes, J. G., Bull. Imp. Bur. Plant. Breed. & Genet., Cambridge, 129, 1944).

Plant tall, with large 5-6-jugate well dissected leaves, often pale green (? darker in EPG nos. 698 and 1077); calyx long and very irregular with the nerve standing out as a rib, especially prominent near the base; corolla lilac the lobes very rounded, the width about twice the length of the free part; filaments and style generally quite long.

Chromosome number : 2n - 24.

Appendix II: Hawkes' 1944 classification

S. stenotomum Juz. et Buk. (1929)

var. pitiquilla Hawkes, pro var. nov.

1. f. ccami (Buk.?) Hawkes, pro f. nov.
2. f. phinu Hawkes, pro f. nov.
3. f. eucaliptae Hawkes, pro f. nov.
4. f. pitoca Hawkes, pro f. nov.
5. f. huamanpa - uman Hawkes, pro f. nov.
6. f. kantillero Hawkes, pro f. nov.
7. f. orcco-amajaya Hawkes, pro f. nov.

var. chapina Hawkes, pro var. nov.

var. cyaneum Hawkes, pro var. nov.

1. f. canastilla Hawkes, pro f. nov.
2. f. cochicallo Hawkes, pro f. nov.
3. f. kamara Hawkes, pro f. nov.
4. f. phitu-huayacas Hawkes, pro f. nov.
5. f. negrum Hawkes, pro f. nov.
6. f. chilcas Hawkes, pro f. nov.
7. f. huallata-chinchi Hawkes, pro f. nov.

var. megalocalyx Hawkes, pro var. nov.

1. f. alcay-imilla Hawkes, pro f. nov.
2. f. catari-papa Hawkes, pro f. nov.
3. f. chojllu Hawkes, pro f. nov.
4. f. piticana Hawkes, pro f. nov.

5. f. koso-nahui Hawkes, pro f. nov.

6. f. yana-cculi Hawkes, pro f. nov.

7. f. ttele Hawkes, pro f. nov.

8. f. kehuillo Hawkes, pro f. nov.

9. f. huanuchi Hawkes, pro f. nov.

var. puca-lunca Hawkes, pro var. nov.

var. kaccrana Hawkes, pro var. nov.

1. f. pallidum Hawkes, pro f. nov.

2. f. roseum Hawkes, pro f. nov.

var. peruanum Hawkes, pro var. nov.

1. f. cohuasa Hawkes, pro f. nov.

2. f. chincheraa Hawkes, pro f. nov.

3. f. cuchipacon Hawkes, pro f. nov.

var. huicu Hawkes, pro var. nov.

var. putis Hawkes, pro f. nov.

S. churuspi Hawkes, pro sp. nov.

S. yabari Hawkes, pro sp. nov.

var. pepino Hawkes, pro var. nov.

var. cuzcoense Hawkes, pro var. nov.

S. goniocalyx Juz. et Buk. (1929)

S. cardenasii Hawkes, sp. nov.

S. phureja Juz. et Buk. (1929)

var. pujeri Hawkes, var. nov.

S. ajanhuiri Juz. et Buk. (1929)

S. ascasabii Hawkes sp. nov.

S. kesselbrenneri

S. rybinii Juz. et Buk. (1929)

var. popayanum Hawkes, var. nov.

var. pastoense Hawkes, var. nov.

Note: S. caniarense Buk. (1937) and S. riobambense Buk. (1937) were not classified because of no specimens.

APPENDIX III : The means and standard deviations of all the 99 characters for the sixteen families.

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.805<br>(5.955) | 4.073<br>(4.606) | 3.095<br>(2.272) | 1.000<br>(1.354) | 2.447<br>(3.261) | 5.595<br>(3.927 | 3.450<br>(3.508) | 3.050<br>(3.226) | 2.071<br>(2.532) | 0.775<br>(1.349) | 2.650<br>(2.675) | 1.500<br>(1.630) | 3.211<br>(3.330) | 2.436<br>(3.299) | 1.625<br>(1.779) | 2.286<br>(2.361) |
| 2 | 5.024<br>(4.339) | 5.171<br>(3.209) | 5.000<br>(3.436) | 3.216<br>(2.428) | 4.395<br>(3.746) | 9.190<br>(4.441) | 9.100<br>(6.931) | 3.775<br>(2.824) | 3.976<br>(3.189) | 5.250<br>(3.492) | 6.025<br>(4.282) | 7.194<br>(4.768) | 4.974<br>(3.080) | 8.949<br>(4.267) | 3.325<br>(2.314) | 4.095<br>(2.658) |
| 3 | 1.463<br>(1.227) | 1.317<br>(1.128) | 1.381<br>(1.035) | 1.432<br>(1.303) | 1.947<br>(1.785) | 2.000<br>(1.498) | 2.450<br>(1.782) | 1.675<br>(1.347) | 2.929<br>(2.321) | 2.250<br>(1.410) | 1.900<br>(1.464) | 1.917<br>(1.317) | 1.947<br>(1.293) | 2.077<br>(1.244) | 1.850<br>(1.657) | 1.500<br>(1.174) |
| 4 | 0.756<br>(0.799) | 1.171<br>(0.998) | 1.881<br>(1.214) | 2.459<br>(0.989) | 1.342<br>(1.192) | 1.786<br>(1.317) | 1.300<br>(0.992) | 2.325<br>(1.269) | 1.786<br>(1.298) | 1.800<br>(1.324) | 1.025<br>(1.271) | 1.389<br>(1.225) | 1.737<br>(1.178) | 0.846<br>(0.933) | 1.525<br>(0.933) | 0.905<br>(0.921) |
| 5 | 4.268<br>(4.013) | 4.390<br>(4.067) | 2.714<br>(1.929) | 1.162<br>(1.500) | 1.605<br>(2.261) | 5.095<br>(4.287) | 2.475<br>(3.038) | 2.050<br>(2.342) | 5.000<br>(4.472) | 0.475<br>(0.847) | 3.025<br>(3.059) | 1.167<br>(1.183) | 2.816<br>(3.109) | 2.333<br>(3.072) | 2.575<br>(2.469) | 4.595<br>(3.729) |
| 6 | 2.707<br>(2.194) | 3.244<br>(3.208) | 0.024<br>(0.154) | 3.162<br>(3.468) | 1.553<br>(2.356) | 0.881<br>(1.783) | 0.525<br>(2.000) | 1.460<br>(1.919) | 8.619<br>(4.884) | 0.075<br>(0.350) | 1.200<br>(1.870) | 2.000<br>(3.338) | 4.132<br>(3.967) | 1.615<br>(3.423) | 5.700<br>(3.480) | 4.048<br>(2.828) |
| 7 | 1.000<br>(0.671) | 1.195<br>(1.030) | 0.024<br>(0.154) | 1.541<br>(1.145) | 0.474<br>(0.506) | 0.333<br>(0.650) | 0.350<br>(0.864) | 0.500<br>(0.506) | 3.000<br>(0.000) | 0.075<br>(0.350) | 0.550<br>(0.846) | 1.083<br>(1.052) | 1.053<br>(0.868) | 0.513<br>(0.985) | 1.900<br>(1.308) | 1.190<br>(0.804) |
| 8 | 3.122<br>(1.144) | 3.049<br>(1.303) | 1.952<br>(0.439) | 2.649<br>(0.949) | 2.447<br>(0.891) | 1.976<br>(0.154) | 2.100<br>(1.057) | 1.800<br>(0.405) | 3.429<br>(1.016) | 3.000<br>(1.013) | 2.550<br>(0.986) | 1.806<br>(0.401) | 2.368<br>(1.324) | 2.923<br>(1.010) | 2.725<br>(1.085) | 2.024<br>(0.841) |
| 9 | 2.098<br>(0.768) | 1.220<br>(0.525) | 1.452<br>(0.504) | 1.297<br>(0.661) | 1.132<br>(0.475) | 2.429<br>(0.801) | 1.825<br>(0.675) | 1.075<br>(0.267) | 1.405<br>(0.798) | 1.650<br>(0.622) | 1.525<br>(0.679) | 1.556<br>(0.773) | 1.184<br>(0.457) | 1.487<br>(0.506) | 1.600<br>(0.591) | 1.000<br>(0.000) |
| 10 | 2.561<br>(1.988) | 2.707<br>(1.927) | 4.357<br>(1.620) | 1.189<br>0.397) | 2.105<br>(1.110) | 1.000<br>(0.000) | 1.625<br>(1.102) | 1.750<br>(1.808) | 2.905<br>(2.070) | 3.025<br>(2.178) | 2.725<br>(1.921) | 3.167<br>(2.171) | 1.000<br>(0.000) | 1.974<br>(1.564) | 3.575<br>(2.352) | 3.286<br>(2.167) |
| 11 | 1.951<br>(0.773) | 2.220<br>(0.652) | 2.810<br>(0.505) | 2.486<br>(0.507) | 3.000<br>(0.000) | 2.190<br>(0.804) | 2.300<br>(0.791) | 1.850<br>(0.580) | 2.619<br>(0.539) | 2.050<br>(0.639) | 1.900<br>(0.778) | 2.056<br>(0.715) | 2.211<br>(0.622) | 2.615<br>(0.493) | 2.375<br>(0.490) | 1.976<br>(0.811) |
| 12 | 0.512<br>(0.078) | 0.927<br>(1.127) | 0.214<br>(0.782) | 1.027<br>(0.897) | 0.947<br>(1.012) | 0.357<br>(0.656) | 0.775<br>(1.165) | 1.325<br>(1.047) | 0.452<br>(1.347) | 0.625<br>(1.055) | 0.975<br>(1.250) | 0.361<br>(0.990) | 1.132<br>(0.991) | 1.179<br>(1.335) | 0.450<br>(0.846) | 0.929<br>(1.276) |
| 13 | 1.122<br>(0.331) | 1.293<br>(0.715) | 1.214<br>(0.782) | 2.189<br>(0.995) | 1.474<br>(0.505) | 1.500<br>(1.132) | 1.000<br>(0.000) | 1.200<br>(0.723) | 1.357<br>(0.983) | 1.100<br>(0.379) | 1.175<br>(0.549) | 1.417<br>(1.052) | 1.000<br>(0.000) | 1.410<br>(0.498) | 1.050<br>(0.316) | 1.048<br>(0.216) |
| 14 | 2.366<br>(0.623) | 2.341<br>(0.762) | 2.905<br>(0.297) | 2.649<br>(0.588) | 2.053<br>(0.899) | 2.190<br>(0.707) | 2.150<br>(0.834) | 2.200<br>(0.648) | 2.619<br>(0.661) | 2.175<br>(0.781) | 2.225<br>(0.800) | 2.917<br>(0.280) | 2.105<br>(0.798) | 2.513<br>(0.601) | 2.425<br>(0.747) | 2.857<br>(0.472) |
| 15 | 1.195<br>(0.401) | 1.366<br>(0.488) | 1.571<br>(0.501) | 1.000<br>(0.000) | 1.000<br>(0.000) | 1.476<br>(0.505) | 1.000<br>(0.000) | 1.100<br>(0.304) | 1.024<br>(0.154) | 1.375<br>(0.490) | 1.600<br>(0.496) | 1.000<br>(0.000) | 1.053<br>(0.226) | 1.513<br>(0.506) | 1.300<br>(0.464) | 1.571<br>(0.501) |
| 16 | 2.293<br>(1.101) | 2.488<br>(0.810) | 3.262<br>(0.701) | 3.405<br>0.725) | 3.000<br>(0.870) | 2.714<br>(1.043) | 2.750<br>(1.149) | 3.250<br>(0.707) | 3.381<br>(0.661) | 1.450<br>(0.639) | 2.625<br>(0.868) | 3.639<br>(0.543) | 3.421<br>(0.826) | 1.897<br>(0.754) | 3.375<br>(0.740) | 2.810<br>(0.882) |
| 17 | 1.683<br>(0.789) | 1.854<br>(0.623) | 2.500<br>(0.773) | 2.243<br>(0.895) | 1.605<br>(0.718) | 2.071<br>(0.838 | 1.600<br>(0.778) | 2.600<br>(0.672) | 2.571<br>(0.668) | 1.225<br>(0.423) | 1.750<br>(0.742) | 2.806<br>(0.401) | 2.447<br>(0.686) | 2.128<br>(0.695) | 1.800<br>(0.791) | 1.833<br>(0.794) |

| Character no. | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 3.854 (1.389) | 3.902 (1.562) | 4.976 (0.154) | 4.108 (0.966) | 4.237 (0.751) | 4.405 (0.767) | 3.950 (0.986) | 4.950 (0.221) | 3.048 (0.309) | 4.400 (0.496) | 4.700 (0.723) | 4.361 (0.899) | 4.500 (0.952) | 3.795 (1.031) | 4.525 (1.109) | 4.976 (0.154) |
| 19 | 1.732 (0.975) | 1.902 (0.995) | 2.167 (1.146) | 1.568 (1.119) | 2.053 (1.184) | 2.905 (0.983) | 1.750 (0.981) | 2.175 (1.107) | 1.262 (0.734) | 3.325 (0.730) | 1.850 (1.027) | 1.722 (1.256) | 1.895 (1.134) | 1.615 (0.990) | 1.700 (0.939) | 1.238 (0.656) |
| 20 | 2.317 (0.687) | 2.146 (0.760) | 2.333 (0.721) | 1.432 (0.555) | 1.500 (0.762) | 1.333 (0.612) | 1.250 (0.543) | 1.975 (0.768) | 2.048 (0.731) | 2.075 (0.694) | 2.375 (0.667) | 1.861 (0.798) | 1.656 (0.708) | 1.564 (0.680) | 2.300 (0.723) | 2.333 (0.490) |
| 21 | 2.073 (0.565) | 3.415 (1.264) | 2.810 (0.634) | 3.676 (0.944) | 3.421 (1.056) | 3.167 (1.080) | 3.000 (0.934) | 4.250 (1.104) | 2.262 (0.964) | 2.700 (0.467) | 1.975 (0.530) | 3.194 (1.037) | 4.105 (1.247) | 4.205 (1.174) | 3.450 (1.339) | 4.167 (1.010) |
| 22 | 1.463 (1.306) | 1.366 (1.428) | 1.024 (0.841) | 0.270 (0.450) | 0.526 (1.268) | 0.690 (0.468) | 0.825 (1.852) | 1.450 (2.075) | 2.833 (2.613) | 0.500 (1.396) | 1.700 (1.843) | 2.333 (2.230) | 1.079 (1.302) | 0.846 (0.366) | 2.575 (2.630) | 2.333 (2.302) |
| 23 | 0.951 (0.312) | 0.829 (0.495) | 0.929 (0.342) | 0.270 (0.450) | 0.342 (0.450) | 0.690 (0.582) | 0.375 (0.868) | 0.675 (0.944) | 1.238 (1.144) | 0.250 (0.543) | 1.175 (0.874) | 1.278 (1.186) | 0.579 (0.683) | 0.846 (0.366) | 1.175 (1.152) | 1.310 (0.950) |
| 24 | 3.278 (1.321) | 3.024 (0.951) | 1.950 (0.412) | 3.005 (1.062) | 2.576 (0.791) | 2.676 (0.630) | 2.967 (1.096) | 2.402 (0.506) | 5.088 (2.585) | 2.957 (1.059) | 2.505 (0.954) | 2.611 (0.585) | 3.297 (1.211) | 2.344 (0.568) | 3.477 (1.277) | 1.993 (0.322) |
| 25 | 2.024 (0.404) | 2.185 (0.477) | 2.700 (0.453) | 2.514 (0.420) | 2.397 (0.436) | 2.319 (0.292) | 2.402 (0.354) | 2.702 (0.320) | 1.743 (0.403) | 2.295 (0.398) | 2.122 (0.471) | 2.428 (0.352) | 2.303 (0.358) | 2.169 (0.356) | 2.307 (0.449) | 2.374 (0.335) |
| 26 | 0.829 (0.704) | 1.049 (0.312) | 1.310 (0.517) | 0.622 (0.545) | 1.053 (0.462) | 0.333 (0.477) | 0.775 (0.698) | 0.775 (0.423) | 2.595 (1.014) | 0.975 (0.480) | 0.975 (0.276) | 1.806 (1.191) | 0.605 (0.547) | 1.077 (0.422) | 1.175 (0.747) | 1.024 (0.289) |
| 27 | 2.463 (2.440) | 3.537 (1.925) | 5.952 (0.216) | 4.216 (1.512) | 1.395 (1.152) | 1.310 (1.893) | 2.750 (2.048) | 3.350 (1.833) | 3.214 (1.970) | 3.300 (2.267) | 3.225 (2.094) | 3.056 (1.956) | 2.211 (0.905) | 2.641 (1.828) | 4.250 (1.873) | 4.571 (1.364) |
| 28 | 2.171 (2.212) | 3.366 (1.670) | 4.905 (0.617) | 4.135 (1.182) | 2.947 (2.382) | 0.881 (1.418) | 3.750 (1.794) | 2.425 (1.907) | 3.119 (1.903) | 3.925 (1.730) | 2.900 (2.098) | 3.833 (1.844) | 4.132 (1.436) | 3.513 (1.848) | 4.575 (1.035) | 4.286 (1.436) |
| 29 | 2.390 (0.737) | 2.780 (0.571) | 2.619 (0.825) | 3.243 (0.597) | 3.211 (0.843) | 2.405 (0.767) | 2.300 (0.911) | 2.125 (0.757) | 2.357 (0.727) | 3.150 (0.770) | 1.900 (0.810) | 2.778 (0.832) | 2.263 (0.685) | 2.795 (0.894) | 2.400 (0.572) | 2.667 (0.650) |
| 30 | 2.268 (0.535) | 2.220 (0.690) | 2.476 (0.594) | 2.054 (0.743) | 2.132 (0.741) | 2.167 (0.660) | 2.250 (0.588) | 2.250 (0.742) | 2.071 (0.640) | 2.275 (0.640) | 2.325 (0.694) | 1.917 (0.500) | 2.316 (0.620) | 2.051 (0.605) | 1.875 (0.648) | 2.286 (0.573) |
| 31 | 88.293 (22.650) | 98.488 (29.445) | 93.571 (24.056) | 99.189 (28.772) | 114.289 (22.773) | 81.452 (24.016) | 85.150 (20.151) | 104.000 (25.296) | 90.119 (26.883) | 78.625 (23.874) | 82.750 (20.779) | 77.500 (18.434) | 90.947 (20.117) | 105.897 (29.055) | 85.775 (17.912) | 77.476 (20.113) |
| 32 | 2.293 (0.716) | 1.780 (0.525) | 1.952 (0.582) | 1.541 (0.558) | 1.684 (0.620) | 2.119 (0.633) | 1.850 (0.580) | 1.500 (0.506) | 1.405 (0.544) | 2.050 (0.450) | 1.800 (0.564) | 1.583 (0.500) | 1.658 (0.627) | 1.410 (0.498) | 1.500 (0.599) | 1.929 (0.453) |
| 33 | 2.341 (0.965) | 3.439 (1.305) | 2.429 (0.966) | 2.405 (1.166) | 3.632 (1.261) | 1.548 (0.670) | 2.200 (1.203) | 2.875 (1.244) | 2.524 (1.110) | 1.975 (1.187) | 1.750 (0.809) | 2.278 (0.849) | 2.421 (1.154) | 2.282 (0.826) | 2.575 (0.931) | 2.690 (1.259) |
| 34 | 1.390 (0.494) | 1.512 (0.553) | 1.690 (0.643) | 2.000 (0.624) | 1.526 (0.557) | 1.262 (0.445) | 1.625 (0.540) | 1.950 (0.597) | 1.667 (0.612) | 1.225 (0.423) | 1.600 (0.591) | 1.417 (0.554) | 1.684 (0.620) | 1.513 (0.506) | 1.550 (0.597) | 1.738 (0.701) |
| 35 | 1.878 (0.640) | 1.854 (0.573) | 1.905 (0.370) | 2.270 (0.608) | 1.632 (0.541) | 2.119 (0.593) | 2.475 (0.679) | 2.500 (0.599) | 1.833 (0.621) | 1.650 (0.483) | 1.825 (0.636) | 1.917 (0.604) | 1.895 (0.559) | 1.744 (0.549) | 1.925 (0.764) | 1.857 (0.683) |

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 1.951 (0.631) | 1.780 (0.725) | 1.786 (0.565) | 1.703 (0.571) | 1.526 (0.557) | 1.738 (0.587) | 1.975 (0.768) | 1.425 (0.594) | 1.296 (0.457) | 1.675 (0.730) | 1.750 (0.630) | 1.278 (0.513) | 1.605 (0.679) | 1.923 (0.623) | 1.200 (0.516) | 1.643 (0.692) |
| 37 | 1.829 (0.946) | 1.390 (0.972) | 0.548 (0.670) | 1.892 (0.843) | 1.289 (0.867) | 2.357 (0.879) | 2.150 (0.770) | 2.600 (0.632) | 2.595 (0.665) | 1.475 (0.905) | 1.825 (0.931) | 1.806 (0.951) | 2.658 (0.534) | 1.692 (0.922) | 1.825 (0.903) | 1.381 (0.764) |
| 38 | 1.195 (0.501) | 1.000 (0.671) | 0.476 (0.505) | 1.486 (0.804) | 0.895 (0.509) | 1.833 (0.881) | 1.250 (0.588) | 1.525 (0.679) | 2.286 (0.708) | 1.025 (0.620) | 1.600 (0.982) | 1.472 (0.878) | 1.053 (0.226) | 0.974 (0.428) | 1.375 (0.838) | 1.357 (0.791) |
| 39 | 3.732 (1.119) | 3.780 (0.725) | 5.595 (1.345) | 3.757 (2.763) | 3.579 (0.793) | 3.524 (1.065) | 4.100 (1.336) | 3.475 (1.450) | 4.095 (0.759) | 4.625 (1.125) | 4.325 (1.071) | 3.722 (1.301) | 3.895 (0.646) | 3.974 (1.063) | 4.400 (1.614) | 3.952 (0.309) |
| 40 | 1.878 (0.980) | 2.000 (0.837) | 2.833 (0.437) | 1.595 (1.040) | 1.553 (0.645) | 0.952 (0.492) | 1.575 (0.747) | 1.400 (0.982) | 2.000 (0.584) | 2.250 (0.840) | 2.050 (0.714) | 2.000 (0.986) | 1.237 (0.490) | 1.615 (0.782) | 2.075 (0.797) | 2.095 (0.726) |
| 41 | 0.976 (0.799) | 1.244 (0.524) | 1.667 (0.587) | 1.622 (1.255) | 1.447 (0.645) | 0.429 (0.737) | 1.100 (0.841) | 0.675 (0.656) | 1.619 (0.539) | 1.650 (0.580) | 1.250 (0.543) | 1.639 (0.867) | 0.947 (0.655) | 1.154 (0.745) | 1.425 (0.781) | 1.571 (0.547) |
| 42 | 1.146 (0.353) | 1.000 (0.500) | 2.524 (0.707) | 1.297 (0.661) | 1.105 (0.388) | 1.310 (0.604) | 1.650 (0.770) | 1.425 (0.747) | 2.310 (0.897) | 1.200 (0.564) | 1.250 (0.809) | 1.861 (0.833) | 1.342 (0.781) | 1.000 (0.000) | 1.850 (0.864) | 1.095 (0.370) |
| 43 | 1.951 (0.865) | 1.707 (0.901) | 2.714 (0.636) | 1.324 (0.626) | 1.263 (0.554) | 1.595 (0.767) | 1.975 (0.862) | 1.675 (0.829) | 2.048 (0.854) | 2.325 (0.917) | 2.475 (0.877) | 2.167 (0.910) | 1.500 (0.797) | 1.205 (0.732) | 2.050 (0.932) | 0.762 (0.431) |
| 44 | 0.951 (0.218) | 0.561 (0.502) | 0.976 (0.269) | 0.784 (0.417) | 0.868 (0.529) | 0.738 (0.587) | 1.125 (0.335) | 1.275 (0.452) | 1.190 (0.397) | 0.850 (0.362) | 0.925 (0.417) | 1.167 (0.447) | 1.079 (0.359) | 0.641 (0.584) | 1.000 (0.483) | 0.667 (0.526) |
| 45 | 1.537 (0.595) | 1.585 (0.547) | 1.786 (0.520) | 1.432 (0.502) | 1.895 (0.727) | 1.714 (0.457) | 1.800 (0.405) | 1.900 (0.379) | 1.643 (0.485) | 1.875 (0.404) | 1.400 (0.496) | 1.750 (0.439) | 1.658 (0.582) | 1.513 (0.501) | 1.425 (0.549) | 1.571 (0.501) |
| 46 | 1.951 (0.218) | 1.829 (0.381) | 1.857 (0.354) | 1.811 (0.397) | 1.763 (0.431) | 1.929 (0.261) | 1.675 (0.474) | 1.825 (0.385) | 1.643 (0.485) | 2.000 (0.000) | 1.975 (0.158) | 1.806 (0.401) | 1.605 (0.495) | 1.769 (0.427) | 1.200 (0.405) | 2.000 (0.000) |
| 47 | 2.512 (0.575) | 2.780 (0.475 | 1.929 (0.745) | 1.486 (0.731) | 2.184 (0.730) | 2.238 (0.726) | 1.125 (0.335) | 1.575 (0.575) | 2.190 (0.707) | 2.000 (0.751) | 1.950 (0.597) | 1.667 (0.717) | 1.842 (0.547) | 2.897 (0.387) | 1.100 (0.304) | 2.595 (0.627) |
| 48 | 2.171 (0.587) | 2.659 (0.575) | 2.119 (0.504) | 2.541 (0.691) | 2.816 (0.393) | 2.500 (0.506) | 2.500 (0.506) | 2.925 (0.267) | 2.452 (0.550) | 2.525 (0.554) | 2.150 (0.662) | 2.806 (0.401) | 2.737 (0.503) | 2.667 (0.621) | 2.275 (0.815) | 2.738 (0.544) |
| 49 | 0.488 (0.553) | 0.610 (0.494) | 0.286 (0.457) | 0.784 (0.479) | 0.605 (0.595) | 0.524 (0.505) | 0.725 (0.452) | 0.225 (0.423) | 0.619 (0.539) | 0.350 (0.483) | 0.550 (0.504) | 0.222 (0.422) | 0.289 (0.460) | 0.564 (0.718) | 0.475 (0.506) | 0.833 (0.537) |
| 50 | 0.195 (0.401) | 0.585 (0.499) | 0.071 (0.261) | 0.027 (0.164) | 0.500 (0.507) | 0.167 (0.377) | 0.225 (0.423) | 0.300 (0.464) | 0.571 (0.501) | 0.050 (0.221) | 0.100 (0.304) | 0.194 (0.401) | 0.395 (0.495) | 0.462 (0.505) | 0.225 (0.423) | 0.667 (0.477) |
| 51 | 0.341 (0.480) | 0.073 (0.264) | 0.095 (0.297) | 0.811 (0.569) | 0.000 (0.000) | 0.976 (0.715) | 0.600 (0.545) | 1.425 (0.712) | 0.762 (0.692) | 0.600 (0.632) | 0.575 (0.594) | 1.194 (0.749) | 0.789 (0.622) | 0.974 (0.668) | 0.525 (0.579) | 0.500 (0.595) |
| 52 | 2.488 (0.637) | 2.293 (0.716) | 1.952 (0.697) | 2.054 (0.575) | 2.342 (0.627) | 1.810 (0.740) | 2.050 (0.714) | 2.450 (0.552) | 2.238 (0.692) | 1.600 (0.632) | 2.575 (0.594) | 1.667 (0.478) | 2.263 (0.644) | 1.846 (0.709) | 1.925 (0.764) | 2.214 (0.545) |
| 53 | 1.293 (0.559) | 1.463 (0.711) | 1.571 (0.703) | 2.811 (0.518) | 2.105 (0.764) | 2.238 (0.759) | 1.550 (0.749) | 2.475 (0.640) | 2.976 (0.154) | 2.175 (0.636) | 1.175 (0.446) | 2.667 (0.586) | 2.658 (0.534) | 2.487 (0.644) | 2.750 (0.439) | 1.810 (0.804) |

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 1.951 (0.659) | 1,951 (0.740) | 1.738 (0.544) | 2.649 (0.588) | 1.895 (0.689) | 1.810 (0.671) | 1.950 (0.597) | 2.100 (0.632) | 2.214 (0.813) | 1.600 (0.632) | 2.500 (0.599) | 1.639 (0.683) | 2.211 (0.777) | 2.385 (0.633) | 2.175 (0.747) | 2.024 (0.749) |
| 55 | 1.317 (0.610) | 1.537 (0.711) | 1.667 (0.612) | 2.324 (0.669) | 1.553 (0.686) | 1.595 (0.665) | 2.150 (0.736) | 2.400 (0.632) | 1.762 (0.692) | 1.900 (0.672) | 1.975 (0.800) | 1.778 (0.591) | 1.842 (0.823) | 2.538 (0.756) | 2.100 (0.709) | 1.976 (0.715) |
| 56 | 1.366 (0.552) | 1.537 (0.674) | 1.762 (0.850) | 1.189 (0.397) | 1.632 (0.751) | 1.571 (0.668) | 1.800 (0.791) | 1.450 (0.677) | 1.500 (0.634) | 1.325 (0.572) | 1.575 (0.712) | 1.500 (0.609) | 1.737 (0.795) | 1.718 (0.793) | 1.900 (0.709) | 1.524 (0.707) |
| 57 | 1.390 (0.586) | 2.049 (0.705) | 1.619 (0.623) | 2.730 (0.652) | 2.132 (0.741) | 1.619 (0.697) | 2.275 (0.640) | 2.250 (0.776) | 1.667 (0.687) | 1.625 (0.628) | 1.950 (0.677) | 1.722 (0.615) | 1.921 (0.712) | 2.359 (0.743) | 2.075 (0.656) | 1.976 (0.715) |
| 58 | 1.902 (1.960) | 3.049 (1.774) | 3.929 (0.677) | 0.992 (0.875) | 2.158 (1.603) | 0.310 (0.897) | 1.875 (1.713) | 1.550 (1.663) | 3.262 (1.415) | 3.075 (1.492) | 3.550 (1.568) | 2.778 (1.675) | 1.105 (1.311) | 2.462 (2.075) | 2.625 (1.705) | 3.381 (1.378) |
| 59 | 0.902 (0.831) | 1.293 (0.559) | 2.333 (0.650) | 0.838 (0.646) | 1.211 (0.622) | 0.214 (0.520) | 0.975 (0.733) | 0.875 (0.757) | 1.833 (0.730) | 2.125 (0.822) | 1.575 (0.903) | 1.500 (0.878) | 0.816 (0.652) | 0.949 (0.647) | 1.400 (0.871) | 1.690 (0.780) |
| 60 | 2.561 (1.718) | 3.171 (1.283) | 3.881 (0.395) | 1.405 (1.189) | 2.816 (1.182) | 1.024 (1.522) | 2.625 (1.596) | 2.700 (1.436) | 3.571 (0.914) | 3.450 (1.011) | 3.825 (0.594) | 3.111 (1.282) | 1.553 (1.309) | 3.000 (1.433) | 3.025 (1.423) | 3.548 (0.861) |
| 61 | 1.659 (1.063) | 2.171 (0.529) | 2.833 (0.437) | 1.405 (0.762) | 1.974 (0.545) | 0.595 (0.798) | 1.625 (0.774) | 1.800 (0.758) | 2.571 (0.590) | 2.625 (0.540) | 2.400 (0.744) | 2.194 (0.749) | 1.737 (0.828) | 1.769 (0.742) | 2.275 (0.784) | 2.452 (0.670) |
| 62 | 1.293 (1.146) | 1.805 (1.054) | 2.738 (0.885) | 1.432 (1.281) | 1.974 (1.026) | 0.286 (0.774) | 1.350 (1.145) | 1.175 (0.958) | 2.048 (0.962) | 2.425 (0.958) | 2.000 (0.987) | 1.806 (1.215) | 0.789 (0.777) | 1.051 (0.944) | 1.800 (1.091) | 1.905 (1.031) |
| 63 | 0.024 (0.156) | 0.098 (0.300) | 1.381 (0.731) | 0.243 (0.495) | 0.263 (0.554) | 0.119 (0.328) | 0.300 (0.464) | 0.325 (0.572) | 1.071 (0.838) | 0.125 (0.335) | 0.375 (0.628) | 0.694 (0.856) | 0.263 (0.446) | 0.077 (0.270) | 0.425 (0.594) | 0.048 (0.216) |
| 64 | 0.878 (0.400) | 1.171 (0.587) | 0.905 (0.431) | 1.270 (0.560) | 0.711 (0.565) | 1.071 (0.407) | 0.925 (0.350) | 1.150 (0.427) | 1.024 (0.269) | 1.075 (0.350) | 0.825 (0.446) | 0.972 (0.291) | 0.947 (0.324) | 1.385 (0.544) | 0.850 (0.483) | 1.071 (0.513) |
| 65 | 16.405 (2.870) | 16.917 (3.021) | 16.536 (3.244) | 19.038 (4.060) | 17.239 (2.735) | 15.629 (2.808) | 15.952 (3.328) | 21.132 (3.673) | 17.957 (2.496) | 19.977 (3.865) | 20.367 (3.836) | 15.033 (2.424) | 17.497 (3.327) | 19.892 (3.499) | 15.750 (2.148) | 20.212 (2.714) |
| 66 | 9.485 (1.370) | 10.351 (2.165) | 10.864 (2.251) | 12.341 (2.390) | 10.345 (1.451) | 9.467 (1.562) | 9.670 (1.744) | 12.445 (2.236) | 10.555 (1.758) | 11.300 (2.089) | 10.450 (1.684) | 9.031 (1.409) | 10.550 (2.357) | 11.995 (1.914) | 10.135 (1.545) | 12.333 (2.314) |
| 67 | 9.676 (2.285) | 9.739 (2.472) | 8.779 (1.911) | 10.168 (2.567) | 9.705 (2.169) | 8.821 (1.936) | 8.985 (2.317) | 11.300 (2.647) | 10.855 (1.586) | 12.112 (2.342) | 12.142 (2.324) | 8.702 (1.444) | 10.129 (2.029) | 10.892 (2.265) | 8.835 (1.544) | 11.493 (1.860) |
| 68 | 2.500 (0.944) | 2.385 (0.525) | 1.850 (0.605) | 1.986 (0.720) | 2.595 (0.737) | 1.986 (0.675) | 1.887 (0.604) | 2.035 (0.595) | 2.588 (0.596) | 2.492 (0.680) | 2.415 (0.784) | 1.592 (0.498) | 2.539 (0.722) | 2.528 (0.700) | 2.170 (0.540) | 3.105 (1.318) |
| 69 | 10.390 (1.3587) | 9.756 (1.908) | 10.619 (1.431) | 10.865 (1.669) | 9.579 (1.154) | 10.429 (1.213) | 10.650 (1.145) | 12.350 (1.099) | 10.714 (1.066) | 11.500 (1.553) | 12.100 (1.972) | 11.444 (1.229) | 10.263 (1.155) | 10.205 (1.105) | 9.950 (0.714) | 10.286 (1.132) |
| 70 | 7.659 (2.955) | 4.707 (2.442) | 8.119 (2.200) | 7.919 (2.178) | 6.395 (1.911) | 8.405 (2.732) | 8.750 (1.613) | 11.450 (3.266) | 1.452 (2.539) | 7.475 (2.660) | 9.625 (2.393) | 7.472 (2.923) | 7.526 (2.227) | 9.051 (2.188) | 7.150 (1.552) | 6.167 (2.315) |
| 71 | 6.098 (5.776) | 3.073 (3.538) | 11.476 (7.229) | 12.324 (5.730) | 8.026 (4.130) | 8.381 (6.317) | 15.400 (6.328) | 19.425 (9.974) | 8.619 (5.305) | 7.425 (4.775) | 8.850 (5.270) | 7.250 (5.694) | 9.684 (5.600) | 17.077 (8.975) | 8.325 (3.661) | 4.286 (2.616) |

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | 0.634 (1.445) | 0.244 (0.699) | 1.190 (1.798) | 1.000 (1.414) | 0.868 (1.319) | 1.143 (1.894) | 1.800 (1.897) | 3.575 (2.890) | 1.571 (1.850) | 0.125 (0.404) | 0.525 (1.086) | 0.889 (1.326) | 2.132 (2.315) | 3.872 (3.458) | 1.375 (1.554) | 0.071 (0.342) |
| 73 | 1.585 (2.366) | 0.293 (0.981) | 1.619 (2.971) | 0.703 (1.102) | 0.289 (0.768) | 2.143 (1.995) | 2.300 (2.564) | 5.125 (3.897) | 1.310 (2.030) | 0.900 (1.446) | 2.200 (1.843) | 1.583 (1.873) | 1.737 (1.913) | 3.436 (3.640) | 0.800 (1.224) | 0.690 (1.115) |
| 74 | 1.878 (1.552) | 1.512 (1.872) | 3.357 (1.998) | 3.378 (1.639) | 2.263 (1.288) | 2.619 (1.248) | 4.075 (1.457) | 4.250 (2.048) | 3.119 (1.641) | 2.450 (1.600) | 3.575 (1.723) | 2.250 (1.628) | 2.895 (1.457) | 3.333 (1.364) | 3.500 (1.559) | 2.238 (1.708) |
| 75 | 1.415 (1.224) | 0.341 (0.794) | 2.238 (1.543) | 1.595 (1.117) | 1.553 (1.201) | 1.881 (1.234) | 3.025 (1.098) | 1.125 (1.265) | 1.033 (1.267) | 0.950 (1.061) | 1.925 (1.439) | 0.444 (0.843) | 1.447 (1.370) | 3.462 (1.760) | 1.850 (1.442) | 1.262 (1.106) |
| 76 | 1.902 (0.539) | 1.683 (0.610) | 2.095 (0.517) | 1.568 (0.647) | 1.632 (0.675) | 1.952 (0.661) | 2.125 (0.563) | 1.850 (0.700) | 1.214 (0.415) | 1.725 (0.716) | 1.725 (0.599) | 1.389 (0.494) | 1.421 (0.642) | 1.769 (0.742) | 1.325 (0.572) | 1.119 (0.395) |
| 77 | 1.585 (0.631) | 1.220 (0.475) | 1.619 (0.697) | 1.108 (0.315) | 1.316 (0.574) | 1.643 (0.791) | 1.600 (0.709) | 1.375 (0.705) | 1.024 (0.154) | 1.450 (0.639) | 1.575 (0.712) | 1.028 (0.167) | 1.289 (0.611) | 1.462 (0.643) | 1.050 (0.221) | 1.048 (0.216) |
| 78 | 2.561 (0.808) | 2.098 (0.766) | 2.881 (0.705) | 2.811 (0.811) | 2.474 (0.830) | 2.548 (0.832) | 3.025 (0.620) | 3.575 (1.035) | 2.429 (0.630) | 2.600 (0.941) | 2.525 (0.784) | 3.194 (0.889) | 2.579 (0.758) | 2.923 (0.839) | 2.525 (0.506) | 2.310 (0.804) |
| 79 | 2.561 (0.502) | 2.805 (0.401) | 2.833 (0.377) | 2.622 (0.639) | 2.763 (0.431) | 2.810 (0.397) | 2.700 (0.464) | 2.650 (0.533) | 2.476 (0.505) | 2.625 (0.540) | 2.625 (0.490) | 2.306 (0.467) | 2.737 (0.446) | 2.846 (0.366) | 2.625 (0.540) | 2.595 (0.497) |
| 80 | 2.220 (0.475) | 2.488 (0.506) | 2.167 (0.377) | 2.405 (0.498) | 2.579 (0.552) | 2.119 (0.328) | 2.000 (0.000) | 2.150 (0.362) | 2.214 (0.415) | 2.000 (0.000) | 2.075 (0.267) | 2.056 (0.232) | 2.237 (0.431) | 2.513 (0.506) | 2.225 (0.423) | 2.238 (0.421) |
| 81 | 2.000 (0.548) | 2.122 (0.400) | 2.405 (0.665) | 2.000 (0.577) | 1.816 (0.563) | 1.762 (0.532) | 1.725 (0.452) | 1.975 (0.577) | 1.952 (0.539) | 2.600 (0.778) | 1.975 (0.490) | 2.361 (0.723) | 1.947 (0.567) | 1.667 (0.530) | 1.625 (0.586) | 2.071 (0.745) |
| 82 | 2.439 (0.550) | 2.707 (0.461) | 2.452 (0.504) | 2.622 (0.545) | 2.868 (0.343) | 2.310 (0.468) | 2.150 (0.362) | 2.275 (0.452) | 2.524 (0.505) | 2.050 (0.221) | 2.175 (0.385) | 2.167 (0.447) | 2.474 (0.506) | 2.821 (0.369) | 2.500 (0.506) | 2.548 (0.504) |
| 83 | 2.073 (0.346) | 1.976 (0.156) | 2.143 (0.354) | 1.973 (0.372) | 1.789 (0.474) | 1.976 (0.154) | 1.975 (0.158) | 1.975 (0.158) | 2.000 (0.000) | 2.025 (0.158) | 2.075) (0.267) | 1.917 (0.260) | 1.921 (0.428) | 1.923 (0.422) | 1.725 (0.452) | 1.905 (0.370) |
| 84 | 2.341 (0.693) | 2.854 (0.358) | 2.167 (0.794) | 2.622 (0.545 | 2.553 (0.555) | 2.143 (0.718) | 1.800 (0.464) | 2.175 (0.712) | 2.333 (0.579) | 2.750 (0.543) | 2.375 (0.740) | 2.583 (0.692) | 2.079 (0.673) | 1.974 (0.628) | 2.275 (0.599) | 2.505 (0.701) |
| 85 | 0.610 (0.494) | 0.439 (0.502) | 0.357 (0.485) | 0.649 (0.588) | 0.500 (0.507) | 0.833 (0.537) | 0.800 (0.464) | 0.775 (0.423) | 0.595 (0.497) | 0.325 (0.474) | 0.550 (0.533) | 0.611 (0.494) | 0.684 (0.525) | 0.795 (0.522) | 0.850 (0.580) | 0.857 (0.570) |
| 86 | 1.395 (0.319) | 1.549 (0.484) | 1.336 (0.416) | 1.268 (0.458) | 1.361 (0.402) | 1.243 (0.351) | 1.382 (0.390) | 1.217 (0.406) | 1.388 (0.372) | 1.257 (0.422) | 1.522 (0.498) | 0.792 (0.280) | 1.258 (0.414) | 1.903 (0.448) | 1.207 (0.324) | 1.705 (0.531) |
| 87 | 4.907 (0.712) | 5.790 (0.994) | 5.110 (0.777) | 6.159 (0.875) | 5.347 (0.731) | 4.933 (0.600) | 4.575 (0.816) | 5.497 (0.755) | 5.695 (0.678) | 6.250 (0.896) | 6.257 (0.650) | 4.661 (0.601) | 5.553 (1.067) | 5.908 (1.037) | 5.027 (0.668) | 7.371 (1.135) |
| 88 | 2.632 (0.408) | 3.456 (0.680) | 2.876 (0.496) | 3.749 (0.555) | 3.363 (0.492) | 2.602 (0.473) | 2.430 (0.446) | 2.895 (0.590) | 3.407 (0.497) | 3.002 (0.510) | 2.982 (0.435) | 2.261 (0.404) | 3.076 (0.717) | 3.777 (0.660) | 2.995 (0.395) | 4.226 (0.597) |
| 89 | 2.473 (0.592) | 2.771 (0.516) | 2.519 (0.490) | 2.884 (0.503) | 2.561 (0.425) | 2.405 (0.408) | 2.100 (0.399 | 2.592 (0.402) | 2.583 (0.393) | 3.210 (0.667) | 3.147 (0.557) | 2.169 (0.490) | 2.679 (0.547) | 2.715 (0.655) | 2.235 (0.547) | 3.457 (0.632) |

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | 0.507<br>(0.215) | 0.368<br>(0.433) | 0.429<br>(0.245) | 0.192<br>(0.206) | 0.432<br>(0.298) | 0.455<br>(0.167) | 0.475<br>(0.256) | 0.447<br>(0.281) | 0.471<br>(0.268) | 0.352<br>(0.314) | 0.472<br>(0.243) | 0.186<br>(0.184) | 0.453<br>(0.259) | 0.772<br>(0.339) | 0.332<br>(0.185) | 0.400<br>(0.370) |
| 91 | 4.458<br>(0.672) | 5.378<br>(0.995) | 4.840<br>(0.759) | 5.886<br>(1.064) | 4.939<br>(0.660) | 4.452<br>(0.564) | 4.387<br>(0.756) | 5.162<br>(0.720) | 5.298<br>(0.687) | 5.885<br>(0.865) | 5.517<br>(0.608) | 4.475<br>(0.592) | 5.137<br>(0.924) | 5.403<br>(0.802) | 4.665<br>(0.688) | 5.550<br>(0.919) |
| 92 | 2.324<br>(0.342) | 2.993<br>(0.568) | 2.624<br>(0.462) | 3.343<br>(0.568) | 2.992<br>(0.401) | 2.226<br>(0.381) | 2.175<br>(0.373) | 2.680<br>(0.574) | 2.998<br>(0.332) | 2.677<br>(0.482) | 2.627<br>(0.323) | 2.164<br>(0.342) | 2.845<br>(0.608) | 3.341<br>(0.527) | 2.760<br>(0.376) | 3.669<br>(0.523) |
| 93 | 2.205<br>(0.501) | 2.502<br>(0.549) | 2.264<br>(0.503) | 2.686<br>(0.590) | 2.311<br>(0.357) | 2.100<br>(0.359) | 1.955<br>(0.424) | 2.342<br>(0.371) | 2.355<br>(0.297) | 2.602<br>(0.571) | 2.632<br>(0.438) | 1.983<br>(0.412) | 2.268<br>(0.512) | 2.510<br>(0.596) | 2.100<br>(0.445) | 3.048<br>(0.620) |
| 94 | 2.405<br>(0.470) | 2.641<br>(0.629) | 2.593<br>(0.625) | 2.868<br>(0.714) | 2.850<br>(0.603) | 2.357<br>(0.604) | 2.485<br>(0.630) | 3.040<br>(0.604) | 2.450<br>(0.446) | 2.795<br>(0.612) | 2.905<br>(0.652) | 2.144<br>(0.411) | 2.408<br>(0.669) | 3.018<br>(0.702) | 2.242<br>(0.384) | 3.095<br>(0.544) |
| 95 | 3.000<br>(0.000) | 2.951<br>(0.218) | 2.952<br>(0.216) | 2.919<br>(0.277) | 2.842<br>(0.495) | 3.000<br>(0.000) | 3.000<br>(0.000) | 2.925<br>(0.267) | 3.000<br>(0.000) | 2.925<br>(0.267) | 2.950<br>(0.221) | 2.778<br>(0.591) | 2.947<br>(0.226) | 3.000<br>(0.000) | 2.950<br>(0.316) | 2.905<br>(0.370) |
| 96 | 1.271<br>(0.551) | 1.090<br>(0.574) | 1.781<br>(0.752) | 2.149<br>(0.753) | 1.474<br>(0.518) | 1.414<br>(0.504) | 1.695<br>(0.512) | 2.675<br>(0.689) | 1.607<br>(0.604) | 1.777<br>(0.760) | 1.600<br>(0.610) | 1.311<br>(0.511) | 1.721<br>(0.681) | 2.545<br>(0.845) | 1.737<br>(0.507) | 1.643<br>(0.642) |
| 97 | 0.829<br>(0.292) | 0.851<br>(0.465) | 1.014<br>(0.384) | 1.368<br>(0.493) | 1.184<br>(0.365) | 0.895<br>(0.285) | 1.100<br>(0.373) | 1.610<br>(0.444) | 1.060<br>(0.322) | 1.005<br>(0.375) | 1.040<br>(0.327) | 0.681<br>(0.301) | 1.158<br>(0.363) | 1.615<br>(0.498) | 1.185<br>(0.261) | 1.126<br>(0.508) |
| 98 | 0.641<br>(0.266) | 0.551<br>(0.323) | 0.888<br>(0.403) | 1.022<br>(0.368) | 0.718<br>(0.250) | 0.683<br>(0.274) | 0.800<br>(0.293) | 1.322<br>(0.375) | 0.762<br>(0.351) | 0.937<br>(0.420) | 0.782<br>(0.362) | 0.625<br>(0.256) | 0.832<br>(0.405) | 1.244<br>(0.437) | 0.802<br>(0.291) | 0.829<br>(0.474) |
| 99 | 0.768<br>(0.345) | 0.690<br>(0.460) | 0.755<br>(0.389) | 0.681<br>(0.314) | 0.682<br>(0.392) | 0.757<br>(0.370) | 0.702<br>(0.417) | 1.392<br>(0.653) | 0.683<br>(0.305) | 0.787<br>(0.266) | 0.830<br>(0.323) | 0.597<br>(0.289) | 0.932<br>(0.581) | 1.454<br>(0.627) | 0.842<br>(0.335) | 0.679<br>(0.479) |

# APPENDIX IV: The first ten vector scores of the sixteen families.

PRINCIPAL COORDINATE ANALYSIS

TRACE = 17,253

FAM-01

| LATENT ROOTS | 1.570 | 1.113 | 1.056 | .965 | .770 | .733 | .716 | .672 | .648 | .552 |
|---|---|---|---|---|---|---|---|---|---|---|
| PERCENT OF TRACE | 9.1 | 15.6 | 21.7 | 26.8 | 31.4 | 35.7 | 39.8 | 43.6 | 47.5 | 50.7 |
| 1 | -.064 | -.268 | -.179 | .017 | .088 | .230 | .108 | .100 | .100 | -.009 |
| 2 | .021 | -.027 | -.201 | .026 | -.051 | .225 | -.166 | -.005 | .031 | .312 |
| 3 | .076 | .117 | .221 | -.151 | .214 | -.156 | .239 | .056 | -.156 | .037 |
| 4 | .361 | .186 | .231 | .056 | -.018 | .109 | .115 | .080 | .021 | .065 |
| 5 | .002 | .008 | .077 | .231 | .013 | .060 | .139 | .035 | .062 | .011 |
| 6 | .044 | .122 | .018 | .272 | .131 | -.016 | .239 | .110 | .066 | -.015 |
| 7 | .002 | .015 | .010 | .124 | .126 | .123 | .033 | .040 | .135 | .022 |
| 8 | .182 | .141 | .136 | .165 | .025 | .110 | .133 | .240 | .139 | .070 |
| 9 | .000 | .118 | .136 | .176 | .194 | .132 | .096 | .101 | .159 | .016 |
| 10 | .121 | .126 | .153 | .153 | .170 | .162 | .220 | .020 | .266 | .111 |
| 11 | .050 | .007 | .020 | .038 | .206 | .064 | .094 | .120 | .030 | .038 |
| 12 | .131 | .007 | .202 | .037 | .157 | .062 | .221 | .011 | .035 | .072 |
| 13 | .116 | .225 | .202 | .061 | .066 | .128 | .045 | .090 | .224 | .014 |
| 14 | .021 | .140 | .048 | .048 | .076 | .164 | .247 | .176 | .121 | .051 |
| 15 | .364 | .010 | .028 | .402 | .062 | .091 | .130 | .040 | .030 | .146 |
| 16 | .370 | .152 | .161 | .202 | .138 | .047 | .166 | .315 | .195 | .125 |
| 17 | .243 | .152 | .161 | .202 | .138 | .047 | .063 | .220 | .195 | .102 |
| 18 | .305 | .000 | .124 | .001 | .029 | .139 | .013 | .103 | .047 | .053 |
| 19 | .008 | .176 | .538 | .124 | .217 | .070 | .102 | .253 | .075 | .055 |
| 20 | .322 | .051 | .026 | .078 | .073 | .274 | .067 | .064 | .073 | .096 |
| 21 | .200 | .066 | .054 | .078 | .026 | .110 | .173 | .015 | .132 | .113 |
| 22 | .050 | .118 | .251 | .166 | .083 | .137 | .066 | .018 | .114 | .169 |
| 23 | .243 | .180 | .023 | .127 | .040 | .075 | .022 | .228 | .035 | .219 |
| 24 | .114 | .022 | .025 | .004 | .103 | .113 | .172 | .178 | .022 | .264 |
| 25 | .055 | .021 | .116 | .128 | .350 | .196 | .147 | .088 | .029 | .222 |
| 26 | .197 | .087 | .173 | .267 | .106 | .022 | .020 | .020 | .276 | .026 |
| 27 | .160 | .118 | .114 | .026 | .265 | .024 | .085 | .109 | .162 | .153 |
| 28 | .057 | .258 | .110 | .250 | .109 | .130 | .023 | .056 | .170 | .025 |
| 29 | .044 | .356 | .271 | .255 | .128 | .075 | .156 | .008 | .082 | .001 |
| 30 | .006 | .302 | .026 | .054 | .114 | .105 | .015 | .108 | .095 | .050 |
| 31 | .166 | .027 | .261 | .027 | .250 | .026 | .068 | .240 | .073 | .054 |
| 32 | .059 | .073 | .265 | .016 | .010 | .118 | .270 | .295 | .119 | .169 |
| 33 | .273 | .207 | .008 | .101 | .093 | .031 | .007 | .051 | .018 | .091 |
| 34 | .240 | .054 | .116 | .117 | .073 | .029 | .010 | .084 | .022 | .003 |
| 35 | .216 | .114 | .056 | .101 | .152 | .154 | .033 | .045 | .006 | .088 |
| 36 | .053 | .347 | .196 | .040 | .164 | .076 | .033 | .063 | .198 | .159 |
| 37 | .119 | .301 | .200 | .167 | .075 | .044 | .004 | .117 | .031 | .186 |
| 38 | .253 | .216 | .001 | .034 | .010 | .083 | .022 | .225 | .063 | .140 |
| 39 | .055 | .184 | .226 | .139 | .000 | .102 | .185 | .005 | .176 | .052 |
| 40 | .335 | .104 | .107 | .085 | .024 | .012 | .053 | .065 | .133 | .134 |
| 41 | .086 | .135 | .080 | .265 | .013 | .383 | .047 | .150 | .051 | .065 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 17,166

FAM-02

| LATENT ROOTS | 1.164 | 1.123 | .952 | .933 | .845 | .847 | .700 | .685 | .642 | .583 |
|---|---|---|---|---|---|---|---|---|---|---|
| PERCENT OF TRACE | 6.8 | 13.3 | 18.9 | 24.3 | 29.2 | 34.2 | 38.2 | 42.2 | 46.0 | 49.4 |
| 1 | .162 | .091 | .316 | .351 | .180 | .147 | .256 | .161 | .055 | .174 |
| 2 | .035 | .054 | .008 | .073 | .273 | .011 | .129 | .135 | .089 | .220 |
| 3 | .177 | .120 | .347 | .094 | .104 | .056 | .061 | .029 | .140 | .036 |
| 4 | .074 | .006 | .189 | .425 | .231 | .113 | .114 | .029 | .032 | .051 |
| 5 | .056 | .201 | .241 | .080 | .008 | .112 | .216 | .122 | .069 | .146 |
| 6 | .162 | .111 | .034 | .101 | .047 | .177 | .102 | .083 | .095 | .005 |
| 7 | .108 | .200 | .138 | .221 | .167 | .017 | .132 | .285 | .063 | .186 |
| 8 | .153 | .200 | .182 | .220 | .109 | .188 | .224 | .126 | .159 | .129 |
| 9 | .196 | .036 | .114 | .063 | .030 | .149 | .058 | .176 | .080 | .155 |
| 10 | .066 | .338 | .235 | .153 | .088 | .001 | .195 | .115 | .170 | .143 |
| 11 | .122 | .055 | .006 | .092 | .022 | .170 | .077 | .064 | .247 | .153 |
| 12 | .278 | .133 | .032 | .210 | .167 | .018 | .102 | .137 | .038 | .079 |
| 13 | .066 | .163 | .073 | .100 | .200 | .132 | .248 | .093 | .044 | .119 |
| 14 | .007 | .006 | .202 | .084 | .394 | .063 | .126 | .005 | .041 | .052 |
| 15 | .187 | .061 | .053 | .252 | .020 | .055 | .017 | .072 | .122 | .058 |
| 16 | .117 | .109 | .229 | .088 | .271 | .026 | .201 | .197 | .036 | .139 |
| 17 | .102 | .061 | .231 | .181 | .114 | .031 | .240 | .061 | .109 | .102 |
| 18 | .285 | .250 | .172 | .096 | .193 | .024 | .123 | .172 | .027 | .134 |
| 19 | .139 | .237 | .031 | .213 | .043 | .159 | .102 | .035 | .102 | .093 |
| 20 | .225 | .256 | .092 | .126 | .247 | .166 | .077 | .077 | .030 | .144 |
| 21 | .165 | .121 | .225 | .134 | .164 | .223 | .073 | .138 | .023 | .047 |
| 22 | .130 | .121 | .030 | .049 | .048 | .153 | .102 | .072 | .375 | .054 |
| 23 | .262 | .205 | .141 | .119 | .034 | .064 | .061 | .044 | .004 | .093 |
| 24 | .012 | .316 | .125 | .063 | .080 | .066 | .052 | .108 | .154 | .125 |
| 25 | .036 | .145 | .032 | .022 | .072 | .264 | .178 | .050 | .026 | .022 |
| 26 | .124 | .070 | .053 | .108 | .119 | .025 | .332 | .170 | .170 | .026 |
| 27 | .296 | .133 | .147 | .049 | .047 | .146 | .140 | .073 | .002 | .046 |
| 28 | .027 | .161 | .056 | .118 | .083 | .290 | .022 | .290 | .003 | .006 |
| 29 | .221 | .196 | .076 | .068 | .020 | .191 | .061 | .270 | .131 | .029 |
| 30 | .116 | .129 | .250 | .084 | .040 | .263 | .076 | .050 | .208 | .120 |
| 31 | .074 | .216 | .095 | .355 | .015 | .031 | .081 | .043 | .030 | .020 |
| 32 | .064 | .266 | .147 | .050 | .129 | .029 | .166 | .113 | .130 | .174 |
| 33 | .151 | .022 | .041 | .001 | .090 | .263 | .055 | .076 | .138 | .155 |
| 34 | .155 | .127 | .087 | .056 | .270 | .040 | .012 | .015 | .135 | .117 |
| 35 | .360 | .020 | .033 | .009 | .036 | .116 | .059 | .052 | .013 | .004 |
| 36 | .301 | .004 | .118 | .081 | .048 | .036 | .143 | .151 | .171 | .024 |
| 37 | .212 | .172 | .057 | .017 | .022 | .135 | .017 | .015 | .053 | .071 |
| 38 | .192 | .138 | .064 | .106 | .227 | .022 | .047 | .105 | .051 | .212 |
| 39 | .066 | .127 | .080 | .021 | .031 | .230 | .004 | .024 | .070 | .202 |
| 40 | .100 | .315 | .048 | .121 | .023 | .176 | .264 | .018 | .253 | .163 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 15,145

FAM-03

| LATENT ROOTS | 1.428 | .992 | .822 | .756 | .701 | .664 | .616 | .573 | .542 | .537 |
|---|---|---|---|---|---|---|---|---|---|---|
| PERCENT OF TRACE | 9.4 | 16.0 | 21.4 | 26.4 | 31.0 | 35.4 | 39.5 | 43.3 | 46.8 | 50.4 |
| 1 | .267 | .166 | .059 | .133 | .013 | .013 | .026 | .135 | .032 | .232 |
| 2 | .281 | .038 | .034 | .162 | .014 | .010 | .047 | .117 | .037 | .100 |
| 3 | .319 | .013 | .638 | .079 | .231 | .038 | .155 | .023 | .048 | .133 |
| 4 | .222 | .170 | .029 | .141 | .101 | .042 | .049 | .007 | .030 | .093 |
| 5 | .051 | .094 | .063 | .008 | .003 | .006 | .155 | .105 | .034 | .106 |
| 6 | .177 | .103 | .070 | .166 | .083 | .068 | .043 | .046 | .105 | .070 |
| 7 | .141 | .042 | .072 | .217 | .179 | .064 | .077 | .220 | .123 | .141 |
| 8 | .264 | .063 | .065 | .002 | .075 | .174 | .053 | .267 | .002 | .051 |
| 9 | .255 | .065 | .045 | .033 | .223 | .028 | .201 | .032 | .116 | .002 |
| 10 | .211 | .151 | .017 | .008 | .067 | .140 | .104 | .056 | .106 | .053 |
| 11 | .118 | .060 | .018 | .110 | .059 | .113 | .176 | .046 | .008 | .375 |
| 12 | .227 | .176 | .154 | .036 | .046 | .021 | .100 | .024 | .270 | .001 |
| 13 | .213 | .057 | .124 | .101 | .103 | .041 | .093 | .168 | .075 | .009 |
| 14 | .351 | .026 | .160 | .050 | .024 | .104 | .034 | .066 | .121 | .119 |
| 15 | .119 | .216 | .107 | .231 | .113 | .087 | .000 | .000 | .112 | .085 |
| 16 | .088 | .159 | .060 | .371 | .107 | .044 | .042 | .061 | .035 | .006 |
| 17 | .164 | .365 | .118 | .009 | .215 | .133 | .096 | .005 | .005 | .111 |
| 18 | .293 | .326 | .022 | .069 | .097 | .612 | .133 | .056 | .035 | .187 |
| 19 | .046 | .023 | .038 | .157 | .141 | .062 | .003 | .179 | .054 | .143 |
| 20 | .156 | .086 | .230 | .187 | .127 | .030 | .085 | .000 | .231 | .184 |
| 21 | .170 | .092 | .272 | .360 | .099 | .190 | .155 | .116 | .153 | .056 |
| 22 | .027 | .192 | .009 | .078 | .110 | .164 | .190 | .007 | .001 | .133 |
| 23 | .201 | .070 | .026 | .210 | .068 | .121 | .105 | .161 | .164 | .031 |
| 24 | .152 | .221 | .069 | .033 | .040 | .094 | .070 | .079 | .062 | .114 |
| 25 | .055 | .215 | .118 | .137 | .195 | .186 | .113 | .038 | .080 | .004 |
| 26 | .172 | .227 | .079 | .155 | .244 | .162 | .036 | .076 | .004 | .072 |
| 27 | .031 | .260 | .010 | .012 | .144 | .076 | .013 | .144 | .155 | .034 |
| 28 | .316 | .034 | .140 | .148 | .068 | .203 | .001 | .024 | .116 | .040 |
| 29 | .297 | .038 | .123 | .086 | .053 | .094 | .049 | .264 | .043 | .031 |
| 30 | .191 | .221 | .071 | .007 | .074 | .085 | .135 | .233 | .135 | .023 |
| 31 | .150 | .153 | .074 | .003 | .064 | .216 | .078 | .131 | .217 | .042 |
| 32 | .200 | .071 | .050 | .147 | .032 | .126 | .013 | .129 | .032 | .014 |
| 33 | .224 | .055 | .046 | .132 | .003 | .201 | .010 | .082 | .084 | .105 |
| 34 | .177 | .130 | .044 | .004 | .141 | .110 | .005 | .070 | .067 | .124 |
| 35 | .028 | .017 | .180 | .042 | .097 | .198 | .140 | .051 | .068 | .122 |
| 36 | .055 | .047 | .197 | .104 | .077 | .045 | .130 | .158 | .041 | .023 |
| 37 | .193 | .126 | .018 | .088 | .170 | .163 | .013 | .053 | .194 | .057 |
| 38 | .137 | .230 | .036 | .102 | .014 | .152 | .254 | .040 | .068 | .013 |
| 39 | .082 | .238 | .049 | .034 | .170 | .056 | .346 | .129 | .069 | .111 |
| 40 | .100 | .203 | .113 | .084 | .171 | .183 | .037 | .001 | .084 | .073 |
| 41 | .254 | .078 | .032 | .105 | .180 | .157 | .017 | .093 | .283 | .021 |
| 42 | .113 | .126 | .102 | .138 | .215 | .179 | .238 | .092 | .032 | .178 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 15,006

FAM-05

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.722 | 1.237 | .982 | .847 | .671 | .624 | .454 | .420 | .369 | .351 |
| PERCENT OF TRACE | 11.0 | 19.0 | 25.3 | 30.7 | 35.0 | 39.0 | 43.8 | 47.8 | 51.4 | 54.9 |
| 1 | -.323 | .265 | .131 | -.101 | .096 | .060 | -.065 | -.042 | .182 | .009 |
| 2 | .162 | .150 | .077 | .043 | -.305 | .022 | .037 | .232 | .166 | .167 |
| 3 | .062 | -.137 | .055 | .153 | .127 | .205 | .069 | .010 | -.026 | .274 |
| 4 | -.266 | -.070 | .178 | .151 | .073 | .058 | .116 | .129 | .134 | .119 |
| 5 | .167 | .310 | .292 | .096 | .177 | .044 | .160 | .061 | .214 | .074 |
| 6 | .232 | .275 | .179 | .092 | .239 | .094 | .070 | .073 | .126 | .030 |
| 7 | .216 | .338 | .101 | .074 | .217 | .083 | .020 | .066 | .010 | .136 |
| 8 | .256 | .172 | .021 | .064 | .054 | .279 | .083 | .004 | .106 | .036 |
| 9 | .243 | -.048 | .192 | .046 | .129 | .051 | .017 | .065 | .091 | .178 |
| 10 | .255 | .041 | .037 | .013 | .142 | .241 | .114 | .043 | .005 | .236 |
| 11 | .153 | .077 | .177 | .058 | .073 | .180 | .109 | .068 | .074 | .202 |
| 12 | .133 | .020 | .141 | .103 | .156 | .022 | .057 | .020 | .006 | .218 |
| 13 | .164 | -.266 | .035 | .271 | -.108 | .122 | .092 | .159 | .077 | .180 |
| 14 | .174 | .054 | .166 | .242 | .136 | .107 | .108 | .071 | .036 | .106 |
| 15 | .116 | .386 | .265 | .106 | -.043 | .044 | .012 | .159 | -.042 | .074 |
| 16 | .300 | .352 | .072 | .325 | .137 | .101 | .118 | .006 | .191 | .069 |
| 17 | .169 | .135 | .042 | .017 | .276 | .001 | .256 | .112 | .242 | .004 |
| 18 | .087 | .058 | .103 | .065 | .076 | .006 | .005 | .050 | .193 | .199 |
| 19 | .169 | .046 | .156 | .174 | .092 | .158 | .244 | .052 | .062 | .014 |
| 20 | .232 | .045 | .240 | .021 | .103 | .043 | .079 | .084 | .100 | .206 |
| 21 | .188 | .127 | .691 | .004 | .048 | .346 | .075 | .084 | .022 | .068 |
| 22 | .117 | .155 | .004 | .007 | .113 | .122 | .283 | .289 | .091 | .115 |
| 23 | .314 | .155 | .162 | .012 | .059 | .086 | .070 | .380 | .106 | .173 |
| 24 | .289 | .142 | .398 | .110 | .099 | .227 | .053 | .101 | .050 | .020 |
| 25 | .142 | .051 | .103 | .070 | .122 | .103 | .165 | .073 | .223 | .092 |
| 26 | .200 | .183 | .020 | .247 | .154 | .021 | .006 | .261 | .267 | .142 |
| 27 | .136 | .240 | .211 | .053 | .115 | .239 | .122 | .179 | .135 | .030 |
| 28 | .177 | .245 | .246 | .066 | .100 | .001 | .029 | .080 | .033 | .021 |
| 29 | .315 | .107 | .041 | .133 | .024 | .027 | .128 | .037 | .062 | .085 |
| 30 | .076 | .074 | .020 | .091 | .181 | .221 | .125 | .011 | .017 | .038 |
| 31 | .240 | .032 | .126 | .373 | .030 | .037 | .002 | .093 | .248 | .036 |
| 32 | .175 | .106 | .240 | .206 | .086 | .075 | .140 | .041 | .136 | .005 |
| 33 | .268 | .012 | .129 | .022 | .007 | .106 | .213 | .004 | .149 | .097 |
| 34 | .152 | .103 | .091 | .054 | .067 | .182 | .035 | .089 | .143 | .061 |
| 35 | .245 | .009 | .324 | .094 | .001 | .067 | .312 | .022 | .144 | .009 |
| 36 | .248 | .174 | .123 | .081 | .024 | .068 | .070 | .041 | .082 | .034 |
| 37 | .246 | .201 | .070 | .012 | .096 | .205 | .154 | .011 | .043 | .111 |
| 38 | .128 | .277 | .166 | .147 | .209 | .043 | .025 | .032 | .064 | .138 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 16,552

FAM-06

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.287 | 1.110 | 1.027 | .885 | .838 | .796 | .757 | .623 | .570 | .582 |
| PERCENT OF TRACE | 7.8 | 14.5 | 20.7 | 26.0 | 31.1 | 35.9 | 40.5 | 44.2 | 47.7 | 51.2 |
| 1 | .005 | .043 | .250 | .190 | .229 | .033 | .313 | .103 | .144 | .005 |
| 2 | .097 | .167 | .143 | .050 | .179 | .160 | .350 | .048 | .047 | .088 |
| 3 | .016 | .308 | .189 | .200 | .051 | .027 | .052 | .067 | .287 | .105 |
| 4 | .031 | .007 | .051 | .177 | .224 | .012 | .012 | .076 | .043 | .022 |
| 5 | .381 | .095 | .122 | .154 | .170 | .069 | .031 | .126 | .142 | .057 |
| 6 | .002 | .108 | .047 | .191 | .074 | .056 | .002 | .206 | .184 | .093 |
| 7 | .005 | .011 | .095 | .041 | .030 | .032 | .381 | .054 | .002 | .169 |
| 8 | .075 | .220 | .053 | .095 | .287 | .046 | .256 | .024 | .078 | .011 |
| 9 | .049 | .106 | .041 | .234 | .256 | .026 | .065 | .007 | .128 | .050 |
| 10 | .016 | .055 | .063 | .131 | .056 | .078 | .109 | .249 | .063 | .130 |
| 11 | .065 | .112 | .101 | .208 | .255 | .106 | .101 | .021 | .242 | .041 |
| 12 | .318 | .364 | .103 | .113 | .027 | .057 | .027 | .070 | .035 | .033 |
| 13 | .006 | .170 | .029 | .164 | .022 | .195 | .022 | .188 | .013 | .018 |
| 14 | .069 | .254 | .181 | .032 | .081 | .146 | .263 | .054 | .100 | .038 |
| 15 | .049 | .068 | .070 | .224 | .059 | .228 | .057 | .042 | .089 | .153 |
| 16 | .340 | .072 | .408 | .048 | .100 | .035 | .103 | .146 | .042 | .145 |
| 17 | .024 | .001 | .122 | .223 | .152 | .031 | .124 | .198 | .041 | .081 |
| 18 | .092 | .041 | .205 | .110 | .024 | .180 | .050 | .004 | .119 | .213 |
| 19 | .170 | .033 | .028 | .275 | .189 | .163 | .094 | .035 | .034 | .147 |
| 20 | .543 | .111 | .180 | .143 | .185 | .014 | .006 | .052 | .006 | .008 |
| 21 | .122 | .218 | .006 | .248 | .051 | .191 | .066 | .040 | .013 | .021 |
| 22 | .061 | .133 | .152 | .074 | .024 | .012 | .025 | .069 | .123 | .250 |
| 23 | .170 | .124 | .287 | .115 | .070 | .193 | .682 | .082 | .022 | .228 |
| 24 | .271 | .278 | .556 | .045 | .069 | .101 | .135 | .137 | .004 | .063 |
| 25 | .074 | .273 | .013 | .153 | .006 | .127 | .299 | .170 | .055 | .011 |
| 26 | .140 | .083 | .207 | .136 | .066 | .163 | .224 | .286 | .084 | .081 |
| 27 | .057 | .234 | .059 | .013 | .131 | .028 | .162 | .133 | .033 | .134 |
| 28 | .044 | .307 | .125 | .191 | .017 | .042 | .119 | .069 | .071 | .118 |
| 29 | .190 | .070 | .001 | .053 | .064 | .017 | .051 | .003 | .250 | .076 |
| 30 | .313 | .060 | .022 | .092 | .162 | .047 | .003 | .178 | .116 | .140 |
| 31 | .145 | .015 | .185 | .045 | .378 | .008 | .124 | .107 | .083 | .115 |
| 32 | .015 | .094 | .150 | .187 | .155 | .144 | .035 | .209 | .037 | .065 |
| 33 | .209 | .151 | .267 | .082 | .022 | .040 | .048 | .045 | .075 | .220 |
| 34 | .110 | .027 | .217 | .167 | .156 | .127 | .040 | .038 | .035 | .283 |
| 35 | .203 | .190 | .045 | .097 | .162 | .193 | .078 | .029 | .169 | .039 |
| 36 | .030 | .181 | .338 | .048 | .064 | .290 | .012 | .114 | .167 | .116 |
| 37 | .235 | .130 | .441 | .116 | .077 | .065 | .648 | .087 | .014 | .036 |
| 38 | .285 | .017 | .295 | .042 | .029 | .224 | .114 | .129 | .127 | .083 |
| 39 | .135 | .232 | .026 | .194 | .007 | .140 | .073 | .132 | .063 | .096 |
| 40 | .012 | .166 | .154 | .020 | .130 | .073 | .117 | .038 | .090 | .198 |
| 41 | .010 | .096 | .017 | .009 | .003 | .376 | .100 | .048 | .098 | .018 |
| 42 | .016 | .013 | .010 | .000 | .217 | .219 | .206 | .074 | .265 | .027 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 16,057

FAM-07

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.349 | 1.117 | .938 | .813 | .787 | .688 | .727 | .627 | .570 | .533 |
| PERCENT OF TRACE | 8.4 | 15.4 | 21.2 | 26.3 | 31.2 | 35.4 | 40.0 | 43.9 | 47.5 | 50.4 |
| 1 | .027 | -.010 | .095 | .082 | -.125 | .024 | .040 | .070 | .021 | .028 |
| 2 | .340 | .061 | .018 | .130 | .084 | .040 | .006 | .232 | .032 | .111 |
| 3 | .266 | .034 | .118 | .018 | .168 | .090 | .053 | .173 | .090 | .121 |
| 4 | .100 | .065 | .004 | .156 | .196 | .180 | .081 | .080 | .045 | .046 |
| 5 | .351 | .287 | .154 | .253 | .145 | .073 | .060 | .146 | .056 | .083 |
| 6 | .075 | .147 | .256 | .073 | .012 | .153 | .012 | .288 | .073 | .028 |
| 7 | .137 | .241 | .111 | .016 | .125 | .100 | .002 | .077 | .118 | .164 |
| 8 | .173 | .256 | .120 | .104 | .135 | .090 | .122 | .217 | .010 | .035 |
| 9 | .103 | .051 | .044 | .092 | .092 | .000 | .056 | .114 | .350 | .017 |
| 10 | .192 | .173 | .050 | .155 | .035 | .118 | .252 | .033 | .128 | .013 |
| 11 | .212 | .183 | .138 | .151 | .046 | .165 | .275 | .057 | .105 | .017 |
| 12 | .166 | .042 | .018 | .137 | .130 | .189 | .053 | .149 | .119 | .280 |
| 13 | .352 | .007 | .048 | .207 | .022 | .073 | .020 | .108 | .205 | .220 |
| 14 | .104 | .141 | .153 | .057 | .210 | .062 | .002 | .123 | .094 | .138 |
| 15 | .209 | .182 | .110 | .035 | .020 | .076 | .183 | .004 | .153 | .038 |
| 16 | .070 | .371 | .139 | .216 | .101 | .058 | .025 | .283 | .046 | .041 |
| 17 | .123 | .025 | .105 | .265 | .105 | .097 | .078 | .132 | .036 | .203 |
| 18 | .276 | .086 | .081 | .100 | .125 | .172 | .169 | .023 | .682 | .007 |
| 19 | .108 | .038 | .271 | .178 | .045 | .121 | .043 | .104 | .625 | .037 |
| 20 | .017 | .073 | .106 | .286 | .241 | .111 | .019 | .098 | .209 | .029 |
| 21 | .072 | .158 | .077 | .114 | .097 | .005 | .052 | .053 | .105 | .061 |
| 22 | .021 | .170 | .172 | .014 | .236 | .205 | .125 | .040 | .084 | .050 |
| 23 | .198 | .193 | .160 | .176 | .095 | .202 | .104 | .083 | .073 | .190 |
| 24 | .186 | .111 | .160 | .155 | .044 | .025 | .080 | .117 | .001 | .133 |
| 25 | .165 | .012 | .160 | .014 | .030 | .016 | .178 | .146 | .167 | .045 |
| 26 | .205 | .174 | .122 | .034 | .008 | .244 | .138 | .049 | .159 | .167 |
| 27 | .069 | .141 | .128 | .067 | .160 | .287 | .180 | .030 | .242 | .096 |
| 28 | .051 | .150 | .009 | .134 | .230 | .216 | .220 | .063 | .204 | .009 |
| 29 | .005 | .111 | .008 | .047 | .016 | .103 | .085 | .003 | .124 | .226 |
| 30 | .355 | .112 | .128 | .047 | .033 | .020 | .206 | .092 | .055 | .020 |
| 31 | .404 | .137 | .095 | .078 | .033 | .007 | .205 | .011 | .106 | .010 |
| 32 | .169 | .136 | .036 | .157 | .281 | .175 | .237 | .038 | .070 | .082 |
| 33 | .091 | .342 | .047 | .161 | .057 | .015 | .019 | .100 | .070 | .066 |
| 34 | .272 | .265 | .054 | .180 | .116 | .012 | .022 | .175 | .122 | .126 |
| 35 | .060 | .168 | .236 | .021 | .023 | .158 | .038 | .175 | .122 | .106 |
| 36 | .126 | .256 | .116 | .144 | .004 | .054 | .040 | .093 | .063 | .219 |
| 37 | .097 | .330 | .059 | .105 | .277 | .079 | .058 | .068 | .060 | .124 |
| 38 | .056 | .317 | .135 | .023 | .105 | .160 | .271 | .014 | .063 | .054 |
| 39 | .068 | .146 | .126 | .241 | .186 | .240 | .253 | .030 | .011 | .153 |
| 40 | .053 | .101 | .223 | .123 | .092 | .120 | .144 | .121 | .025 | .092 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 16.378

FAM-08

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.452 | 1.102 | .967 | .842 | .805 | .684 | .712 | .649 | .577 | .556 |
| PERCENT OF TRACE | 8.9 | 15.6 | 21.5 | 26.6 | 31.5 | 35.7 | 40.1 | 44.1 | 47.6 | 51.0 |
| 1 | -.272 | -.306 | .326 | .191 | -.165 | .135 | -.101 | -.076 | -.209 | .050 |
| 2 | .331 | -.168 | -.126 | -.244 | -.061 | -.031 | -.013 | .173 | -.154 | .033 |
| 3 | .146 | .180 | .162 | -.165 | .153 | .055 | .060 | .088 | -.005 | -.052 |
| 4 | .105 | -.271 | -.069 | -.027 | .180 | -.046 | -.076 | -.166 | -.215 | -.076 |
| 5 | .066 | .097 | .166 | .018 | -.232 | -.242 | .052 | -.012 | -.203 | .051 |
| 6 | -.312 | -.247 | -.062 | .034 | .008 | .075 | -.083 | -.029 | .071 | -.200 |
| 7 | .107 | .356 | .097 | .040 | .000 | .014 | -.153 | .309 | -.078 | .091 |
| 8 | -.191 | -.172 | -.243 | -.065 | .250 | -.339 | .620 | .069 | .224 | -.067 |
| 9 | .206 | .116 | .129 | -.116 | -.099 | -.190 | .278 | .006 | .171 | -.074 |
| 10 | -.171 | -.075 | -.038 | -.184 | -.187 | -.176 | -.172 | -.001 | -.048 | -.145 |
| 11 | .214 | -.115 | -.033 | -.015 | -.146 | -.153 | -.120 | -.064 | -.152 | -.103 |
| 12 | -.169 | -.048 | -.088 | -.064 | -.049 | -.226 | -.206 | -.068 | -.054 | -.112 |
| 13 | -.224 | -.290 | -.100 | -.074 | -.074 | -.039 | -.214 | -.191 | -.001 | -.021 |
| 14 | .273 | -.056 | -.066 | -.225 | -.131 | -.217 | -.073 | -.051 | -.137 | -.045 |
| 15 | -.213 | -.058 | -.189 | -.070 | -.067 | -.065 | -.084 | -.132 | -.053 | -.076 |
| 16 | .323 | -.050 | -.103 | -.081 | -.137 | -.162 | -.034 | -.241 | -.013 | -.062 |
| 17 | .317 | -.019 | -.059 | -.153 | -.210 | -.086 | -.130 | -.046 | -.093 | -.094 |
| 18 | -.243 | -.195 | -.183 | -.122 | -.106 | -.114 | -.069 | -.138 | -.058 | -.212 |
| 19 | -.152 | -.092 | -.272 | -.087 | -.053 | -.036 | -.213 | -.055 | -.169 | -.202 |
| 20 | .265 | -.184 | -.134 | -.035 | -.201 | -.118 | -.220 | -.103 | -.130 | -.176 |
| 21 | .224 | -.075 | -.049 | -.256 | -.033 | -.085 | -.084 | -.075 | -.023 | -.130 |
| 22 | -.213 | -.124 | -.048 | -.056 | -.070 | -.243 | -.060 | -.174 | -.044 | -.133 |
| 23 | .144 | -.003 | -.011 | -.106 | .058 | -.292 | -.062 | -.055 | -.144 | -.167 |
| 24 | .194 | -.325 | -.148 | -.078 | .089 | -.067 | -.063 | -.020 | -.144 | -.070 |
| 25 | .193 | -.052 | -.284 | -.226 | .143 | -.013 | -.030 | -.045 | -.038 | -.175 |
| 26 | .059 | -.140 | -.288 | -.082 | .096 | -.003 | -.123 | .161 | -.129 | -.117 |
| 27 | .098 | -.030 | -.319 | -.046 | -.059 | -.026 | -.023 | .313 | -.133 | -.032 |
| 28 | .145 | -.161 | -.165 | -.206 | -.234 | -.024 | -.055 | -.165 | -.070 | -.122 |
| 29 | .118 | -.125 | -.185 | -.154 | -.280 | -.070 | -.032 | -.285 | -.013 | -.021 |
| 30 | .145 | -.033 | -.015 | -.263 | -.106 | -.123 | -.237 | -.040 | -.077 | -.147 |
| 31 | .075 | -.265 | -.189 | -.042 | -.019 | -.046 | -.072 | -.056 | -.175 | -.084 |
| 32 | .230 | -.033 | -.095 | -.040 | -.008 | -.158 | -.145 | -.057 | -.133 | -.076 |
| 33 | .019 | -.106 | -.198 | -.266 | -.041 | -.002 | -.101 | -.116 | -.056 | -.247 |
| 34 | .014 | -.059 | -.289 | -.171 | -.174 | -.231 | -.056 | -.061 | -.205 | -.008 |
| 35 | .207 | -.264 | -.096 | -.019 | -.076 | -.042 | -.072 | -.095 | -.031 | -.095 |
| 36 | .121 | -.010 | -.096 | -.181 | -.045 | -.013 | -.365 | -.002 | -.011 | -.014 |
| 37 | .048 | -.153 | -.057 | -.015 | -.312 | -.090 | -.032 | -.002 | -.169 | -.110 |
| 38 | .050 | -.330 | -.022 | -.260 | -.014 | -.155 | -.055 | -.028 | -.024 | -.173 |
| 39 | .066 | -.241 | -.155 | -.214 | -.202 | -.159 | -.056 | -.000 | -.062 | -.005 |
| 40 | .116 | -.214 | -.011 | -.113 | -.097 | -.005 | -.214 | -.033 | -.050 | -.036 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 16.768

FAM-09

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.331 | 1.164 | .987 | .856 | .856 | .782 | .691 | .644 | .613 | .573 |
| PERCENT OF TRACE | 7.9 | 14.9 | 20.8 | 25.9 | 31.0 | 35.6 | 39.8 | 43.6 | 47.2 | 50.7 |
| 1 | .101 | .201 | .085 | .074 | .071 | .094 | -.021 | .212 | .212 | -.155 |
| 2 | .123 | .057 | -.064 | .117 | .076 | -.355 | -.109 | -.626 | -.146 | -.101 |
| 3 | .198 | -.267 | .239 | .102 | -.005 | -.039 | -.227 | -.067 | -.119 | -.060 |
| 4 | -.066 | .117 | -.180 | -.068 | -.157 | -.089 | -.007 | -.059 | -.023 | -.019 |
| 5 | .153 | .351 | -.057 | -.090 | -.014 | -.064 | -.236 | -.009 | -.037 | -.119 |
| 6 | .269 | -.037 | -.076 | -.063 | -.044 | -.137 | -.165 | -.234 | -.128 | -.148 |
| 7 | .342 | -.054 | -.056 | -.156 | -.134 | -.198 | -.119 | -.130 | -.117 | -.021 |
| 8 | -.127 | -.111 | -.007 | -.177 | -.205 | -.056 | -.124 | -.036 | -.047 | -.005 |
| 9 | -.108 | -.168 | -.195 | -.023 | -.055 | -.071 | -.215 | -.001 | -.180 | -.071 |
| 10 | .224 | -.058 | -.123 | -.213 | -.137 | -.145 | -.023 | -.023 | -.098 | -.253 |
| 11 | .272 | .294 | -.003 | -.098 | -.258 | -.055 | -.146 | -.189 | -.066 | -.225 |
| 12 | .161 | -.305 | -.084 | -.165 | -.089 | -.091 | -.065 | -.217 | -.222 | -.052 |
| 13 | -.104 | -.077 | -.250 | -.029 | -.008 | -.157 | -.120 | -.094 | -.097 | -.144 |
| 14 | -.042 | -.264 | -.242 | -.064 | -.052 | -.176 | -.063 | -.009 | -.023 | -.181 |
| 15 | .067 | -.053 | -.169 | -.190 | -.226 | -.159 | -.103 | -.101 | -.053 | -.139 |
| 16 | .121 | -.066 | -.044 | -.187 | -.106 | -.122 | -.053 | -.232 | -.225 | -.018 |
| 17 | -.161 | -.069 | -.037 | -.211 | -.049 | -.286 | -.216 | -.057 | -.117 | -.004 |
| 18 | -.120 | -.133 | -.225 | -.132 | -.305 | -.023 | -.052 | -.012 | -.022 | -.010 |
| 19 | -.160 | -.158 | -.010 | -.201 | -.123 | -.318 | -.077 | -.014 | -.032 | -.196 |
| 20 | -.382 | -.256 | -.030 | -.087 | -.141 | -.046 | -.060 | -.193 | -.112 | -.090 |
| 21 | .236 | -.041 | -.108 | -.123 | -.153 | -.014 | -.232 | -.225 | -.090 | -.076 |
| 22 | .027 | -.141 | -.205 | -.009 | -.022 | -.018 | -.262 | -.141 | -.178 | -.031 |
| 23 | .093 | -.150 | -.165 | -.067 | -.111 | -.128 | -.137 | -.054 | -.093 | -.027 |
| 24 | -.304 | -.115 | -.142 | -.187 | -.038 | -.060 | -.084 | -.089 | -.004 | -.005 |
| 25 | -.159 | -.096 | -.154 | -.100 | -.087 | -.162 | -.018 | -.177 | -.031 | -.009 |
| 26 | -.014 | -.074 | -.134 | -.395 | -.090 | -.019 | -.103 | -.131 | -.052 | -.002 |
| 27 | .297 | -.267 | -.164 | -.028 | -.023 | -.080 | -.217 | -.174 | -.071 | -.096 |
| 28 | -.008 | -.267 | -.160 | -.063 | -.114 | -.138 | -.036 | -.040 | -.067 | -.180 |
| 29 | .182 | -.077 | -.212 | -.092 | -.083 | -.007 | -.007 | -.152 | -.010 | -.017 |
| 30 | -.177 | -.023 | -.532 | -.292 | -.133 | -.091 | -.007 | -.094 | -.152 | -.051 |
| 31 | .066 | -.252 | -.026 | -.065 | -.012 | -.278 | -.037 | -.010 | -.116 | -.153 |
| 32 | .046 | -.024 | -.247 | -.123 | -.086 | -.027 | -.162 | -.117 | -.070 | -.044 |
| 33 | .050 | -.220 | -.005 | -.055 | -.324 | -.020 | -.006 | -.068 | -.053 | -.007 |
| 34 | -.172 | -.552 | -.040 | -.048 | -.095 | -.055 | -.051 | -.120 | -.112 | -.062 |
| 35 | .127 | -.198 | -.181 | -.101 | -.253 | -.136 | -.004 | -.087 | -.093 | -.135 |
| 36 | .117 | -.013 | -.320 | -.129 | -.097 | -.090 | -.196 | -.031 | -.210 | -.023 |
| 37 | -.158 | -.124 | -.067 | -.234 | -.076 | -.141 | -.157 | -.008 | -.064 | -.016 |
| 38 | .002 | -.020 | -.156 | -.046 | -.036 | -.003 | -.022 | -.188 | -.242 | -.203 |
| 39 | .048 | -.077 | -.043 | -.075 | -.046 | -.171 | -.040 | -.105 | -.010 | -.221 |
| 40 | .400 | -.140 | -.074 | -.114 | -.241 | -.000 | -.011 | -.005 | -.091 | -.031 |
| 41 | .215 | -.161 | -.026 | -.026 | -.114 | -.009 | -.009 | -.003 | -.159 | -.056 |
| 42 | .147 | -.045 | -.140 | -.194 | -.300 | -.002 | -.008 | -.167 | -.253 | -.073 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 15.538

FAM-10

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.684 | 1.010 | .972 | .832 | .751 | .673 | .660 | .613 | .577 | .524 |
| PERCENT OF TRACE | 10.8 | 17.3 | 23.6 | 29.0 | 33.8 | 38.1 | 42.4 | 46.3 | 50.0 | 53.4 |
| 1 | -.148 | .016 | .294 | -.272 | -.031 | -.182 | .132 | .043 | .043 | -.043 |
| 2 | .057 | .265 | .021 | -.098 | .030 | .123 | .121 | .055 | .154 | -.008 |
| 3 | .297 | .016 | .157 | -.034 | -.243 | -.021 | .030 | .076 | .018 | .009 |
| 4 | .186 | .095 | .089 | .290 | .145 | .144 | .024 | .234 | .122 | .155 |
| 5 | -.136 | .313 | .172 | .108 | .088 | .074 | .356 | .087 | .024 | .106 |
| 6 | .152 | .033 | .299 | .129 | .219 | .061 | .206 | .047 | .153 | .108 |
| 7 | .184 | .097 | .117 | .080 | .572 | .016 | .124 | .031 | .045 | .033 |
| 8 | .195 | .097 | .157 | .271 | .047 | .052 | .004 | .379 | .012 | .151 |
| 9 | .188 | .188 | .137 | .046 | .128 | .077 | .032 | .172 | .006 | .042 |
| 10 | .184 | .004 | .174 | .057 | .044 | .201 | .330 | .032 | .026 | .103 |
| 11 | .190 | .203 | .603 | .074 | .059 | .028 | .112 | .078 | .140 | .170 |
| 12 | .281 | .162 | .255 | .196 | .608 | .224 | .085 | .064 | .034 | .204 |
| 13 | .008 | .135 | .087 | .123 | .131 | .040 | .043 | .243 | .060 | .027 |
| 14 | .046 | .003 | .054 | .160 | .101 | .072 | .105 | .110 | .036 | .003 |
| 15 | .008 | .237 | .007 | .150 | .208 | .050 | .037 | .055 | .033 | .041 |
| 16 | .035 | .132 | .069 | .081 | .199 | .221 | .203 | .028 | .076 | .335 |
| 17 | .090 | .121 | .004 | .063 | .196 | .287 | .026 | .008 | .222 | .081 |
| 18 | .222 | .095 | .042 | .027 | .238 | .022 | .045 | .002 | .120 | .069 |
| 19 | .211 | .055 | .100 | .176 | .114 | .069 | .134 | .059 | .129 | .026 |
| 20 | .026 | .100 | .118 | .063 | .088 | .105 | .041 | .126 | .336 | .061 |
| 21 | .156 | .170 | .150 | .221 | .173 | .051 | .189 | .022 | .041 | .093 |
| 22 | .018 | .311 | .003 | .060 | .130 | .313 | .110 | .091 | .110 | .206 |
| 23 | .044 | .326 | .054 | .100 | .237 | .174 | .145 | .091 | .002 | .028 |
| 24 | .027 | .241 | .096 | .168 | .170 | .106 | .135 | .096 | .157 | .068 |
| 25 | .018 | .272 | .112 | .034 | .040 | .115 | .384 | .079 | .056 | .138 |
| 26 | .340 | .001 | .681 | .035 | .058 | .057 | .115 | .329 | .130 | .143 |
| 27 | .126 | .000 | .133 | .254 | .009 | .150 | .373 | .155 | .009 | .187 |
| 28 | .410 | .035 | .123 | .144 | .044 | .120 | .148 | .126 | .213 | .068 |
| 29 | .410 | .034 | .320 | .096 | .038 | .021 | .092 | .050 | .166 | .158 |
| 30 | .186 | .113 | .118 | .157 | .124 | .139 | .132 | .060 | .126 | .031 |
| 31 | .170 | .024 | .322 | .035 | .104 | .107 | .050 | .084 | .028 | .004 |
| 32 | .065 | .047 | .146 | .206 | .119 | .024 | .228 | .101 | .004 | .055 |
| 33 | .229 | .035 | .138 | .128 | .086 | .059 | .089 | .120 | .169 | .052 |
| 34 | .315 | .038 | .138 | .062 | .044 | .064 | .064 | .012 | .042 | .125 |
| 35 | .412 | .133 | .057 | .061 | .160 | .085 | .153 | .076 | .043 | .028 |
| 36 | .344 | .136 | .004 | .136 | .185 | .005 | .024 | .035 | .153 | .062 |
| 37 | .356 | .154 | .027 | .095 | .120 | .185 | .056 | .055 | .061 | .097 |
| 38 | .308 | .200 | .015 | .155 | .226 | .105 | .009 | .028 | .155 | .027 |
| 39 | .308 | .200 | .015 | .155 | .226 | .105 | .009 | .028 | .155 | .027 |
| 40 | .320 | .056 | .214 | .169 | .282 | .064 | .226 | .031 | .107 | .148 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 16.014

FAM-11

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.197 | 1.001 | .940 | .779 | .742 | .683 | .663 | .646 | .624 | .627 |
| PERCENT OF TRACE | 7.2 | 13.6 | 19.2 | 23.9 | 28.7 | 32.8 | 36.8 | 40.7 | 44.4 | 48.2 |
| 1 | .034 | -.247 | .041 | -.282 | -.126 | -.094 | .277 | -.146 | -.032 | .052 |
| 2 | .126 | -.110 | .102 | .130 | .152 | -.094 | .008 | .379 | -.165 | .226 |
| 3 | -.126 | -.032 | .384 | .058 | -.065 | .118 | .071 | .018 | .228 | .096 |
| 4 | .273 | .011 | .066 | -.034 | .059 | -.030 | .250 | -.031 | .024 | -.157 |
| 5 | .110 | .020 | .359 | .157 | .079 | .120 | .129 | .130 | .205 | .143 |
| 6 | .220 | .008 | .426 | .182 | .106 | .069 | .063 | .154 | .071 | .172 |
| 7 | .332 | .108 | .065 | .062 | .033 | .037 | .251 | .061 | .060 | .040 |
| 8 | .090 | .274 | .153 | .067 | .247 | .124 | .180 | .051 | .060 | .044 |
| 9 | .011 | .113 | .275 | .137 | .143 | .144 | -.031 | .192 | .052 | .017 |
| 10 | .283 | -.059 | .160 | .042 | .029 | .126 | .122 | .212 | .114 | .116 |
| 11 | .256 | .027 | .135 | .049 | .179 | .041 | -.020 | .018 | .126 | .104 |
| 12 | .031 | .268 | .136 | .025 | .034 | .034 | .127 | .125 | .090 | .103 |
| 13 | .172 | .155 | .116 | .038 | .122 | .036 | .144 | .013 | .078 | .052 |
| 14 | .196 | .176 | .091 | .206 | .035 | .034 | .025 | .062 | .309 | .003 |
| 15 | .035 | .305 | .149 | .022 | .037 | .115 | .137 | .062 | .048 | .022 |
| 16 | .066 | .180 | .152 | .104 | .069 | .271 | .047 | .155 | .027 | .094 |
| 17 | .103 | .083 | .136 | .024 | .018 | .291 | .013 | .225 | .184 | .044 |
| 18 | .231 | .116 | .116 | .198 | .081 | .149 | .043 | .031 | .171 | .185 |
| 19 | .136 | .078 | .077 | .010 | .342 | .100 | .020 | .111 | .024 | .100 |
| 20 | .095 | .198 | .034 | .298 | .119 | .156 | .128 | .166 | .189 | .045 |
| 21 | .034 | .065 | .199 | .144 | .034 | .015 | .141 | .096 | .031 | .236 |
| 22 | .031 | .372 | .077 | .133 | .138 | .041 | .223 | .104 | .009 | .030 |
| 23 | .239 | .163 | .261 | .074 | .028 | .078 | .003 | .011 | .012 | .046 |
| 24 | .190 | .140 | .167 | .041 | .002 | .064 | .018 | .004 | .019 | .010 |
| 25 | .055 | .303 | .035 | .117 | .037 | .070 | .140 | .210 | .149 | .003 |
| 26 | .193 | .036 | .127 | .124 | .031 | .101 | .075 | .181 | .137 | .033 |
| 27 | .102 | .104 | .080 | .073 | .213 | .004 | .002 | .028 | .051 | .090 |
| 28 | .028 | .243 | .150 | .294 | .068 | .150 | .036 | .035 | .063 | .082 |
| 29 | .067 | .136 | .104 | .317 | .205 | .121 | .158 | .056 | .078 | .196 |
| 30 | .075 | .078 | .020 | .148 | .132 | .307 | .167 | .045 | .060 | .072 |
| 31 | .175 | .119 | .065 | .013 | .246 | .106 | .239 | .120 | .135 | .061 |
| 32 | .038 | .053 | .151 | .008 | .064 | .023 | .161 | .042 | .084 | .035 |
| 33 | .267 | .015 | .037 | .137 | .080 | .114 | .054 | .043 | .144 | .005 |
| 34 | .215 | .146 | .168 | .070 | .102 | .111 | .249 | .077 | .046 | .120 |
| 35 | .191 | .111 | .098 | .078 | .335 | .110 | .073 | .069 | .172 | .126 |
| 36 | .216 | .000 | .104 | .173 | .280 | .034 | .017 | .051 | .143 | .150 |
| 37 | .036 | .265 | .145 | .020 | .002 | .270 | .049 | .168 | .135 | .021 |
| 38 | .190 | .209 | .004 | .148 | .188 | .113 | .060 | .058 | .011 | .195 |
| 39 | .354 | .161 | .217 | .100 | .055 | .162 | .003 | .074 | .019 | .058 |
| 40 | .131 | .052 | .097 | -.152 | .089 | .173 | .023 | .018 | -.179 | -.384 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 15.008

FAM-12

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.259 | 1.066 | .903 | .838 | .734 | .806 | .657 | .618 | .580 | .549 |
| PERCENT OF TRACE | 8.4 | 15.5 | 21.5 | 27.1 | 32.0 | 37.3 | 41.7 | 45.8 | 49.7 | 53.4 |
| 1 | -.050 | .000 | .424 | .053 | -.009 | .029 | -.077 | .258 | .023 | -.039 |
| 2 | .179 | .132 | .244 | .015 | .056 | .043 | .106 | .103 | .115 | -.185 |
| 3 | .060 | .028 | .010 | .091 | .108 | .147 | .038 | .034 | .136 | .169 |
| 4 | .049 | .206 | .124 | .040 | .187 | .192 | .146 | .075 | .023 | .023 |
| 5 | .165 | .190 | .163 | .108 | .274 | .269 | .008 | .124 | .040 | .122 |
| 6 | .216 | .146 | .177 | .168 | .162 | .154 | .038 | .047 | .078 | .037 |
| 7 | .102 | .055 | .262 | .052 | .281 | .083 | .049 | .245 | .069 | .125 |
| 8 | .008 | .052 | .209 | .259 | .028 | .120 | .046 | .178 | .109 | .121 |
| 9 | .100 | .175 | .162 | .323 | .158 | .155 | .042 | .109 | .069 | .056 |
| 10 | .253 | .062 | .118 | .058 | .091 | .114 | .060 | .061 | .126 | .128 |
| 11 | .221 | .151 | .055 | .093 | .119 | .056 | .062 | .076 | .267 | .021 |
| 12 | .225 | .101 | .038 | .079 | .133 | .159 | .073 | .228 | .138 | .005 |
| 13 | .067 | .038 | .054 | .147 | .142 | .065 | .045 | .005 | .203 | .171 |
| 14 | .283 | .066 | .018 | .134 | .135 | .010 | .012 | .016 | .151 | .138 |
| 15 | .253 | .166 | .227 | .277 | .097 | .063 | .048 | .031 | .053 | .142 |
| 16 | .143 | .261 | .214 | .043 | .048 | .039 | .017 | .173 | .085 | .127 |
| 17 | .136 | .122 | .187 | .143 | .195 | .020 | .067 | .106 | .247 | .028 |
| 18 | .205 | .067 | .221 | .031 | .368 | .067 | .085 | .078 | .079 | .038 |
| 19 | .028 | .207 | .002 | .331 | .117 | .036 | .119 | .110 | .165 | .085 |
| 20 | .179 | .251 | .024 | .108 | .086 | .119 | .238 | .013 | .046 | .247 |
| 21 | .088 | .086 | .027 | .121 | .131 | .110 | .320 | .221 | .025 | .062 |
| 22 | .238 | .000 | .027 | .052 | .134 | .252 | .150 | .061 | .046 | .027 |
| 23 | .177 | .151 | .224 | .051 | .018 | .233 | .120 | .104 | .009 | .295 |
| 24 | .161 | .024 | .077 | .303 | .163 | .264 | .143 | .143 | .117 | .071 |
| 25 | .040 | .232 | .244 | .051 | .163 | .187 | .240 | .206 | .064 | .033 |
| 26 | .336 | .121 | .010 | .102 | .050 | .207 | .117 | .246 | .185 | .215 |
| 27 | .227 | .033 | .261 | .022 | .021 | .035 | .145 | .070 | .004 | .095 |
| 28 | .220 | .021 | .078 | .103 | .060 | .217 | .302 | .087 | .141 | .035 |
| 29 | .252 | .304 | .058 | .306 | .068 | .139 | .026 | .096 | .073 | .153 |
| 30 | .182 | .300 | .052 | .028 | .004 | .276 | .210 | .052 | .053 | .007 |
| 31 | .333 | .160 | .026 | .038 | .019 | .036 | .248 | .111 | .117 | .067 |
| 32 | .014 | .020 | .196 | .006 | .357 | .237 | .119 | .068 | .205 | .080 |
| 33 | .244 | .153 | .124 | .203 | .005 | .159 | .014 | .046 | .098 | .042 |
| 34 | .159 | .363 | .185 | .064 | .024 | .052 | .039 | .043 | .260 | .010 |
| 35 | .278 | .117 | .037 | .083 | .124 | .118 | .070 | .017 | .186 | .071 |
| 36 | .187 | .300 | .023 | .054 | .051 | .033 | .144 | .263 | .035 | .251 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 15.720

FAM-13

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.649 | 1.205 | .957 | .906 | .751 | .736 | .673 | .636 | .594 | .569 |
| PERCENT OF TRACE | 10.5 | 18.2 | 24.2 | 30.0 | 34.8 | 39.5 | 43.7 | 47.8 | 51.6 | 55.2 |
| 1 | .181 | .072 | .263 | .184 | -.125 | .131 | -.106 | -.075 | -.009 | -.186 |
| 2 | -.343 | -.006 | .077 | .194 | .015 | .099 | -.132 | -.054 | -.126 | .162 |
| 3 | .201 | .060 | .079 | .286 | -.283 | -.037 | .067 | -.062 | .080 | .012 |
| 4 | -.073 | .286 | .316 | .107 | .050 | .110 | .000 | -.010 | .156 | -.079 |
| 5 | .090 | .191 | .405 | .161 | .199 | .059 | .006 | -.155 | .003 | .146 |
| 6 | -.029 | .411 | .160 | .074 | .025 | .120 | -.134 | .189 | .040 | .038 |
| 7 | .156 | .038 | .078 | .113 | .019 | .134 | .205 | .134 | .009 | .222 |
| 8 | .193 | .049 | .059 | .146 | .057 | .287 | .087 | .175 | .027 | .047 |
| 9 | .070 | .101 | .277 | .067 | .147 | .072 | .281 | .017 | .031 | .195 |
| 10 | .206 | .175 | .099 | .062 | .013 | .074 | .052 | .006 | .130 | .165 |
| 11 | .092 | .135 | .242 | .058 | .067 | .150 | .124 | .004 | .024 | .084 |
| 12 | .148 | .214 | .157 | .089 | .173 | .200 | .142 | .064 | .033 | .027 |
| 13 | .312 | .140 | .059 | .020 | .131 | .029 | .214 | .102 | .084 | .206 |
| 14 | .139 | .061 | .079 | .007 | .141 | .026 | .013 | .017 | .324 | .247 |
| 15 | .001 | .007 | .089 | .031 | .289 | .206 | .249 | .026 | .027 | .043 |
| 16 | .231 | .234 | .127 | .070 | .107 | .208 | .105 | .142 | .018 | .042 |
| 17 | .276 | .147 | .165 | .080 | .118 | .243 | .044 | .044 | .022 | .123 |
| 18 | .477 | .147 | .135 | .177 | .100 | .174 | .032 | .102 | .006 | .018 |
| 19 | .247 | .141 | .143 | .008 | .025 | .004 | .110 | .229 | .069 | .012 |
| 20 | .104 | .135 | .344 | .157 | .060 | .004 | .170 | .001 | .135 | .107 |
| 21 | .103 | .167 | .212 | .308 | .408 | .170 | .027 | .165 | .219 | .206 |
| 22 | .273 | .107 | .080 | .100 | .005 | .107 | .016 | .108 | .227 | .075 |
| 23 | .111 | .076 | .071 | .052 | .141 | .013 | .188 | .030 | .045 | .020 |
| 24 | .359 | .013 | .137 | .063 | .009 | .054 | .210 | .155 | .089 | .050 |
| 25 | .317 | .026 | .056 | .019 | .014 | .054 | .099 | .006 | .307 | .209 |
| 26 | .304 | .036 | .039 | .157 | .070 | .062 | .272 | .065 | .018 | .026 |
| 27 | .328 | .151 | .004 | .208 | .078 | .000 | .112 | .122 | .032 | .150 |
| 28 | .074 | .094 | .022 | .038 | .097 | .275 | .061 | .016 | .005 | .173 |
| 29 | .102 | .256 | .044 | .201 | .062 | .056 | .070 | .411 | .132 | .096 |
| 30 | .088 | .126 | .023 | .182 | .198 | .107 | .144 | .047 | .125 | .052 |
| 31 | .040 | .173 | .090 | .028 | .208 | .192 | .074 | .071 | .034 | .100 |
| 32 | .290 | .245 | .116 | .005 | .006 | .178 | .107 | .083 | .109 | .112 |
| 33 | .265 | .013 | .069 | .024 | .272 | .030 | .061 | .006 | .250 | .017 |
| 34 | .059 | .251 | .228 | .212 | .005 | .037 | .025 | .152 | .044 | .019 |
| 35 | .135 | .220 | .053 | .520 | .033 | .187 | .040 | .318 | .135 | .092 |
| 36 | .131 | .046 | .035 | .367 | .071 | .159 | .009 | .017 | .005 | .152 |
| 37 | .214 | .373 | .008 | .210 | .057 | .067 | .110 | .021 | .029 | .134 |
| 38 | .003 | .366 | .033 | .035 | .103 | .211 | .139 | .055 | .107 | .001 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 16.117

## FAM-14

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.365 | 1.196 | .942 | .994 | .877 | .672 | .638 | .621 | .572 | .537 |
| PERCENT OF TRACE | 8.5 | 15.9 | 21.7 | 27.9 | 33.3 | 37.5 | 41.5 | 45.3 | 48.9 | 52.2 |
| 1 | .104 | -.168 | .086 | -.003 | .044 | -.015 | .153 | .022 | .298 | -.092 |
| 2 | .223 | -.046 | .683 | .247 | .162 | -.055 | .245 | -.222 | .138 | -.050 |
| 3 | .257 | -.104 | .106 | .086 | .079 | -.021 | .204 | -.042 | .104 | -.037 |
| 4 | .229 | -.094 | .656 | .074 | .261 | -.042 | .075 | .077 | -.020 | -.092 |
| 5 | .135 | -.002 | .163 | .038 | .403 | -.054 | .014 | .085 | -.106 | -.212 |
| 6 | .171 | -.222 | .109 | .249 | .019 | .102 | .033 | .030 | -.202 | .059 |
| 7 | .210 | -.103 | .612 | .088 | .025 | .255 | .070 | .010 | .017 | -.218 |
| 8 | .047 | .142 | -.131 | .034 | .144 | .164 | .382 | .277 | .153 | .070 |
| 9 | .180 | -.328 | .011 | .290 | .120 | .065 | .047 | .143 | -.085 | -.104 |
| 10 | .255 | -.001 | .650 | .052 | .279 | .071 | .018 | .031 | .008 | -.011 |
| 11 | .226 | -.093 | -.244 | .166 | .074 | -.202 | .142 | -.158 | .061 | .129 |
| 12 | .143 | -.008 | .122 | .238 | .145 | .028 | .064 | .103 | -.047 | -.002 |
| 13 | .042 | .244 | .105 | .209 | .023 | .042 | .043 | -.061 | .045 | .046 |
| 14 | .209 | -.123 | .231 | .153 | .071 | .001 | .038 | .015 | .013 | -.118 |
| 15 | .281 | .148 | .056 | .185 | .020 | .138 | .270 | .108 | .100 | .046 |
| 16 | .189 | -.150 | -.142 | .182 | .068 | .266 | .198 | .070 | .152 | .025 |
| 17 | .033 | -.162 | .135 | .001 | .162 | .189 | .265 | .107 | .039 | .048 |
| 18 | .211 | .051 | .681 | .067 | .361 | .010 | .065 | .105 | .106 | .038 |
| 19 | .129 | .077 | .040 | .068 | .063 | .097 | .020 | .171 | .046 | .073 |
| 20 | .058 | .184 | .116 | .251 | .134 | .304 | .018 | .060 | .049 | .064 |
| 21 | .187 | -.020 | .167 | .159 | .094 | .003 | .056 | .268 | .269 | .073 |
| 22 | .167 | .206 | .083 | .125 | .215 | .066 | .050 | .279 | .170 | .148 |
| 23 | .051 | .233 | .053 | .108 | .043 | .231 | .090 | .136 | .108 | .117 |
| 24 | .042 | .154 | .198 | .026 | .071 | .100 | .122 | .115 | .232 | .113 |
| 25 | .024 | .277 | .200 | .122 | .079 | .050 | .104 | .071 | .167 | .128 |
| 26 | .068 | .210 | .221 | .681 | .080 | .145 | .026 | .191 | .113 | .142 |
| 27 | .034 | .310 | .111 | .254 | .077 | .001 | .012 | .179 | .183 | .196 |
| 28 | .106 | .201 | .096 | .068 | .127 | .008 | .043 | .000 | .094 | .210 |
| 29 | .077 | .102 | .279 | .060 | .145 | .021 | .022 | .036 | .106 | .088 |
| 30 | .268 | .020 | .265 | .151 | .136 | .066 | .014 | .122 | .055 | .155 |
| 31 | .084 | .214 | .214 | .147 | .080 | .090 | .153 | .116 | .137 | .241 |
| 32 | .017 | .150 | .349 | .148 | .055 | .198 | .095 | .121 | .039 | .067 |
| 33 | .233 | .278 | .081 | .221 | .041 | .117 | .140 | .042 | .084 | .105 |
| 34 | .001 | .245 | .105 | .191 | .053 | .108 | .073 | .059 | .173 | .020 |
| 35 | .382 | .017 | .125 | .026 | .048 | .074 | .047 | .151 | .004 | .052 |
| 36 | .093 | .074 | .206 | .147 | .068 | .037 | .032 | .026 | .007 | .206 |
| 37 | .272 | .050 | .037 | .259 | .032 | .164 | .165 | .182 | .042 | .149 |
| 38 | .145 | .133 | .063 | .280 | .214 | .196 | .191 | .021 | .096 | .079 |
| 39 | .474 | .216 | .266 | .008 | .198 | .004 | .028 | .177 | .047 | .059 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 17.368

## FAM-15

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.612 | 1.330 | 1.162 | .844 | .791 | .713 | .663 | .633 | .587 | .553 |
| PERCENT OF TRACE | 9.3 | 16.6 | 23.6 | 28.5 | 33.0 | 37.1 | 41.0 | 44.6 | 48.0 | 51.2 |
| 1 | .018 | -.094 | -.121 | .020 | .222 | -.181 | .199 | -.242 | .039 | -.117 |
| 2 | .286 | -.111 | .016 | .067 | .092 | .134 | .000 | .087 | -.042 | .211 |
| 3 | .118 | .048 | .167 | .244 | .070 | .031 | -.017 | .145 | .195 | |
| 4 | .256 | -.097 | .415 | .053 | .018 | .004 | -.048 | -.032 | -.042 | -.030 |
| 5 | .156 | -.123 | .231 | .041 | .263 | .126 | -.023 | .075 | .261 | -.097 |
| 6 | .013 | -.009 | .028 | .333 | .057 | .331 | .071 | -.057 | -.069 | -.047 |
| 7 | .004 | .207 | .170 | .258 | .093 | .042 | .060 | .047 | .007 | .098 |
| 8 | .250 | -.145 | .324 | .042 | .026 | .060 | .029 | .081 | .100 | .036 |
| 9 | .078 | -.001 | .312 | .118 | .135 | .073 | .121 | .071 | -.095 | -.005 |
| 10 | .261 | -.071 | .279 | .150 | .040 | .082 | .136 | -.048 | .043 | -.110 |
| 11 | .260 | -.302 | .111 | .003 | .097 | -.041 | -.211 | -.102 | .007 | .050 |
| 12 | .015 | -.085 | .081 | .043 | .243 | .171 | .018 | .009 | .158 | .003 |
| 13 | .174 | -.123 | .186 | .232 | .148 | .104 | -.025 | .158 | .241 | .050 |
| 14 | .200 | -.140 | .037 | .017 | .087 | .125 | .327 | .097 | -.085 | .191 |
| 15 | .210 | .142 | .033 | .114 | .107 | .057 | .008 | .222 | .020 | .090 |
| 16 | .174 | -.113 | .269 | .144 | -.021 | .119 | .278 | .088 | .114 | -.136 |
| 17 | .258 | -.081 | .317 | .023 | .117 | .155 | .215 | .032 | .010 | .003 |
| 18 | .234 | -.234 | .116 | .018 | .129 | .051 | .127 | .064 | .079 | -.223 |
| 19 | .303 | -.134 | .083 | .081 | .019 | -.103 | -.082 | .044 | .063 | .029 |
| 20 | .270 | .180 | .199 | .196 | .161 | -.005 | -.012 | .267 | -.141 | .042 |
| 21 | .264 | -.110 | .084 | .375 | .103 | -.058 | .116 | -.037 | -.006 | .025 |
| 22 | .283 | .029 | .069 | .214 | .124 | -.002 | .168 | .020 | .133 | -.041 |
| 23 | .217 | .099 | .044 | .240 | .013 | .196 | .045 | .065 | .143 | .010 |
| 24 | .199 | .111 | .151 | .012 | .020 | .007 | .138 | -.085 | .132 | .193 |
| 25 | .046 | .030 | .023 | .109 | .083 | .286 | .098 | .129 | .005 | .102 |
| 26 | .193 | .146 | .039 | .229 | .118 | .211 | .228 | .007 | -.020 | .075 |
| 27 | .251 | .203 | .255 | .055 | .143 | .094 | .036 | .063 | .163 | .034 |
| 28 | .103 | .187 | .069 | .003 | .206 | .040 | .103 | .019 | .208 | .178 |
| 29 | .116 | .280 | .003 | .072 | .022 | .038 | .069 | .010 | .261 | .001 |
| 30 | .204 | .293 | .021 | .010 | .078 | .025 | .249 | .103 | .073 | .129 |
| 31 | .380 | .192 | .038 | .076 | .081 | .057 | .002 | .000 | .228 | .085 |
| 32 | .158 | .115 | .243 | .054 | .098 | .348 | .012 | .048 | .023 | .045 |
| 33 | .105 | .267 | .094 | .248 | .134 | .025 | .028 | .355 | .110 | .031 |
| 34 | .260 | .077 | .024 | .003 | .066 | .050 | .115 | .202 | .083 | .270 |
| 35 | .010 | .427 | .051 | .116 | .109 | .031 | .024 | .181 | .062 | .170 |
| 36 | .090 | .365 | .104 | .138 | .129 | .195 | .074 | .095 | .125 | .132 |
| 37 | .138 | .333 | .076 | .033 | .155 | .171 | .049 | .217 | .004 | .019 |
| 38 | .172 | .207 | .067 | .021 | .189 | .125 | .141 | .158 | .096 | .137 |
| 39 | .033 | .303 | .262 | .058 | .181 | .106 | .156 | .063 | .009 | .081 |
| 40 | .247 | .054 | .163 | .013 | .243 | .012 | .019 | .199 | .088 | .162 |

PRINCIPAL COORDINATE ANALYSIS

TRACE = 16.459

## FAM-16

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LATENT ROOTS | 1.212 | 1.000 | .959 | .816 | .787 | .703 | .631 | .663 | .581 | .574 |
| PERCENT OF TRACE | 7.4 | 13.8 | 19.6 | 24.6 | 29.4 | 33.6 | 37.5 | 41.5 | 45.0 | 48.5 |
| 1 | .105 | .182 | .047 | .057 | .158 | .059 | .215 | .078 | .060 | .134 |
| 2 | .381 | .056 | .096 | .086 | .039 | .012 | .011 | .021 | .215 | .160 |
| 3 | .002 | .133 | .408 | .199 | .145 | .111 | .169 | .164 | .063 | .104 |
| 4 | .049 | .032 | .277 | .252 | .111 | .057 | .077 | .138 | .102 | .039 |
| 5 | .126 | .234 | .053 | .016 | .200 | .007 | .009 | .001 | .098 | .076 |
| 6 | .088 | .041 | .140 | .030 | .070 | .038 | .019 | .029 | .170 | .029 |
| 7 | .009 | .148 | .078 | .137 | .167 | .044 | .073 | .124 | .069 | .262 |
| 8 | .397 | .050 | .037 | .112 | .110 | .056 | .114 | .030 | .036 | .119 |
| 9 | .222 | .044 | .043 | .061 | .024 | .238 | .025 | .041 | .105 | .038 |
| 10 | .107 | .236 | .125 | .191 | .249 | .029 | .131 | .076 | .021 | .029 |
| 11 | .114 | .261 | .082 | .020 | .065 | .065 | .168 | .032 | .023 | .230 |
| 12 | .090 | .235 | .002 | .041 | .039 | .240 | .348 | .015 | .006 | .042 |
| 13 | .032 | .351 | .132 | .193 | .061 | .116 | .182 | .033 | .041 | .137 |
| 14 | .088 | .138 | .052 | .109 | .133 | .178 | .047 | .086 | .176 | .059 |
| 15 | .093 | .140 | .092 | .123 | .080 | .065 | .045 | .035 | .115 | .093 |
| 16 | .170 | .014 | .116 | .114 | .206 | .178 | .063 | .081 | .010 | .021 |
| 17 | .369 | .095 | .054 | .131 | .023 | .058 | .117 | .050 | .043 | .116 |
| 18 | .295 | .124 | .103 | .133 | .041 | .036 | .090 | .050 | .120 | .133 |
| 19 | .049 | .064 | .041 | .327 | .038 | .105 | .042 | .145 | .210 | .030 |
| 20 | .064 | .090 | .157 | .080 | .009 | .376 | .064 | .104 | .025 | .022 |
| 21 | .011 | .253 | .154 | .136 | .048 | .020 | .057 | .239 | .056 | .025 |
| 22 | .045 | .088 | .005 | .041 | .001 | .154 | .098 | .177 | .053 | .082 |
| 23 | .011 | .229 | .011 | .181 | .057 | .043 | .114 | .074 | .058 | .114 |
| 24 | .035 | .020 | .112 | .181 | .004 | .262 | .242 | .056 | .031 | .138 |
| 25 | .109 | .071 | .113 | .335 | .083 | .034 | .086 | .081 | .037 | .077 |
| 26 | .091 | .106 | .080 | .128 | .170 | .026 | .158 | .255 | .358 | .015 |
| 27 | .071 | .165 | .227 | .197 | .015 | .028 | .145 | .136 | .155 | .155 |
| 28 | .072 | .150 | .191 | .035 | .033 | .175 | .243 | .065 | .055 | .037 |
| 29 | .009 | .252 | .068 | .256 | .246 | .115 | .122 | .086 | .224 | .130 |
| 30 | .030 | .022 | .199 | .250 | .014 | .130 | .009 | .139 | .105 | .233 |
| 31 | .001 | .130 | .086 | .181 | .219 | .223 | .058 | .216 | .057 | .024 |
| 32 | .144 | .326 | .044 | .084 | .155 | .047 | .096 | .085 | .145 | .122 |
| 33 | .236 | .115 | .204 | .177 | .120 | .066 | .069 | .092 | .035 | .007 |
| 34 | .259 | .009 | .252 | .150 | .010 | .083 | .122 | .077 | .018 | .045 |
| 35 | .344 | .008 | .342 | .193 | .121 | .049 | .035 | .073 | .070 | .098 |
| 36 | .092 | .088 | .086 | .184 | .079 | .034 | .203 | .203 | .196 | .110 |
| 37 | .295 | .208 | .102 | .145 | .051 | .064 | .163 | .163 | .041 | .026 |
| 38 | .305 | .065 | .177 | .123 | .165 | .091 | .021 | .021 | .049 | .154 |
| 39 | .108 | .137 | .026 | .026 | .048 | .113 | .300 | .300 | .248 | .024 |
| 40 | .002 | .137 | .033 | .033 | .290 | .012 | .098 | .121 | .065 | .035 |
| 41 | .245 | .047 | .047 | .026 | .040 | .040 | .054 | .054 | .095 | .193 |
| 42 | | | | | | | | | | |

APPENDIX V : The five nearest neighbours, of all the individuals of the sixteen families (within-family list)

FAM-01

| | | | | | |
|---|---|---|---|---|---|
| 1 | 37 | 10 | 13 | 3 | 36 |
| 2 | 37 | 32 | 3 | 38 | 29 |
| 3 | 34 | 5 | 40 | 2 | 8 |
| 4 | 34 | 5 | 21 | 18 | 16 |
| 5 | 18 | 40 | 34 | 12 | 4 |
| 6 | 7 | 13 | 41 | 22 | 3 |
| 7 | 11 | 35 | 23 | 6 | 13 |
| 8 | 26 | 35 | 11 | 13 | 3 |
| 9 | 17 | 11 | 22 | 13 | 27 |
| 10 | 1 | 13 | 12 | 24 | 5 |
| 11 | 7 | 13 | 8 | 27 | 24 |
| 12 | 22 | 34 | 21 | 5 | 18 |
| 13 | 11 | 8 | 10 | 7 | 1 |
| 14 | 22 | 35 | 21 | 17 | 18 |
| 15 | 33 | 41 | 7 | 24 | 23 |
| 16 | 38 | 18 | 40 | 4 | 34 |
| 17 | 28 | 35 | 9 | 22 | 7 |
| 18 | 38 | 20 | 40 | 34 | 5 |
| 19 | 34 | 11 | 4 | 20 | 22 |
| 20 | 18 | 40 | 38 | 16 | 19 |
| 21 | 12 | 22 | 4 | 38 | 14 |
| 22 | 12 | 35 | 38 | 21 | 27 |
| 23 | 24 | 33 | 27 | 25 | 7 |
| 24 | 23 | 40 | 11 | 36 | 22 |
| 25 | 31 | 23 | 22 | 32 | 1 |
| 26 | 35 | 8 | 22 | 11 | 27 |
| 27 | 29 | 30 | 22 | 32 | 11 |
| 28 | 17 | 30 | 29 | 24 | 27 |
| 29 | 30 | 27 | 33 | 24 | 28 |
| 30 | 29 | 27 | 28 | 18 | 12 |
| 31 | 25 | 12 | 3 | 5 | 2 |
| 32 | 27 | 30 | 2 | 33 | 9 |
| 33 | 23 | 15 | 29 | 30 | 32 |
| 34 | 18 | 40 | 3 | 12 | 5 |
| 35 | 26 | 22 | 8 | 37 | 17 |
| 36 | 24 | 41 | 1 | 37 | 27 |
| 37 | 1 | 39 | 35 | 2 | 24 |
| 38 | 18 | 16 | 22 | 40 | 21 |
| 39 | 37 | 24 | 40 | 1 | 12 |
| 40 | 18 | 34 | 5 | 38 | 16 |
| 41 | 35 | 15 | 36 | 7 | 6 |

FAM-02

| | | | | | |
|---|---|---|---|---|---|
| 1 | 5 | 25 | 3 | 6 | 35 |
| 2 | 38 | 40 | 12 | 22 | 34 |
| 3 | 18 | 25 | 8 | 24 | 37 |
| 4 | 7 | 30 | 31 | 11 | 22 |
| 5 | 35 | 29 | 34 | 10 | 27 |
| 6 | 41 | 35 | 11 | 16 | 33 |
| 7 | 4 | 36 | 9 | 26 | 6 |
| 8 | 29 | 40 | 3 | 26 | 5 |
| 9 | 11 | 41 | 33 | 7 | 35 |
| 10 | 32 | 30 | 6 | 16 | 39 |
| 11 | 35 | 9 | 6 | 32 | 29 |
| 12 | 18 | 19 | 37 | 36 | 15 |
| 13 | 19 | 35 | 20 | 27 | 11 |
| 14 | 26 | 13 | 16 | 30 | 15 |
| 15 | 37 | 26 | 22 | 12 | 25 |
| 16 | 6 | 30 | 33 | 10 | 9 |
| 17 | 23 | 35 | 34 | 41 | 26 |
| 18 | 12 | 37 | 19 | 3 | 36 |
| 19 | 12 | 18 | 26 | 13 | 37 |
| 20 | 27 | 23 | 34 | 38 | 13 |
| 21 | 30 | 31 | 24 | 14 | 37 |
| 22 | 39 | 32 | 15 | 26 | 12 |
| 23 | 27 | 34 | 20 | 17 | 35 |
| 24 | 19 | 23 | 30 | 37 | 35 |
| 25 | 15 | 26 | 28 | 20 | 27 |
| 26 | 15 | 11 | 19 | 22 | 36 |
| 27 | 20 | 23 | 34 | 35 | 38 |
| 28 | 26 | 25 | 15 | 39 | 20 |
| 29 | 11 | 32 | 22 | 15 | 36 |
| 30 | 34 | 4 | 27 | 10 | 32 |
| 31 | 4 | 33 | 6 | 21 | 9 |
| 32 | 10 | 22 | 11 | 38 | 30 |
| 33 | 9 | 11 | 35 | 37 | 6 |
| 34 | 27 | 23 | 30 | 11 | 35 |
| 35 | 41 | 11 | 27 | 6 | 38 |
| 36 | 7 | 12 | 15 | 26 | 37 |
| 37 | 15 | 18 | 12 | 33 | 36 |
| 38 | 27 | 32 | 2 | 35 | 20 |
| 39 | 22 | 41 | 28 | 10 | 32 |
| 40 | 2 | 38 | 15 | 32 | 8 |
| 41 | 35 | 6 | 9 | 11 | 39 |

FAM-03

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 13 | 6 | 10 | 36 |
| 2 | 1 | 6 | 10 | 4 | 13 |
| 3 | 20 | 9 | 2 | 10 | 4 |
| 4 | 6 | 2 | 7 | 9 | 10 |
| 5 | 36 | 34 | 8 | 24 | 38 |
| 6 | 4 | 2 | 1 | 25 | 40 |
| 7 | 4 | 5 | 2 | 10 | 6 |
| 8 | 36 | 22 | 5 | 10 | 34 |
| 9 | 15 | 10 | 40 | 22 | 16 |
| 10 | 9 | 2 | 40 | 8 | 1 |
| 11 | 22 | 37 | 23 | 8 | 10 |
| 12 | 24 | 15 | 2 | 32 | 10 |
| 13 | 24 | 1 | 2 | 9 | 36 |
| 14 | 34 | 28 | 33 | 41 | 26 |
| 15 | 16 | 9 | 24 | 12 | 36 |
| 16 | 15 | 36 | 33 | 19 | 27 |
| 17 | 34 | 16 | 27 | 14 | 15 |
| 18 | 24 | 13 | 27 | 12 | 2 |
| 19 | 35 | 16 | 36 | 34 | 22 |
| 20 | 24 | 1 | 13 | 5 | 10 |
| 21 | 1 | 12 | 8 | 32 | 38 |
| 22 | 25 | 11 | 36 | 8 | 31 |
| 23 | 36 | 34 | 38 | 28 | 37 |
| 24 | 13 | 15 | 5 | 12 | 26 |
| 25 | 22 | 37 | 6 | 4 | 38 |
| 26 | 27 | 24 | 14 | 34 | 23 |
| 27 | 26 | 16 | 34 | 36 | 8 |
| 28 | 14 | 41 | 40 | 23 | 33 |
| 29 | 8 | 34 | 40 | 37 | 14 |
| 30 | 8 | 5 | 16 | 34 | 37 |
| 31 | 38 | 22 | 34 | 37 | 36 |
| 32 | 24 | 10 | 12 | 1 | 5 |
| 33 | 16 | 14 | 40 | 36 | 28 |
| 34 | 14 | 5 | 17 | 36 | 23 |
| 35 | 19 | 40 | 36 | 33 | 16 |
| 36 | 5 | 40 | 16 | 23 | 38 |
| 37 | 25 | 23 | 11 | 36 | 38 |
| 38 | 31 | 36 | 39 | 23 | 5 |
| 39 | 38 | 2 | 4 | 6 | 10 |
| 40 | 36 | 9 | 10 | 28 | 35 |
| 41 | 28 | 36 | 14 | 16 | 33 |
| 42 | 10 | 6 | 20 | 11 | 9 |

FAM-04

| | | | | | |
|---|---|---|---|---|---|
| 1 | 15 | 28 | 9 | 3 | 19 |
| 2 | 3 | 11 | 12 | 16 | 25 |
| 3 | 18 | 2 | 17 | 25 | 11 |
| 4 | 8 | 12 | 29 | 6 | 2 |
| 5 | 14 | 16 | 3 | 26 | 2 |
| 6 | 8 | 29 | 23 | 4 | 11 |
| 7 | 13 | 22 | 30 | 23 | 11 |
| 8 | 6 | 4 | 29 | 31 | 36 |
| 9 | 15 | 28 | 26 | 1 | 3 |
| 10 | 22 | 31 | 14 | 20 | 3 |
| 11 | 33 | 2 | 16 | 3 | 31 |
| 12 | 2 | 4 | 17 | 3 | 11 |
| 13 | 7 | 22 | 30 | 12 | 27 |
| 14 | 16 | 20 | 5 | 17 | 15 |
| 15 | 9 | 19 | 17 | 1 | 28 |
| 16 | 27 | 17 | 14 | 25 | 11 |
| 17 | 16 | 3 | 15 | 28 | 2 |
| 18 | 3 | 25 | 11 | 16 | 17 |
| 19 | 15 | 28 | 1 | 9 | 27 |
| 20 | 14 | 22 | 16 | 34 | 36 |
| 21 | 2 | 32 | 20 | 33 | 16 |
| 22 | 30 | 10 | 20 | 7 | 35 |
| 23 | 36 | 6 | 30 | 33 | 29 |
| 24 | 25 | 17 | 26 | 3 | 16 |
| 25 | 3 | 16 | 27 | 26 | 2 |
| 26 | 25 | 9 | 27 | 11 | 5 |
| 27 | 28 | 16 | 25 | 26 | 2 |
| 28 | 27 | 15 | 9 | 17 | 19 |
| 29 | 31 | 8 | 4 | 6 | 23 |
| 30 | 22 | 11 | 35 | 23 | 32 |
| 31 | 33 | 29 | 11 | 3 | 27 |
| 32 | 21 | 30 | 11 | 33 | 31 |
| 33 | 31 | 11 | 36 | 16 | 17 |
| 34 | 35 | 36 | 16 | 20 | 33 |
| 35 | 34 | 36 | 22 | 30 | 37 |
| 36 | 33 | 37 | 23 | 34 | 35 |
| 37 | 36 | 35 | 34 | 25 | 9 |

FAM-05

| | | | | | |
|---|---|---|---|---|---|
| 1 | 31 | 12 | 23 | 4 | 34 |
| 2 | 6 | 3 | 29 | 33 | 28 |
| 3 | 12 | 18 | 2 | 8 | 1 |
| 4 | 26 | 31 | 32 | 1 | 18 |
| 5 | 15 | 6 | 3 | 9 | 8 |
| 6 | 2 | 7 | 5 | 8 | 24 |
| 7 | 6 | 8 | 14 | 24 | 29 |
| 8 | 35 | 37 | 33 | 9 | 36 |
| 9 | 29 | 37 | 28 | 36 | 19 |
| 10 | 12 | 1 | 17 | 18 | 32 |
| 11 | 13 | 34 | 30 | 12 | 20 |
| 12 | 10 | 3 | 30 | 1 | 20 |
| 13 | 38 | 11 | 32 | 28 | 12 |
| 14 | 19 | 36 | 9 | 30 | 28 |
| 15 | 5 | 14 | 8 | 19 | 9 |
| 16 | 20 | 1 | 23 | 11 | 19 |
| 17 | 10 | 18 | 12 | 30 | 1 |
| 18 | 34 | 32 | 3 | 28 | 12 |
| 19 | 14 | 28 | 36 | 9 | 21 |
| 20 | 25 | 12 | 26 | 30 | 1 |
| 21 | 29 | 24 | 19 | 28 | 35 |
| 22 | 37 | 21 | 28 | 35 | 9 |
| 23 | 1 | 34 | 10 | 20 | 25 |
| 24 | 29 | 21 | 33 | 37 | 35 |
| 25 | 26 | 20 | 12 | 1 | 38 |
| 26 | 4 | 25 | 32 | 31 | 20 |
| 27 | 34 | 30 | 25 | 26 | 37 |
| 28 | 36 | 38 | 19 | 29 | 9 |
| 29 | 24 | 36 | 9 | 21 | 28 |
| 30 | 34 | 12 | 14 | 32 | 18 |
| 31 | 32 | 4 | 1 | 26 | 3 |
| 32 | 31 | 4 | 34 | 18 | 26 |
| 33 | 29 | 36 | 37 | 8 | 9 |
| 34 | 32 | 30 | 18 | 38 | 11 |
| 35 | 37 | 8 | 21 | 22 | 24 |
| 36 | 28 | 37 | 29 | 14 | 9 |
| 37 | 36 | 9 | 35 | 28 | 22 |
| 38 | 28 | 13 | 34 | 36 | 18 |

FAM-06

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 39 | 7 | 19 | 4 |
| 2 | 22 | 1 | 3 | 7 | 10 |
| 3 | 2 | 35 | 25 | 28 | 37 |
| 4 | 42 | 29 | 10 | 15 | 6 |
| 5 | 37 | 35 | 30 | 17 | 38 |
| 6 | 27 | 29 | 28 | 4 | 33 |
| 7 | 26 | 29 | 27 | 8 | 14 |
| 8 | 14 | 31 | 7 | 13 | 37 |
| 9 | 34 | 11 | 7 | 40 | 14 |
| 10 | 14 | 32 | 4 | 29 | 21 |
| 11 | 13 | 9 | 14 | 37 | 40 |
| 12 | 23 | 36 | 13 | 21 | 39 |
| 13 | 11 | 41 | 37 | 21 | 8 |
| 14 | 37 | 10 | 8 | 39 | 7 |
| 15 | 40 | 4 | 29 | 37 | 21 |
| 16 | 20 | 40 | 17 | 14 | 28 |
| 17 | 32 | 10 | 7 | 21 | 27 |
| 18 | 29 | 39 | 32 | 36 | 31 |
| 19 | 21 | 6 | 15 | 17 | 39 |
| 20 | 16 | 24 | 12 | 27 | 8 |
| 21 | 13 | 10 | 41 | 39 | 17 |
| 22 | 29 | 13 | 2 | 32 | 25 |
| 23 | 12 | 22 | 7 | 36 | 13 |
| 24 | 27 | 22 | 6 | 7 | 34 |
| 25 | 27 | 29 | 22 | 35 | 32 |
| 26 | 7 | 34 | 33 | 29 | 35 |
| 27 | 35 | 30 | 25 | 7 | 6 |
| 28 | 6 | 29 | 32 | 2 | 33 |
| 29 | 33 | 34 | 7 | 37 | 39 |
| 30 | 35 | 27 | 37 | 29 | 33 |
| 31 | 8 | 32 | 7 | 18 | 36 |
| 32 | 33 | 10 | 36 | 29 | 17 |
| 33 | 34 | 29 | 32 | 35 | 26 |
| 34 | 33 | 29 | 26 | 37 | 9 |
| 35 | 30 | 37 | 27 | 33 | 34 |
| 36 | 39 | 32 | 14 | 34 | 12 |
| 37 | 35 | 14 | 30 | 39 | 29 |
| 38 | 37 | 39 | 5 | 14 | 29 |
| 39 | 36 | 14 | 37 | 29 | 21 |
| 40 | 37 | 15 | 13 | 29 | 42 |
| 41 | 13 | 21 | 37 | 35 | 15 |
| 42 | 4 | 40 | 39 | 10 | 36 |

FAM-07

| | | | | | |
|---|---|---|---|---|---|
| 1 | 9 | 2 | 6 | 28 | 40 |
| 2 | 3 | 1 | 18 | 6 | 33 |
| 3 | 2 | 4 | 26 | 17 | 12 |
| 4 | 3 | 39 | 6 | 1 | 25 |
| 5 | 13 | 37 | 33 | 2 | 12 |
| 6 | 14 | 7 | 1 | 3 | 2 |
| 7 | 6 | 26 | 14 | 13 | 21 |
| 8 | 31 | 37 | 30 | 35 | 36 |
| 9 | 29 | 1 | 14 | 21 | 39 |
| 10 | 34 | 21 | 23 | 9 | 14 |
| 11 | 24 | 34 | 28 | 23 | 9 |
| 12 | 15 | 3 | 2 | 1 | 6 |
| 13 | 5 | 2 | 7 | 12 | 18 |
| 14 | 6 | 22 | 25 | 9 | 26 |
| 15 | 18 | 12 | 3 | 1 | 2 |
| 16 | 19 | 26 | 21 | 15 | 18 |
| 17 | 3 | 18 | 21 | 39 | 27 |
| 18 | 15 | 17 | 2 | 3 | 27 |
| 19 | 17 | 27 | 15 | 29 | 16 |
| 20 | 38 | 14 | 15 | 17 | 29 |
| 21 | 22 | 26 | 10 | 9 | 23 |
| 22 | 21 | 14 | 26 | 29 | 6 |
| 23 | 24 | 21 | 10 | 30 | 11 |
| 24 | 23 | 11 | 25 | 9 | 14 |
| 25 | 29 | 14 | 34 | 9 | 39 |
| 26 | 22 | 29 | 3 | 21 | 7 |
| 27 | 29 | 39 | 3 | 9 | 36 |
| 28 | 1 | 34 | 11 | 27 | 29 |
| 29 | 9 | 27 | 36 | 26 | 25 |
| 30 | 31 | 23 | 34 | 36 | 21 |
| 31 | 30 | 34 | 10 | 36 | 32 |
| 32 | 31 | 9 | 30 | 17 | 4 |
| 33 | 37 | 2 | 5 | 36 | 29 |
| 34 | 31 | 10 | 28 | 11 | 25 |
| 35 | 39 | 40 | 8 | 1 | 22 |
| 36 | 29 | 38 | 30 | 39 | 27 |
| 37 | 33 | 5 | 38 | 2 | 36 |
| 38 | 36 | 37 | 20 | 25 | 22 |
| 39 | 40 | 27 | 4 | 9 | 1 |
| 40 | 39 | 1 | 21 | 14 | 34 |

FAM-08

| | | | | | |
|---|---|---|---|---|---|
| 1 | 22 | 2 | 6 | 13 | 24 |
| 2 | 1 | 6 | 22 | 25 | 35 |
| 3 | 30 | 35 | 14 | 27 | 12 |
| 4 | 40 | 5 | 23 | 38 | 35 |
| 5 | 23 | 4 | 11 | 33 | 39 |
| 6 | 13 | 22 | 23 | 12 | 25 |
| 7 | 28 | 24 | 11 | 26 | 23 |
| 8 | 25 | 6 | 19 | 10 | 37 |
| 9 | 14 | 34 | 23 | 35 | 36 |
| 10 | 15 | 28 | 32 | 16 | 37 |
| 11 | 15 | 23 | 16 | 17 | 32 |
| 12 | 23 | 6 | 3 | 30 | 14 |
| 13 | 6 | 22 | 36 | 14 | 15 |
| 14 | 9 | 3 | 30 | 12 | 35 |
| 15 | 16 | 11 | 32 | 10 | 18 |
| 16 | 15 | 32 | 11 | 10 | 18 |
| 17 | 23 | 11 | 20 | 32 | 21 |
| 18 | 24 | 15 | 23 | 16 | 32 |
| 19 | 38 | 12 | 23 | 25 | 15 |
| 20 | 17 | 23 | 24 | 16 | 40 |
| 21 | 23 | 32 | 17 | 15 | 11 |
| 22 | 6 | 30 | 1 | 10 | 15 |
| 23 | 26 | 18 | 15 | 5 | 11 |
| 24 | 18 | 28 | 23 | 26 | 20 |
| 25 | 36 | 6 | 8 | 19 | 18 |
| 26 | 23 | 10 | 24 | 36 | 15 |
| 27 | 29 | 3 | 15 | 40 | 32 |
| 28 | 10 | 24 | 7 | 33 | 26 |
| 29 | 27 | 11 | 17 | 15 | 19 |
| 30 | 3 | 22 | 6 | 14 | 12 |
| 31 | 35 | 23 | 37 | 33 | 11 |
| 32 | 15 | 16 | 10 | 11 | 17 |
| 33 | 28 | 34 | 31 | 35 | 30 |
| 34 | 33 | 9 | 30 | 26 | 35 |
| 35 | 31 | 3 | 38 | 4 | 9 |
| 36 | 25 | 26 | 32 | 9 | 13 |
| 37 | 39 | 40 | 10 | 23 | 31 |
| 38 | 39 | 35 | 4 | 19 | 37 |
| 39 | 37 | 38 | 40 | 4 | 23 |
| 40 | 4 | 37 | 11 | 39 | 12 |

FAM-09

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 21 | 14 | 32 | 34 |
| 2 | 7 | 1 | 39 | 36 | 34 |
| 3 | 9 | 5 | 25 | 13 | 7 |
| 4 | 18 | 35 | 33 | 42 | 31 |
| 5 | 13 | 3 | 9 | 28 | 2 |
| 6 | 29 | 25 | 39 | 17 | 16 |
| 7 | 2 | 39 | 3 | 1 | 17 |
| 8 | 18 | 10 | 39 | 15 | 16 |
| 9 | 13 | 3 | 42 | 18 | 28 |
| 10 | 8 | 14 | 34 | 18 | 37 |
| 11 | 8 | 37 | 18 | 20 | 9 |
| 12 | 22 | 28 | 37 | 9 | 15 |
| 13 | 9 | 35 | 5 | 14 | 31 |
| 14 | 18 | 35 | 34 | 10 | 31 |
| 15 | 8 | 25 | 32 | 39 | 23 |
| 16 | 36 | 8 | 29 | 39 | 15 |
| 17 | 22 | 39 | 6 | 2 | 21 |
| 18 | 14 | 8 | 34 | 4 | 10 |
| 19 | 27 | 25 | 9 | 23 | 28 |
| 20 | 40 | 24 | 11 | 37 | 9 |
| 21 | 33 | 35 | 1 | 27 | 29 |
| 22 | 17 | 12 | 13 | 37 | 6 |
| 23 | 25 | 15 | 24 | 34 | 1 |
| 24 | 30 | 40 | 34 | 23 | 25 |
| 25 | 29 | 31 | 6 | 23 | 15 |
| 26 | 36 | 33 | 8 | 35 | 32 |
| 27 | 21 | 25 | 29 | 17 | 19 |
| 28 | 25 | 12 | 9 | 15 | 36 |
| 29 | 36 | 25 | 6 | 16 | 39 |
| 30 | 24 | 32 | 34 | 36 | 23 |
| 31 | 25 | 33 | 35 | 14 | 15 |
| 32 | 30 | 15 | 26 | 36 | 29 |
| 33 | 35 | 21 | 31 | 39 | 26 |
| 34 | 14 | 8 | 18 | 10 | 2 |
| 35 | 33 | 14 | 31 | 13 | 21 |
| 36 | 29 | 26 | 16 | 2 | 25 |
| 37 | 26 | 36 | 12 | 22 | 40 |
| 38 | 39 | 35 | 31 | 21 | 37 |
| 39 | 2 | 8 | 6 | 33 | 17 |
| 40 | 20 | 24 | 41 | 37 | 42 |
| 41 | 25 | 33 | 14 | 40 | 34 |
| 42 | 9 | 4 | 34 | 33 | 24 |

FAM-10

| | | | | | |
|---|---|---|---|---|---|
| 1 | 30 | 5 | 7 | 36 | 28 |
| 2 | 25 | 11 | 24 | 9 | 14 |
| 3 | 9 | 11 | 10 | 7 | 18 |
| 4 | 24 | 25 | 6 | 23 | 2 |
| 5 | 1 | 7 | 36 | 15 | 14 |
| 6 | 9 | 8 | 25 | 33 | 4 |
| 7 | 3 | 15 | 1 | 10 | 20 |
| 8 | 9 | 6 | 17 | 12 | 14 |
| 9 | 11 | 13 | 25 | 18 | 3 |
| 10 | 13 | 3 | 7 | 33 | 17 |
| 11 | 9 | 2 | 3 | 18 | 25 |
| 12 | 9 | 4 | 8 | 6 | 33 |
| 13 | 9 | 14 | 25 | 27 | 10 |
| 14 | 13 | 9 | 25 | 15 | 27 |
| 15 | 14 | 21 | 7 | 17 | 29 |
| 16 | 14 | 3 | 13 | 15 | 11 |
| 17 | 20 | 15 | 24 | 10 | 8 |
| 18 | 9 | 33 | 11 | 3 | 25 |
| 19 | 21 | 15 | 27 | 11 | 9 |
| 20 | 25 | 13 | 30 | 17 | 7 |
| 21 | 15 | 19 | 27 | 13 | 7 |
| 22 | 34 | 27 | 3 | 33 | 13 |
| 23 | 24 | 37 | 9 | 25 | 13 |
| 24 | 24 | 2 | 23 | 37 | 9 |
| 25 | 2 | 31 | 9 | 24 | 13 |
| 26 | 3 | 11 | 25 | 33 | 21 |
| 27 | 13 | 14 | 9 | 3 | 15 |
| 28 | 35 | 24 | 36 | 40 | 34 |
| 29 | 31 | 25 | 14 | 9 | 15 |
| 30 | 25 | 1 | 13 | 20 | 2 |
| 31 | 25 | 29 | 35 | 38 | 30 |
| 32 | 11 | 25 | 7 | 14 | 37 |
| 33 | 18 | 6 | 3 | 15 | 14 |
| 34 | 36 | 35 | 29 | 31 | 28 |
| 35 | 28 | 36 | 34 | 31 | 38 |
| 36 | 35 | 34 | 1 | 30 | 28 |
| 37 | 38 | 40 | 24 | 23 | 13 |
| 38 | 37 | 13 | 40 | 25 | 31 |
| 39 | 40 | 14 | 37 | 32 | 25 |
| 40 | 37 | 38 | 39 | 15 | 25 |

FAM-11

| | | | | | |
|---|---|---|---|---|---|
| 1 | 20 | 7 | 30 | 27 | 37 |
| 2 | 25 | 19 | 30 | 9 | 24 |
| 3 | 21 | 7 | 35 | 9 | 27 |
| 4 | 24 | 32 | 38 | 26 | 23 |
| 5 | 33 | 22 | 25 | 7 | 12 |
| 6 | 10 | 11 | 7 | 15 | 25 |
| 7 | 10 | 33 | 18 | 11 | 21 |
| 8 | 9 | 7 | 24 | 12 | 21 |
| 9 | 8 | 29 | 15 | 14 | 19 |
| 10 | 6 | 18 | 11 | 7 | 39 |
| 11 | 10 | 6 | 33 | 7 | 13 |
| 12 | 16 | 24 | 11 | 8 | 9 |
| 13 | 15 | 33 | 30 | 11 | 24 |
| 14 | 24 | 15 | 34 | 23 | 25 |
| 15 | 13 | 23 | 16 | 22 | 24 |
| 16 | 18 | 15 | 26 | 12 | 13 |
| 17 | 23 | 15 | 24 | 30 | 4 |
| 18 | 16 | 10 | 33 | 37 | 7 |
| 19 | 20 | 23 | 26 | 18 | 31 |
| 20 | 30 | 19 | 26 | 25 | 31 |
| 21 | 7 | 3 | 18 | 8 | 13 |
| 22 | 15 | 14 | 9 | 24 | 30 |
| 23 | 24 | 26 | 15 | 34 | 17 |
| 24 | 23 | 26 | 34 | 15 | 4 |
| 25 | 37 | 27 | 20 | 30 | 38 |
| 26 | 23 | 24 | 20 | 31 | 16 |
| 27 | 25 | 36 | 28 | 26 | 30 |
| 28 | 29 | 38 | 27 | 18 | 30 |
| 29 | 28 | 31 | 18 | 9 | 26 |
| 30 | 20 | 13 | 24 | 27 | 26 |
| 31 | 26 | 29 | 20 | 24 | 19 |
| 32 | 4 | 23 | 6 | 24 | 21 |
| 33 | 13 | 18 | 7 | 11 | 6 |
| 34 | 24 | 23 | 26 | 14 | 27 |
| 35 | 13 | 3 | 22 | 33 | 16 |
| 36 | 38 | 27 | 26 | 23 | 24 |
| 37 | 25 | 18 | 38 | 26 | 27 |
| 38 | 36 | 37 | 26 | 28 | 24 |
| 39 | 10 | 18 | 11 | 7 | 13 |
| 40 | 38 | 12 | 4 | 20 | 26 |

FAM-12

| | | | | | |
|---|---|---|---|---|---|
| 1 | 21 | 2 | 22 | 13 | 34 |
| 2 | 1 | 22 | 19 | 16 | 4 |
| 3 | 13 | 19 | 8 | 22 | 9 |
| 4 | 3 | 9 | 16 | 10 | 20 |
| 5 | 18 | 6 | 3 | 21 | 12 |
| 6 | 24 | 35 | 12 | 5 | 11 |
| 7 | 10 | 27 | 19 | 3 | 13 |
| 8 | 3 | 11 | 21 | 22 | 10 |
| 9 | 3 | 22 | 21 | 4 | 19 |
| 10 | 11 | 31 | 27 | 14 | 20 |
| 11 | 17 | 10 | 31 | 13 | 8 |
| 12 | 36 | 35 | 3 | 26 | 6 |
| 13 | 3 | 19 | 16 | 11 | 10 |
| 14 | 10 | 13 | 11 | 31 | 27 |
| 15 | 20 | 16 | 14 | 11 | 13 |
| 16 | 13 | 19 | 10 | 3 | 15 |
| 17 | 11 | 10 | 3 | 13 | 16 |
| 18 | 27 | 10 | 5 | 31 | 11 |
| 19 | 3 | 13 | 20 | 16 | 21 |
| 20 | 10 | 19 | 15 | 11 | 21 |
| 21 | 19 | 10 | 1 | 8 | 13 |
| 22 | 3 | 23 | 8 | 9 | 13 |
| 23 | 22 | 8 | 19 | 10 | 28 |
| 24 | 6 | 35 | 12 | 21 | 29 |
| 25 | 31 | 17 | 12 | 11 | 34 |
| 26 | 12 | 29 | 22 | 35 | 19 |
| 27 | 10 | 18 | 7 | 31 | 14 |
| 28 | 22 | 32 | 3 | 13 | 8 |
| 29 | 26 | 35 | 24 | 16 | 6 |
| 30 | 11 | 14 | 36 | 31 | 13 |
| 31 | 11 | 10 | 27 | 18 | 14 |
| 32 | 8 | 18 | 21 | 28 | 27 |
| 33 | 31 | 14 | 10 | 11 | 13 |
| 34 | 36 | 1 | 22 | 12 | 35 |
| 35 | 12 | 36 | 6 | 11 | 24 |
| 36 | 12 | 34 | 35 | 30 | 7 |

FAM-13

| | | | | | |
|---|---|---|---|---|---|
| 1 | 27 | 32 | 10 | 23 | 8 |
| 2 | 14 | 23 | 3 | 24 | 26 |
| 3 | 23 | 4 | 14 | 25 | 2 |
| 4 | 34 | 3 | 14 | 38 | 27 |
| 5 | 6 | 20 | 4 | 11 | 15 |
| 6 | 29 | 5 | 11 | 10 | 30 |
| 7 | 10 | 22 | 27 | 35 | 23 |
| 8 | 10 | 27 | 32 | 9 | 11 |
| 9 | 10 | 30 | 8 | 12 | 22 |
| 10 | 8 | 27 | 30 | 9 | 22 |
| 11 | 20 | 26 | 8 | 10 | 6 |
| 12 | 30 | 22 | 27 | 10 | 9 |
| 13 | 25 | 3 | 18 | 16 | 30 |
| 14 | 30 | 2 | 3 | 4 | 23 |
| 15 | 8 | 34 | 5 | 17 | 10 |
| 16 | 19 | 38 | 17 | 14 | 23 |
| 17 | 19 | 16 | 14 | 15 | 25 |
| 18 | 24 | 13 | 17 | 19 | 25 |
| 19 | 16 | 17 | 31 | 14 | 4 |
| 20 | 11 | 5 | 4 | 34 | 31 |
| 21 | 27 | 12 | 33 | 15 | 8 |
| 22 | 37 | 10 | 27 | 38 | 33 |
| 23 | 3 | 31 | 38 | 2 | 1 |
| 24 | 26 | 25 | 23 | 2 | 18 |
| 25 | 24 | 3 | 23 | 16 | 13 |
| 26 | 24 | 11 | 31 | 23 | 2 |
| 27 | 32 | 1 | 8 | 10 | 22 |
| 28 | 10 | 30 | 38 | 36 | 22 |
| 29 | 6 | 30 | 36 | 10 | 11 |
| 30 | 36 | 35 | 10 | 31 | 9 |
| 31 | 34 | 23 | 30 | 19 | 3 |
| 32 | 27 | 37 | 1 | 8 | 22 |
| 33 | 10 | 22 | 37 | 27 | 34 |
| 34 | 37 | 31 | 4 | 35 | 22 |
| 35 | 36 | 30 | 34 | 7 | 27 |
| 36 | 35 | 30 | 29 | 22 | 34 |
| 37 | 34 | 22 | 32 | 38 | 36 |
| 38 | 16 | 37 | 23 | 22 | 4 |

FAM-14

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 26 | 19 | 3 | 12 |
| 2 | 3 | 18 | 1 | 10 | 6 |
| 3 | 6 | 26 | 7 | 2 | 5 |
| 4 | 5 | 7 | 3 | 6 | 16 |
| 5 | 3 | 4 | 6 | 19 | 32 |
| 6 | 3 | 7 | 4 | 5 | 2 |
| 7 | 6 | 3 | 4 | 10 | 12 |
| 8 | 26 | 9 | 7 | 30 | 34 |
| 9 | 13 | 34 | 31 | 8 | 28 |
| 10 | 12 | 18 | 2 | 3 | 7 |
| 11 | 34 | 31 | 10 | 13 | 3 |
| 12 | 10 | 13 | 17 | 34 | 24 |
| 13 | 24 | 12 | 9 | 29 | 34 |
| 14 | 36 | 29 | 13 | 24 | 25 |
| 15 | 14 | 19 | 29 | 35 | 17 |
| 16 | 17 | 3 | 20 | 6 | 4 |
| 17 | 12 | 19 | 16 | 18 | 10 |
| 18 | 10 | 2 | 20 | 17 | 24 |
| 19 | 31 | 13 | 34 | 17 | 25 |
| 20 | 25 | 18 | 2 | 16 | 19 |
| 21 | 12 | 31 | 10 | 32 | 18 |
| 22 | 33 | 23 | 27 | 3 | 7 |
| 23 | 33 | 22 | 24 | 19 | 3 |
| 24 | 29 | 13 | 28 | 12 | 25 |
| 25 | 29 | 20 | 13 | 19 | 24 |
| 26 | 3 | 36 | 1 | 27 | 17 |
| 27 | 33 | 38 | 26 | 17 | 12 |
| 28 | 24 | 19 | 34 | 36 | 31 |
| 29 | 25 | 14 | 24 | 13 | 36 |
| 30 | 35 | 32 | 39 | 36 | 20 |
| 31 | 34 | 19 | 32 | 13 | 11 |
| 32 | 30 | 31 | 34 | 6 | 35 |
| 33 | 22 | 27 | 23 | 35 | 38 |
| 34 | 31 | 13 | 19 | 12 | 9 |
| 35 | 30 | 37 | 19 | 33 | 34 |
| 36 | 14 | 26 | 3 | 29 | 19 |
| 37 | 35 | 14 | 29 | 36 | 19 |
| 38 | 12 | 27 | 33 | 17 | 19 |
| 39 | 30 | 35 | 38 | 23 | 33 |

FAM-15

| | | | | | |
|---|---|---|---|---|---|
| 1 | 3 | 25 | 4 | 11 | 29 |
| 2 | 3 | 22 | 24 | 30 | 19 |
| 3 | 2 | 24 | 40 | 22 | 10 |
| 4 | 8 | 10 | 9 | 39 | 15 |
| 5 | 10 | 4 | 21 | 9 | 12 |
| 6 | 7 | 22 | 12 | 21 | 36 |
| 7 | 24 | 6 | 23 | 36 | 22 |
| 8 | 4 | 10 | 9 | 21 | 25 |
| 9 | 4 | 10 | 8 | 3 | 26 |
| 10 | 4 | 8 | 9 | 3 | 33 |
| 11 | 14 | 28 | 29 | 22 | 34 |
| 12 | 24 | 6 | 38 | 37 | 28 |
| 13 | 20 | 32 | 16 | 18 | 29 |
| 14 | 11 | 31 | 28 | 2 | 22 |
| 15 | 39 | 33 | 4 | 24 | 10 |
| 16 | 17 | 27 | 18 | 13 | 20 |
| 17 | 16 | 23 | 20 | 27 | 18 |
| 18 | 27 | 20 | 17 | 16 | 13 |
| 19 | 26 | 2 | 31 | 24 | 29 |
| 20 | 27 | 18 | 13 | 17 | 32 |
| 21 | 25 | 6 | 23 | 8 | 27 |
| 22 | 2 | 40 | 31 | 6 | 7 |
| 23 | 7 | 21 | 17 | 25 | 37 |
| 24 | 37 | 7 | 26 | 3 | 25 |
| 25 | 24 | 21 | 23 | 7 | 40 |
| 26 | 24 | 19 | 37 | 38 | 35 |
| 27 | 20 | 28 | 18 | 16 | 21 |
| 28 | 11 | 24 | 27 | 12 | 29 |
| 29 | 11 | 24 | 28 | 2 | 30 |
| 30 | 2 | 31 | 28 | 29 | 40 |
| 31 | 22 | 30 | 11 | 2 | 19 |
| 32 | 36 | 24 | 7 | 13 | 33 |
| 33 | 24 | 10 | 15 | 32 | 12 |
| 34 | 11 | 22 | 24 | 40 | 2 |
| 35 | 37 | 39 | 26 | 7 | 38 |
| 36 | 7 | 32 | 6 | 35 | 12 |
| 37 | 38 | 33 | 24 | 7 | 12 |
| 38 | 37 | 24 | 12 | 7 | 22 |
| 39 | 35 | 40 | 15 | 37 | 3 |
| 40 | 22 | 3 | 39 | 2 | 24 |

FAM-16

| | | | | | |
|---|---|---|---|---|---|
| 1 | 32 | 6 | 36 | 2 | 29 |
| 2 | 17 | 1 | 16 | 18 | 37 |
| 3 | 4 | 35 | 33 | 6 | 9 |
| 4 | 3 | 20 | 10 | 9 | 1 |
| 5 | 29 | 31 | 16 | 22 | 25 |
| 6 | 33 | 38 | 35 | 22 | 1 |
| 7 | 22 | 13 | 33 | 11 | 6 |
| 8 | 9 | 38 | 33 | 34 | 35 |
| 9 | 12 | 8 | 31 | 38 | 33 |
| 10 | 12 | 11 | 30 | 27 | 16 |
| 11 | 12 | 42 | 23 | 6 | 38 |
| 12 | 11 | 9 | 10 | 18 | 35 |
| 13 | 29 | 32 | 14 | 7 | 5 |
| 14 | 13 | 19 | 42 | 20 | 32 |
| 15 | 25 | 20 | 21 | 38 | 16 |
| 16 | 25 | 20 | 5 | 23 | 10 |
| 17 | 2 | 18 | 25 | 6 | 5 |
| 18 | 25 | 17 | 11 | 37 | 16 |
| 19 | 25 | 34 | 14 | 38 | 42 |
| 20 | 16 | 4 | 11 | 14 | 15 |
| 21 | 20 | 15 | 6 | 33 | 9 |
| 22 | 6 | 9 | 7 | 36 | 33 |
| 23 | 11 | 28 | 16 | 22 | 24 |
| 24 | 25 | 22 | 42 | 9 | 23 |
| 25 | 24 | 16 | 18 | 19 | 38 |
| 26 | 37 | 11 | 22 | 23 | 1 |
| 27 | 30 | 28 | 42 | 40 | 10 |
| 28 | 27 | 23 | 42 | 11 | 16 |
| 29 | 13 | 5 | 38 | 31 | 1 |
| 30 | 27 | 40 | 36 | 10 | 9 |
| 31 | 9 | 5 | 22 | 29 | 13 |
| 32 | 13 | 1 | 7 | 33 | 14 |
| 33 | 35 | 6 | 34 | 8 | 9 |
| 34 | 35 | 33 | 38 | 19 | 9 |
| 35 | 33 | 34 | 6 | 38 | 9 |
| 36 | 22 | 37 | 1 | 30 | 11 |
| 37 | 36 | 18 | 26 | 2 | 20 |
| 38 | 8 | 6 | 35 | 9 | 34 |
| 39 | 42 | 22 | 36 | 10 | 20 |
| 40 | 30 | 27 | 11 | 18 | 24 |
| 41 | 36 | 40 | 30 | 25 | 14 |
| 42 | 11 | 38 | 28 | 19 | 27 |

APPENDIX VI : Pseudo-F values (> 10) for all the 99 characters on the first ten vectors of the PCO analysis on the sixteen families

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | 12.5(5) | 13.9(7) | 10.9(1) | - | - | - | - | - | 12.4(2) 13.9(4) | - | - | - | - | - |
| 2 | - | 13.8(2) | 11.8(1) | - | - | 10.9(4) | - | - | - | - | - | - | - | 29.5(5) | 12.4(2) | - |
| 3 | - | 10.8(3) | - | 12.9(9) | - | - | - | - | - | - | - | - | - | 11.7(1) 10.7(6) | 11.1(7) | - |
| 4 | 12.3(2) | 17.2(5) | - | - | - | - | 12.2(2) | - | - | - | - | 11.6(5) | 11.0(4) | - | 13.0(3) | 24.4(5) |
| 5 | - | - | 13.3(5) | - | - | 10.7(6) | - | - | - | 20.7(7) | - | - | - | - | - | 15.0(8) |
| 6 | - | - | - | 28.7(3) | 11.7(5) | - | - | 17.5(2) | - | 10.9(7) | 11.4(8) | - | - | - | 29.7(1) | 18.9(8) |
| 7 | - | - | - | - | 16.9(5) | - | - | 22.9(2) | - | - | - | - | - | - | - | - |
| 8 | 12.4(1) | 16.6(1) | 24.9(3) | 26.4(1) 13.7(3) | 17.2(8) | - | - | - | 11.1(8) | 20.6(2) 20.6(3) | - | 17.6(9) | 10.0(1) | 28.5(4) | 13.0(3) | - |
| 9 | - | - | - | - | - | 11.8(2) | - | - | - | - | - | - | - | - | 10.8(3) | - |
| 10 | - | - | 11.3(3) | 21.4(1) | 158.2(1) | - | - | 18.1(1) 13.9(2) | 11.1(2) | - | - | - | - | 10.1(2) | 22.9(1) | - |
| 11 | - | - | - | 15.1(6) | - | - | - | - | 25.8(2) | - | - | - | 15.2(1) | - | - | - |
| 12 | - | - | - | 15.2(2) | 316.5(1) | - | - | 31.4(1) | 14.1(1) | - | - | - | 41.4(1) | - | 11.6(1) | - |
| 13 | 11.3(2) | - | - | 31.4(2) | 316.5(1) | 17.7(2) | - | - | 26.9(1) | - | - | 11.0(5) | - | 26.9(2) | - | - |
| 14 | - | 17.5(1) | - | 12.5(1) | - | 14.5(2) | - | - | - | 12.6(2) | - | - | - | - | - | - |
| 15 | - | 13.8(1) 11.3(6) | - | - | - | 12.3(4) | - | - | - | - | 12.2(2) | - | 17.3(5) | 13.1(4) 17.1(9) | - | - |
| 16 | - | - | - | 13.5(4) | - | - | - | 17.8(2) | 10.7(8) | 16.3(2) | - | - | - | 11.0(4) | - | - |
| 17 | - | 20.5(10) | - | 11.5(1) 13.2(2) | - | - | - | - | - | - | - | - | 11.3(1) | - | - | - |
| 18 | - | - | 41.2(3) | 12.3(1) | 18.4(6) | - | - | - | - | 12.3(2) 18.1(3) | - | - | - | - | - | - |
| 19 | - | - | - | - | 11.7(1) | - | - | - | - | - | - | - | - | - | - | - |
| 20 | - | - | - | - | - | - | - | 12.4(1) | - | - | - | 10.9(1) | 10.8(4) | - | - | - |
| 21 | - | - | - | - | - | - | - | - | - | 17.4(2) | - | - | - | - | - | - |
| 22 | - | - | - | 24.4(1) | - | 11.1(5) | - | 13.8(1) | 10.9(2) | - | 17.5(1) | - | 12.2(1) | - | - | - |
| 23 | - | - | - | 24.4(1) | 11.0(1) | 11.1(5) | - | 12.7(1) | - | - | 20.6(1) | - | - | - | - | - |
| 24 | - | 15.8(1) | 11.9(5) | 27.3(1) | 14.3(8) | - | 13.8(2) | - | - | 22.0(2) | 16.9(2) 10.5(3) | - | - | 26.0(4) | - | - |
| 25 | 11.5(2) | 21.2(1) | 15.6(3) | - | - | - | - | - | 11.4(3) | 16.4(2) 12.6(3) | - | - | - | - | - | - |
| 26 | 40.1(1) | - | 21.7(3) | - | - | - | - | 14.6(8) | - | - | - | - | 41.5(1) | - | 12.5(1) 20.0(3) | - |

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | - | - | 10.7(3) | - | 120.3(1) | - | - | - | - | - | - | - | - | - | - | - |
| 28 | - | - | 41.2(3) | - | 119.6(1) | - | - | - | - | - | - | - | 10.7(2) | 10.4(2) | - | - |
| 29 | - | - | 10.1(6) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 30 | - | - | - | - | - | - | - | 10.9(3) 13.8(6) | - | - | - | - | - | 14.8(1) | - | - |
| 31 | - | - | - | 18.1(1) | 16.8(2) | 17.9(1) | 17.7(5) | - | - | - | 22.2(2) | 16.6(2) | 11.5(4) | 23.6(1) | 17.6(5) | 13.8(10) |
| 32 | - | - | - | - | - | - | 15.8(4) | - | - | - | 12.3(3) | - | - | 14.0(1) 11.2(3) | - | - |
| 33 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 34 | 25.9(4) | - | 12.4(1) | 10.3(1) | - | 25.2(7) | 21.0(5) | - | 12.5(1) | 12.8(1) | - | - | - | 18.3(1) | - | 21.1(3) |
| 35 | - | - | - | - | - | - | 12.2(5) | - | - | - | - | - | - | - | - | - |
| 36 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 37 | - | - | 13.6(2) | - | - | 11.2(1) | 14.8(5) | 12.4(5) | - | 10.7(5) | - | - | - | - | - | - |
| 38 | - | - | 38.1(2) 12.1(4) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 39 | - | - | 10.2(1) | 11.1(2) | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 10.1(1) | - | 22.2(3) | 17.5(2) | - | - | 11.7(4) | 12.3(1) | - | 15.6(1) 19.9(4) | - | 19.1(1) | 12.8(2) | - | 19.1(1) | 12.0(1) |
| 41 | 22.2(1) | - | - | 11.5(2) 11.4(9) | - | - | - | 39.2(1) | - | - | - | 11.0(1) | - | - | - | - |
| 42 | 14.4(2) | - | - | - | - | - | 12.8(1) | 14.7(1) | 10.8(1) | - | - | - | - | - | - | - |
| 43 | - | - | 12.6(3) | - | - | - | - | 10.7(1) | - | - | - | - | - | - | - | 11.6(1) |
| 44 | 12.1(10) | 14.8(4) | - | 11.6(4) | - | 12.7(1) | - | 23.4(4) | - | - | - | - | - | - | - | - |
| 45 | 13.1(5) | - | - | - | - | - | - | - | 13.7(3) | - | - | 12.5(3) | - | - | - | - |
| 46 | - | - | - | - | 32.4(2) | - | - | - | 14.9(3) | - | - | - | 11.1(2) 14.7(4) | - | - | - |
| 47 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 12.7(4) | - |
| 48 | - | - | - | - | - | 12.7(4) | - | - | - | 18.4(5) | 15.2(4) | - | - | - | - | - |
| 49 | - | - | - | - | - | - | 11.5(8) | - | - | 11.5(9) | 19.4(10) | 11.5(10) | - | - | - | - |
| 50 | 15.0(7) | - | - | - | 16.1(4) | 15.4(4) | 11.5(1) | 15.3(4) | 21.5(2) | 14.2(8) | - | - | - | - | - | 10.1(4) |
| 51 | 14.2(2) | - | - | 13.5(8) | - | - | - | - | - | 16.2(10) | - | - | - | - | - | - |
| 52 | - | - | 13.8(9) | - | - | 10.9(3) | 14.4(2) | - | - | - | - | - | 16.5(1) | - | - | - |
| 53 | - | - | - | - | - | 11.2(4) | - | - | - | - | - | - | - | - | 12.9(7) | - |
| 54 | - | - | 13.7(5) | - | - | 16.9(7) | - | - | 11.8(5) | - | - | - | 10.1(3) | - | - | - |
| 55 | - | - | - | - | - | - | - | - | - | - | - | - | - | 12.4(1) | - | - |
| 56 | - | 11.7(2) | 11.0(2) | - | - | 10.8(7) | - | - | - | - | - | - | - | - | - | - |

| Character no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | FAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 | - | 15.2(2) | - | - | - | - | - | - | - | - | 17.8(2) | - | 18.6(7) | - | - | - |
| 58 | 40.4(1) | - | - | 15.3(2) | - | 15.0(3) | - | 15.4(1) | - | - | - | 13.4(1) | - | - | 11.8(1) | - |
| 59 | 43.1(1) | - | 11.8(3) | 17.7(2) | - | 15.0(3) | 10.7(2) | 21.6(1) | - | - | 12.5(1) | 39.9(1) | 11.1(1)<br>18.4(5) | 10.6(2) | 47.3(1) | - |
| 60 | 23.3(1) | 15.1(2) | - | - | 10.9(6) | - | - | - | - | 30.7(1) | - | 10.9(1) | - | 15.1(3) | - | - |
| 61 | 51.4(1) | 11.8(2)<br>17.3(7) | 22.2(3) | - | - | 12.4(5) | - | 10.7(1) | 12.1(2) | 17.6(1) | 20.0(1) | 59.4(1) | 11.3(5) | 10.2(2) | 27.0(1) | - |
| 62 | 32.1 | - | 17.1(3) | 11.7(2) | - | - | - | 19.9(1) | - | - | - | - | - | - | 15.2(1) | - |
| 63 | - | - | - | - | - | - | 18.6(7) | - | 12.3(8) | - | - | - | 14.3(3) | 16.7(7) | - | - |
| 64 | - | - | - | - | - | - | - | - | - | - | - | - | - | 13.4(10) | - | - |
| 65 | 96.2(3) | 13.1(3)<br>21.5(4) | 172.7(1) | 15.3(1)<br>11.8(3) | 78.2(2) | 16.7(1)<br>19.4(3) | 19.0(2) | 26.7(3) | 63.6(1) | 51.0(1) | 27.5(3) | - | 33.5(1)<br>11.6(2) | 57.7(1) | 77.0(2) | 12.1(1)<br>12.4(3) |
| 66 | 23.2(3) | 28.8(3) | 90.7(1) | 15.0(1)<br>18.8(3) | 20.4(2) | 29.0(1)<br>10.0(3) | 13.6(1)<br>15.6(2) | 19.6(3) | 47.2(1) | 42.2(1) | 12.9(3) | - | 24.4(1) | 29.2(1) | 34.9(2) | 18.0(3) |
| 67 | 19.9(3) | 11.4(4)<br>11.7(7) | 28.1(1) | - | 25.9(2) | 14.9(3) | 10.6(2) | 25.8(3) | 53.4(1) | 20.2(1) | - | 12.2(3) | 11.1(1)<br>10.8(2) | 35.1(1) | 49.1(2) | - |
| 68 | 17.2(2)<br>11.8(3) | - | - | 16.9(1) | 20.5(2) | 11.7(3) | - | - | - | - | - | - | 12.1(7) | 11.7(6) | - | 14.4(3) |
| 69 | 12.7(2) | - | 32.7(1) | 13.0(3) | - | 13.3(1) | - | 14.0(8) | - | 11.9(1) | - | 11.6(2) | - | - | - | - |
| 70 | 17.5(1) | 12.6(4)<br>10.1(6) | 58.7(1) | 19.1(1) | 15.9(2)<br>12.0(4) | 45.9(1) | 16.5(3) | 12.8(2)<br>11.3(3) | 13.2(1)<br>10.9(4) | 33.2(1) | 13.6(1)<br>14.2(2) | 35.0(2) | 10.5(2)<br>10.5(9) | - | 10.3(2) | 29.7(2) |
| 71 | 18.1(2) | 18.5(4) | 62.4(1) | - | 25.1(2) | 46.5(1) | 14.6(2)<br>12.8(3) | 17.9(2) | 14.9(1) | 13.9(1)<br>15.1(2) | - | 33.2(2) | - | 16.3(2) | - | 21.9(2) |
| 72 | 12.2(1) | 29.9(4) | 47.4(1) | - | 14.6(2) | 17.9(1) | 23.2(3) | 21.1(3) | 20.6(1) | - | 11.0(5) | 16.1(2)<br>10.0(3) | - | 10.1(2) | - | - |
| 73 | - | 24.6(4) | 16.6(1)<br>19.9(3) | - | - | 33.8(1) | 11.9(3) | 10.7(2)<br>10.9(3) | 10.0(4) | 13.5(1) | 13.1(2) | 26.5(2) | 15.3(9) | - | - | 22.3(2) |
| 74 | - | 11.0(4)<br>10.6(6) | - | - | 17.6(3) | - | 14.3(2) | 13.4(2) | 15.8(5) | - | - | - | - | - | - | 28.9(2) |
| 75 | 33.6(2) | - | 21.4(1) | 17.6(1) | 17.6(3) | 27.9(1) | - | 14.4(2) | 11.4(4) | 24.9(1) | 17.7(1) | - | - | 13.3(2) | - | 25.9(2) |
| 76 | - | - | - | - | 13.1(5) | - | - | - | 14.2(7) | 12.2(1) | - | - | - | - | - | - |
| 77 | - | - | - | - | - | - | 12.8 | - | - | - | - | - | - | - | - | - |
| 78 | - | - | 27.8(6) | - | - | - | - | - | 12.3(5) | - | - | - | - | - | 11.3(4) | - |
| 79 | 11.7(4)<br>13.8(8) | - | 27.2(10) | - | 11.1(7) | - | - | - | 11.5(2)<br>12.6(10) | - | 21.4(4) | - | - | - | - | 11.0(6) |
| 80 | - | 21.2(5) | - | - | - | - | - | 22.3(7) | 11.8(10) | - | - | - | 33.4(4) | - | 10.4(3) | - |

| Charac-ter no.* | FAM-01 | FAM-02 | FAM-03 | FAM-04 | GAM-05 | FAM-06 | FAM-07 | FAM-08 | FAM-09 | FAM-10 | FAM-11 | FAM-12 | FAM-13 | FAM-14 | FAM-15 | FAM-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | - | - | - | - | 14.9(3) | - | 13.1(1) | - | - | - | - | - | - | - | - | - |
| 82 | - | - | 12.2(4) | - | - | 10.2(8) | 10.7(2) | - | - | - | - | - | - | - | 11.1(3) | 13.3(1) 16.6(5) |
| 83 | - | - | 12.0(6) | - | - | - | 10.0(3) | - | - | - | - | - | - | - | - | - |
| 84 | 10.5(4) | - | 12.2(1) | - | 11.2(3) | - | - | - | - | - | - | - | - | - | - | 15.0(2) |
| 85 | 13.9(7) | - | - | - | 11.1(6) 14.6(7) | - | - | - | - | - | - | 10.0(5) | - | - | - | - |
| 86 | 17.5(3) | - | 35.8(1) | - | - | - | - | 12.4(3) | - | 22.3(1) | - | 14.6(5) | 11.5(2) | 23.9(1) | - | 18.7(2) |
| 87 | 28.1(3) | 25.8(3) | 18.9(1) | 10.8(1) 15.6(3) | - | 12.5(5) | 10.6(1) 20.0(2) | - | 25.9(1) | 16.3(1) | - | 35.0(6) | 22.9(1) | 23.3(1) | 15.7(2) | 12.6(1) |
| 88 | 12.1(3) | 10.2(3) | 22.5(1) | 17.3(4) | - | - | 23.8(2) | - | 10.3(1) | 20.6(1) 14.3(5) | - | - | - | 41.3(1) | 18.7(2) | 13.6(1) |
| 89 | - | 12.6(3) | - | 13.7(4) | - | - | 10.2(1) 10.8(2) | - | - | - | 11.2(8) | - | 19.2(1) | 14.6(1) | 23.9(2) | 15.2(1) |
| 90 | 10.7(3) | 16.9(4) | 51.9(1) | - | 10.0(3) | 16.6(1) | 12.4(3) | 23.9(3) | - | 12.5(1) | - | 15.5(2) 14.5(3) | 13.9(2) | 15.1(1) | 10.9(4) | 32.4(2) |
| 91 | 31.8(3) | 25.0(3) | 41.7(1) | 19.6(3) | - | 18.2(3) | 14.6(1) 13.3(2) | 13.1(3) 13.3(6) | 35.7(1) | 23.0(1) | - | 20.0(6) | 20.0(1) | 40.6(1) | 22.3(2) | 10.3(1) 27.5(3) |
| 92 | 19.3(3) | 11.5(3) | 45.3(1) | 11.0(4) | 12.3(2) | 14.3(3) | 12.1(1) 12.5(2) | 14.5(3) | 17.1(1) | 17.5(1) | 11.2(1) | 10.9(1) 12.0(3) | 10.0(1) | 25.3(1) | 20.6(2) | 11.7(1) 14.7(3) |
| 93 | 18.9(3) | 17.8(3) | 21.0(1) | 13.2(3) | 12.2(2) | - | 34.3(2) | 10.0(8) | 28.0(1) | 16.0(1) | 13.4(1) | 12.2(6) | - | 23.9 | 20.0(2) | - |
| 94 | 39.2(3) | 14.8(3) | 75.6(1) | 12.0(3) | 40.0(2) | 13.1(3) | - | 18.6(3) | 18.6(1) | 45.8(1) | 22.1(3) | 18.5(5) | 14.2(1) | 34.0(1) | 46.3(2) | 15.0(1) 12.6(3) |
| 95 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 96 | 26.3(3) | 35.8(4) | 117.0(1) | 21.0(3) | 18.0(2) | 35.0(1) | 11.2(1) | 51.7(3) | 18.6(1) | 76.2(1) | 10.7(3) | 21.7(2) 12.3(3) | 11.6(2) | 41.0(1) | 18.0(3) | 18.4(2) |
| 97 | 28.5(3) | 31.0(4) | 141.4(1) | 12.1(4) | 31.5(2) | 39.5(1) | 11.4(3) | 49.2(3) | 30.9(1) | 89.5(1) | 17.0(3) | 10.6(2) 18.5(3) | 16.8(1) 14.7(2) | 40.1(1) | - | 15.7(2) |
| 98 | 39.4(3) | 27.6(4) | 94.4(1) | 16.2(3) | 19.6(2) | 29.1(1) | - | 26.2(3) | 12.7(1) | 88.7(1) | 12.5(3) | 19.0(2) 13.8(3) | 15.1(2) | 42.5(1) | 12.4(3) | 21.6(2) |
| 99 | 21.4(3) | 38.9(4) | 32.0(1) | 16.6(8) | 11.1(2) | 17.1(1) 17.7(3) | 15.6(3) 14.2(7) | 53.9(3) | 10.9(1) | 31.9(1) | 12.1(3) | - | 10.8(2) | 16.0(1) 16.1(2) | 12.4(2) | 29.7(2) |

* - Values greater than ten may be considered to show some significant contribution to the vector by the character (Dr. G. J. S. Ross, personal communication.

** the character names were given in the text (cf. Sect. 4.4.2.)

# APPENDIX VII: The first four vector scores of the sixteen families analysed together.

PRINCIPAL COORDINATE ANALYSIS (a) SAMPLE-I MIXED TYPE + STANDARD COEFFICIENT

TRACE = 70,580

| | | | | |
|---|---|---|---|---|
| LATENT ROOTS | 4,394 | 3,596 | 2,991 | 2,736 |
| PERCENT OF TRACE | 6,2 | 11,4 | 15,6 | 19,5 |

| | | | | |
|---|---|---|---|---|
| 1 | ,160 | ,304 | ,031 | ,297 |
| 2 | ,125 | ,234 | -,120 | ,233 |
| 3 | ,182 | ,234 | ,079 | ,012 |
| 4 | ,262 | ,370 | ,029 | ,052 |
| 5 | ,257 | ,418 | ,077 | ,080 |
| 6 | ,170 | ,207 | ,033 | ,247 |
| 7 | ,078 | ,202 | ,023 | ,162 |
| 8 | ,164 | ,270 | ,051 | ,061 |
| 9 | ,183 | ,385 | ,109 | ,114 |
| 10 | ,194 | ,248 | ,046 | ,046 |
| 11 | ,245 | ,074 | ,074 | ,107 |
| 12 | ,186 | ,168 | ,231 | ,114 |
| 13 | ,117 | ,152 | ,102 | ,072 |
| 14 | ,052 | ,080 | ,149 | ,043 |
| 15 | ,089 | ,113 | ,201 | ,157 |
| 16 | ,112 | ,084 | ,165 | ,101 |
| 17 | ,041 | ,015 | ,083 | ,028 |
| 18 | ,178 | ,110 | ,189 | ,108 |
| 19 | ,105 | ,107 | ,248 | ,032 |
| 20 | ,144 | ,008 | ,165 | ,122 |
| 21 | ,306 | ,064 | ,253 | ,183 |
| 22 | ,187 | ,070 | ,333 | ,141 |
| 23 | ,097 | ,071 | ,056 | ,217 |
| 24 | ,159 | ,089 | ,243 | ,176 |
| 25 | ,134 | ,155 | ,260 | ,125 |
| 26 | ,200 | ,090 | ,193 | ,130 |
| 27 | ,244 | ,093 | ,173 | ,136 |
| 28 | ,243 | ,140 | ,213 | ,127 |
| 29 | ,214 | ,039 | ,135 | ,206 |
| 30 | ,224 | ,135 | ,251 | ,112 |
| 31 | ,151 | ,278 | ,019 | ,033 |
| 32 | ,047 | ,374 | ,021 | ,073 |
| 33 | ,150 | -,241 | ,126 | ,059 |
| 34 | ,075 | -,207 | ,048 | ,057 |
| 35 | ,069 | -,240 | ,124 | ,096 |
| 36 | ,052 | -,281 | ,102 | ,037 |
| 37 | ,103 | -,305 | ,019 | ,121 |
| 38 | ,115 | -,141 | ,050 | ,045 |
| 39 | ,028 | -,235 | ,064 | ,050 |
| 40 | ,053 | -,186 | ,014 | ,076 |
| 41 | ,158 | -,206 | ,177 | ,007 |
| 42 | ,161 | -,122 | ,102 | ,105 |
| 43 | ,228 | -,145 | ,055 | ,060 |
| 44 | ,172 | -,053 | ,059 | ,090 |
| 45 | ,244 | -,038 | ,180 | ,034 |
| 46 | ,232 | -,092 | ,188 | ,063 |
| 47 | ,206 | -,144 | ,222 | ,072 |
| 48 | ,176 | -,178 | ,057 | ,066 |
| 49 | ,178 | -,063 | ,238 | ,055 |
| 50 | ,222 | -,111 | ,176 | ,099 |
| 51 | ,174 | -,179 | ,006 | ,072 |
| 52 | ,174 | -,164 | ,005 | ,037 |
| 53 | ,191 | -,243 | ,076 | ,111 |
| 54 | ,145 | -,226 | ,086 | ,005 |
| 55 | ,181 | -,200 | ,135 | ,016 |
| 56 | ,215 | -,340 | ,080 | ,066 |
| 57 | ,174 | -,160 | ,048 | ,087 |
| 58 | ,197 | -,247 | ,089 | ,058 |
| 59 | ,234 | -,277 | ,011 | ,039 |
| 60 | ,186 | -,298 | ,109 | ,098 |
| 61 | ,206 | -,046 | ,017 | ,103 |
| 62 | ,211 | -,114 | ,004 | ,051 |
| 63 | ,105 | -,138 | ,090 | ,001 |
| 64 | ,161 | -,045 | ,106 | ,045 |
| 65 | ,207 | -,028 | ,091 | ,160 |
| 66 | ,079 | -,071 | ,141 | ,053 |
| 67 | ,241 | -,103 | ,062 | ,033 |
| 68 | ,016 | -,028 | ,072 | ,099 |
| 69 | ,093 | -,112 | ,060 | ,150 |
| 70 | ,176 | -,067 | ,061 | ,095 |
| 71 | ,153 | -,171 | ,115 | ,073 |
| 72 | ,133 | -,151 | ,113 | ,153 |
| 73 | ,023 | -,146 | ,204 | ,056 |
| 74 | ,026 | -,233 | ,056 | ,064 |
| 75 | ,065 | -,047 | ,119 | ,203 |
| 76 | ,064 | -,193 | ,046 | ,015 |
| 77 | ,165 | -,156 | ,185 | ,048 |
| 78 | ,161 | -,104 | ,184 | ,132 |
| 79 | ,162 | -,005 | ,121 | ,043 |
| 80 | ,240 | -,075 | ,145 | ,152 |
| 81 | ,121 | -,024 | ,207 | ,223 |
| 82 | ,265 | -,115 | ,138 | ,087 |
| 83 | ,180 | -,007 | ,089 | ,006 |
| 84 | ,167 | -,077 | ,147 | ,052 |
| 85 | ,257 | -,042 | ,199 | ,004 |
| 86 | ,223 | -,058 | ,132 | ,067 |
| 87 | ,223 | -,087 | ,233 | ,021 |
| 88 | ,112 | -,003 | ,231 | ,152 |
| 89 | ,314 | -,055 | ,100 | ,093 |
| 90 | ,154 | -,036 | ,229 | ,015 |
| 91 | ,149 | -,000 | ,147 | ,054 |
| 92 | ,016 | -,158 | ,078 | ,073 |
| 93 | ,044 | -,091 | ,181 | ,172 |
| 94 | ,008 | -,034 | ,216 | ,127 |
| 95 | ,025 | -,047 | ,230 | ,228 |
| 96 | ,051 | -,006 | ,162 | ,069 |
| 97 | ,063 | -,037 | ,137 | ,029 |
| 98 | ,137 | -,000 | ,085 | ,147 |
| 99 | ,125 | -,045 | ,260 | ,097 |
| 100 | ,087 | -,004 | ,247 | ,025 |
| 101 | ,136 | -,001 | ,087 | ,161 |
| 102 | ,005 | -,003 | ,173 | ,246 |
| 103 | ,060 | -,134 | ,098 | ,125 |
| 104 | ,149 | -,072 | ,048 | ,215 |
| 105 | ,148 | -,108 | ,158 | ,141 |
| 106 | ,159 | -,144 | ,015 | ,023 |
| 107 | ,078 | -,084 | ,055 | ,094 |
| 108 | ,004 | -,172 | ,125 | ,195 |
| 109 | ,119 | -,040 | ,153 | ,189 |
| 110 | ,073 | -,078 | ,019 | ,201 |
| 111 | ,008 | -,031 | ,010 | ,322 |
| 112 | ,199 | -,006 | ,032 | ,291 |
| 113 | ,235 | -,050 | ,055 | ,251 |
| 114 | ,148 | -,028 | ,031 | ,266 |
| 115 | ,191 | -,069 | ,005 | ,222 |
| 116 | ,243 | -,023 | ,000 | ,163 |
| 117 | ,259 | -,048 | ,040 | ,196 |
| 118 | ,128 | -,102 | ,014 | ,124 |
| 119 | ,150 | -,000 | ,017 | ,232 |
| 120 | ,282 | -,008 | ,037 | ,123 |
| 121 | ,189 | -,072 | ,124 | ,127 |
| 122 | ,191 | -,204 | ,088 | ,028 |
| 123 | ,169 | -,206 | ,030 | ,159 |
| 124 | ,061 | -,139 | ,070 | ,000 |
| 125 | ,043 | -,032 | ,091 | ,022 |
| 126 | ,092 | -,000 | ,086 | ,076 |
| 127 | ,060 | -,204 | ,094 | ,015 |
| 128 | ,005 | -,003 | ,018 | ,066 |
| 129 | ,092 | -,122 | ,082 | ,021 |
| 130 | ,115 | -,101 | ,089 | ,128 |
| 131 | ,009 | -,082 | ,141 | ,325 |
| 132 | ,071 | -,029 | ,149 | ,108 |
| 133 | ,052 | -,045 | ,043 | ,238 |
| 134 | ,007 | -,174 | ,080 | ,250 |
| 135 | ,115 | -,046 | ,254 | ,229 |
| 136 | ,003 | -,179 | ,055 | ,185 |
| 137 | ,143 | -,101 | ,173 | ,178 |
| 138 | ,067 | -,202 | ,069 | ,254 |
| 139 | ,004 | -,106 | ,021 | ,402 |
| 140 | ,064 | -,015 | ,176 | ,083 |
| 141 | ,096 | -,011 | ,095 | ,074 |
| 142 | ,080 | -,030 | ,135 | ,009 |
| 143 | ,245 | -,017 | ,062 | ,078 |
| 144 | ,143 | -,021 | ,065 | ,085 |
| 145 | ,298 | -,060 | ,119 | ,057 |
| 146 | ,153 | -,071 | ,067 | ,071 |
| 147 | ,235 | -,016 | ,067 | ,053 |
| 148 | ,166 | -,072 | ,042 | ,070 |
| 149 | ,299 | -,065 | ,024 | ,089 |
| 150 | ,311 | -,040 | ,218 | ,055 |
| 151 | ,169 | -,064 | ,132 | ,001 |
| 152 | ,076 | -,149 | ,046 | ,035 |
| 153 | ,160 | -,021 | ,291 | ,105 |
| 154 | ,138 | -,145 | ,224 | ,034 |
| 155 | ,066 | -,163 | ,154 | ,035 |
| 156 | ,016 | -,147 | ,181 | ,009 |
| 157 | ,226 | -,001 | ,237 | ,059 |
| 158 | ,160 | -,098 | ,200 | ,037 |
| 159 | ,187 | -,028 | ,159 | ,064 |
| 160 | ,155 | -,024 | ,181 | ,047 |

PAL COORDINATE ANALYSIS (b) SAMPLE-I CONTINUOUS TYPE + EUCLIDEAN DIST

= 44,619

| | | | | |
|---|---|---|---|---|
| ROOTS | 3,703 | 2,456 | 2,359 | 2,028 |
| OF TRACE | 8,3 | 13,8 | 19,1 | 23,6 |

| | | | | |
|---|---|---|---|---|
| 1 | ,254 | ,063 | -,075 | -,050 |
| 2 | ,175 | ,052 | -,082 | -,074 |
| 3 | ,190 | ,111 | -,023 | -,058 |
| 4 | ,345 | ,186 | -,085 | -,108 |
| 5 | ,329 | ,235 | -,005 | -,022 |
| 6 | ,206 | ,032 | -,042 | -,047 |
| 7 | ,069 | ,113 | -,018 | -,047 |
| 8 | ,220 | ,145 | -,002 | -,017 |
| 9 | ,265 | ,266 | -,052 | -,039 |
| 10 | ,253 | ,160 | -,005 | -,046 |
| 11 | ,210 | ,004 | -,169 | -,177 |
| 12 | ,148 | ,107 | -,245 | -,147 |
| 13 | ,110 | ,017 | -,195 | -,288 |
| 14 | ,006 | ,136 | -,146 | -,198 |
| 15 | ,088 | ,070 | -,169 | -,244 |
| 16 | ,140 | ,096 | -,154 | -,193 |
| 17 | ,103 | ,136 | -,108 | -,212 |
| 18 | ,099 | ,024 | -,186 | -,149 |
| 19 | ,099 | ,191 | -,184 | -,197 |
| 20 | ,130 | ,008 | -,135 | -,199 |
| 21 | ,222 | ,092 | -,275 | -,005 |
| 22 | ,130 | ,077 | -,271 | -,053 |
| 23 | ,060 | ,111 | -,065 | -,060 |
| 24 | ,117 | ,018 | -,236 | -,047 |
| 25 | ,172 | ,047 | -,291 | -,021 |
| 26 | ,129 | ,004 | -,249 | -,076 |
| 27 | ,187 | ,012 | -,179 | -,080 |
| 28 | ,170 | ,006 | -,225 | -,059 |
| 29 | ,148 | ,059 | -,168 | -,085 |
| 30 | ,152 | ,007 | -,275 | -,114 |
| 31 | ,079 | ,200 | -,096 | -,003 |
| 32 | ,014 | ,300 | -,064 | -,116 |
| 33 | ,073 | ,108 | -,200 | -,064 |
| 34 | ,025 | ,203 | -,058 | -,014 |
| 35 | ,029 | ,160 | -,004 | -,059 |
| 36 | ,009 | ,257 | -,018 | -,117 |
| 37 | ,037 | ,208 | -,105 | -,038 |
| 38 | ,132 | ,168 | -,001 | -,217 |
| 39 | ,032 | ,201 | -,027 | -,080 |
| 40 | ,094 | ,151 | -,118 | -,049 |
| 41 | ,104 | ,103 | -,226 | -,034 |
| 42 | ,070 | ,126 | -,134 | -,083 |
| 43 | ,134 | ,047 | -,062 | -,022 |
| 44 | ,113 | ,055 | -,049 | -,058 |
| 45 | ,215 | ,050 | -,175 | -,040 |
| 46 | ,164 | ,036 | -,150 | -,044 |
| 47 | ,140 | ,089 | -,228 | -,088 |
| 48 | ,147 | ,141 | -,080 | -,070 |
| 49 | ,140 | ,023 | -,194 | -,022 |
| 50 | ,175 | ,015 | -,177 | -,049 |
| 51 | ,217 | ,005 | -,000 | -,184 |
| 52 | ,168 | ,106 | -,013 | -,029 |
| 53 | ,235 | ,007 | -,052 | -,052 |
| 54 | ,197 | ,111 | -,068 | -,177 |
| 55 | ,232 | ,180 | -,038 | -,024 |
| 56 | ,251 | ,216 | -,026 | -,126 |
| 57 | ,214 | ,041 | -,026 | -,115 |
| 58 | ,229 | ,174 | -,016 | -,032 |
| 59 | ,265 | ,157 | -,074 | -,051 |
| 60 | ,233 | ,222 | -,029 | -,152 |
| 61 | ,193 | ,101 | -,011 | -,012 |
| 62 | ,181 | ,070 | -,030 | -,011 |
| 63 | ,082 | ,126 | -,025 | -,010 |
| 64 | ,110 | ,004 | -,098 | -,034 |
| 65 | ,209 | ,140 | -,111 | -,010 |
| 66 | ,116 | ,013 | -,188 | -,038 |
| 67 | ,187 | ,014 | -,100 | -,030 |
| 68 | ,019 | ,067 | -,113 | -,054 |
| 69 | ,097 | ,144 | -,098 | -,045 |
| 70 | ,112 | ,023 | -,062 | -,008 |
| 71 | ,045 | ,080 | -,026 | -,123 |
| 72 | ,199 | ,052 | -,043 | -,040 |
| 73 | ,007 | ,188 | -,086 | -,099 |
| 74 | ,035 | ,147 | -,018 | -,055 |
| 75 | ,031 | ,077 | -,119 | -,156 |
| 76 | ,016 | ,159 | -,030 | -,093 |
| 77 | ,158 | ,150 | -,127 | -,080 |
| 78 | ,125 | ,041 | -,144 | -,142 |
| 79 | ,125 | ,065 | -,122 | -,088 |
| 80 | ,199 | ,020 | -,088 | -,002 |
| 81 | ,086 | ,142 | -,151 | -,160 |
| 82 | ,226 | ,196 | -,049 | -,175 |
| 83 | ,171 | ,065 | -,021 | -,042 |
| 84 | ,125 | ,000 | -,154 | -,045 |
| 85 | ,187 | ,113 | -,110 | -,061 |
| 86 | ,208 | ,146 | -,096 | -,140 |
| 87 | ,170 | ,150 | -,133 | -,079 |
| 88 | ,087 | ,083 | -,171 | -,163 |
| 89 | ,256 | ,000 | -,104 | -,047 |
| 90 | ,169 | ,003 | -,172 | -,131 |
| 91 | ,148 | ,042 | -,084 | -,103 |
| 92 | ,017 | ,097 | -,135 | -,241 |
| 93 | ,058 | ,114 | -,152 | -,107 |
| 94 | ,027 | ,008 | -,163 | -,106 |
| 95 | ,030 | ,015 | -,136 | -,133 |
| 96 | ,085 | ,003 | -,226 | -,158 |
| 97 | ,050 | ,000 | -,089 | -,127 |
| 98 | ,085 | ,044 | -,270 | -,155 |
| 99 | ,084 | ,104 | -,227 | -,149 |
| 100 | ,074 | ,065 | -,185 | -,116 |
| 101 | ,096 | ,121 | -,115 | -,068 |
| 102 | ,011 | ,067 | -,136 | -,133 |
| 103 | ,036 | ,107 | -,107 | -,121 |
| 104 | ,100 | ,147 | -,083 | -,056 |
| 105 | ,107 | ,100 | -,154 | -,007 |
| 106 | ,115 | ,105 | -,097 | -,133 |
| 107 | ,097 | ,138 | -,098 | -,052 |
| 108 | ,016 | ,156 | -,156 | -,124 |
| 109 | ,089 | ,056 | -,137 | -,044 |
| 110 | ,029 | ,115 | -,005 | -,148 |
| 111 | ,020 | ,165 | -,022 | -,205 |
| 112 | ,165 | ,206 | -,012 | -,181 |
| 113 | ,227 | ,108 | -,083 | -,124 |
| 114 | ,125 | ,117 | -,030 | -,030 |
| 115 | ,078 | ,171 | -,012 | -,141 |
| 116 | ,255 | ,140 | -,032 | -,181 |
| 117 | ,187 | ,001 | -,075 | -,211 |
| 118 | ,119 | ,103 | -,060 | -,114 |
| 119 | ,110 | ,140 | -,004 | -,183 |
| 120 | ,257 | ,082 | -,005 | -,109 |
| 121 | ,158 | ,035 | -,058 | -,013 |
| 122 | ,101 | ,136 | -,141 | -,082 |
| 123 | ,108 | ,214 | -,082 | -,132 |
| 124 | ,020 | ,191 | -,140 | -,066 |
| 125 | ,009 | ,065 | -,080 | -,053 |
| 126 | ,084 | ,064 | -,054 | -,159 |
| 127 | ,035 | ,137 | -,026 | -,180 |
| 128 | ,015 | ,036 | -,011 | -,013 |
| 129 | ,105 | ,041 | -,041 | -,120 |
| 130 | ,110 | ,005 | -,042 | -,195 |
| 131 | ,024 | ,244 | -,048 | -,045 |
| 132 | ,065 | ,103 | -,089 | -,061 |
| 133 | ,005 | ,156 | -,014 | -,069 |
| 134 | ,037 | ,244 | -,017 | -,014 |
| 135 | ,055 | ,216 | -,211 | -,074 |
| 136 | ,041 | ,217 | -,041 | -,027 |
| 137 | ,124 | ,200 | -,079 | -,051 |
| 138 | ,023 | ,311 | -,017 | -,037 |
| 139 | ,033 | ,321 | -,025 | -,041 |
| 140 | ,064 | ,086 | -,158 | -,026 |
| 141 | ,289 | ,058 | -,009 | -,055 |
| 142 | ,206 | ,012 | -,057 | -,168 |
| 143 | ,199 | ,012 | -,070 | -,057 |
| 144 | ,136 | ,007 | -,079 | -,011 |
| 145 | ,310 | ,020 | -,111 | -,130 |
| 146 | ,136 | ,013 | -,088 | -,036 |
| 147 | ,193 | ,006 | -,047 | -,016 |
| 148 | ,209 | ,032 | -,010 | -,032 |
| 149 | ,264 | ,074 | -,019 | -,053 |
| 150 | ,289 | ,017 | -,142 | -,114 |
| 151 | ,154 | ,002 | -,074 | -,172 |
| 152 | ,056 | ,146 | -,080 | -,090 |
| 153 | ,200 | ,006 | -,228 | -,090 |
| 154 | ,167 | ,007 | -,215 | -,165 |
| 155 | ,107 | ,043 | -,161 | -,246 |
| 156 | ,040 | ,014 | -,157 | -,115 |
| 157 | ,212 | ,000 | -,193 | -,133 |
| 158 | ,202 | ,039 | -,196 | -,102 |
| 159 | ,192 | ,008 | -,141 | -,112 |
| 160 | ,148 | ,008 | -,129 | -,127 |

PRINCIPAL COORDINATE ANALYSIS (c) SAMPLE-II MIXED TYPE + STANDARD COEFFICIENT

TRACE = 71.053

| LATENT ROOTS | 3.811 | 2.815 | 2.799 | 2.688 |
|---|---|---|---|---|
| PERCENT OF TRACE | 5.4 | 9.5 | 13.4 | 17.2 |

| | | | | |
|---|---|---|---|---|
| 1 | .010 | .200 | .056 | .032 |
| 2 | .166 | .100 | .086 | .221 |
| 3 | .147 | .055 | .082 | .156 |
| 4 | .167 | .147 | .339 | .224 |
| 5 | .027 | .047 | .241 | .137 |
| 6 | .089 | .086 | .017 | .139 |
| 7 | .059 | .271 | .004 | .143 |
| 8 | .151 | .268 | .032 | .145 |
| 9 | .151 | .071 | .147 | .131 |
| 10 | .150 | .157 | .086 | .040 |
| 11 | .242 | .060 | .183 | .104 |
| 12 | .032 | .168 | .097 | .038 |
| 13 | .235 | .071 | .209 | .058 |
| 14 | .119 | .124 | .067 | .222 |
| 15 | .089 | .139 | .019 | .102 |
| 16 | .131 | .111 | .118 | .259 |
| 17 | .080 | .035 | .210 | .110 |
| 18 | .012 | .180 | .140 | .110 |
| 19 | .009 | .141 | .175 | .196 |
| 20 | .140 | .302 | .153 | .089 |
| 21 | .218 | .095 | .095 | .062 |
| 22 | .218 | .095 | .175 | .054 |
| 23 | .315 | .084 | .157 | .075 |
| 24 | .123 | .197 | .039 | .040 |
| 25 | .223 | .110 | .113 | .146 |
| 26 | .267 | .111 | .111 | .062 |
| 27 | .260 | .284 | .080 | .006 |
| 28 | .260 | .027 | .076 | .022 |
| 29 | .235 | .014 | .065 | .059 |
| 30 | .370 | .114 | .092 | .008 |
| 31 | .197 | .158 | .038 | .037 |
| 32 | .235 | .064 | .019 | .145 |
| 33 | .108 | .125 | .081 | .002 |
| 34 | .020 | .100 | .013 | .246 |
| 35 | .029 | .257 | .113 | .271 |
| 36 | .258 | .064 | .111 | .174 |
| 37 | .120 | .100 | .067 | .324 |
| 38 | .008 | .165 | .052 | .235 |
| 39 | .163 | .077 | .084 | .175 |
| 40 | .010 | .032 | .020 | .202 |
| 41 | .026 | .038 | .070 | .138 |
| 42 | .307 | .068 | .114 | .023 |
| 43 | .151 | .041 | .165 | .004 |
| 44 | .067 | .162 | .024 | .179 |
| 45 | .124 | .086 | .080 | .020 |
| 46 | .021 | .007 | .035 | .146 |
| 47 | .023 | .199 | .044 | .055 |
| 48 | .020 | .036 | .087 | .156 |
| 49 | .174 | .173 | .109 | .107 |
| 50 | .001 | .167 | .101 | .051 |
| 51 | .129 | .232 | .017 | .054 |
| 52 | .168 | .237 | .325 | .153 |
| 53 | .192 | .005 | .320 | .022 |
| 54 | .058 | .002 | .216 | .127 |
| 55 | .041 | .141 | .124 | .022 |
| 56 | .202 | .125 | .129 | .095 |
| 57 | .142 | .190 | .265 | .010 |
| 58 | .174 | .121 | .199 | .038 |
| 59 | .154 | .206 | .361 | .108 |
| 60 | .115 | .074 | .252 | .006 |
| 61 | .204 | .112 | .003 | .177 |
| 62 | .223 | .095 | .230 | .056 |
| 63 | .013 | .003 | .022 | .082 |
| 64 | .067 | .146 | .126 | .058 |
| 65 | .157 | .067 | .080 | .134 |
| 66 | .107 | .017 | .232 | .120 |
| 67 | .222 | .000 | .154 | .279 |
| 68 | .203 | .061 | .160 | .164 |
| 69 | .034 | .016 | .151 | .126 |
| 70 | .042 | .021 | .061 | .137 |
| 71 | .059 | .040 | .045 | .091 |
| 72 | .233 | .200 | .004 | .060 |
| 73 | .024 | .193 | .040 | .015 |
| 74 | .188 | .162 | .161 | .080 |
| 75 | .113 | .224 | .100 | .181 |
| 76 | .155 | .303 | .035 | .077 |
| 77 | .155 | .107 | .110 | .061 |
| 78 | .023 | .194 | .032 | .091 |
| 79 | .025 | .125 | .040 | .194 |
| 80 | .107 | .025 | .056 | .093 |
| 81 | .119 | .086 | .105 | .005 |
| 82 | .183 | .153 | .061 | .038 |
| 83 | .154 | .051 | .109 | .020 |
| 84 | .009 | .040 | .172 | .223 |
| 85 | .206 | .138 | .183 | .127 |
| 86 | .065 | .118 | .181 | .047 |
| 87 | .085 | .055 | .049 | .036 |
| 88 | .168 | .160 | .146 | .088 |
| 89 | .106 | .037 | .127 | .083 |
| 90 | .170 | .073 | .114 | .016 |
| 91 | .080 | .051 | .160 | .017 |
| 92 | .231 | .002 | .026 | .079 |
| 93 | .173 | .002 | .092 | .110 |
| 94 | .050 | .083 | .001 | .052 |
| 95 | .079 | .076 | .176 | .053 |
| 96 | .180 | .210 | .035 | .035 |
| 97 | .266 | .163 | .060 | .038 |
| 98 | .290 | .122 | .195 | .068 |
| 99 | .037 | .232 | .107 | .008 |
| 100 | .008 | .260 | .055 | .111 |
| 101 | .224 | .129 | .016 | .166 |
| 102 | .096 | .157 | .048 | .179 |
| 103 | .162 | .068 | .062 | .101 |
| 104 | .150 | .117 | .048 | .003 |
| 105 | .108 | .018 | .031 | .159 |
| 106 | .068 | .013 | .225 | .168 |
| 107 | .046 | .028 | .085 | .059 |
| 108 | .069 | .004 | .070 | .148 |
| 109 | .142 | .048 | .052 | .212 |
| 110 | .069 | .092 | .172 | .087 |
| 111 | .030 | .026 | .101 | .073 |
| 112 | .092 | .078 | .145 | .169 |
| 113 | .030 | .014 | .033 | .161 |
| 114 | .187 | .043 | .068 | .150 |
| 115 | .183 | .069 | .017 | .095 |
| 116 | .216 | .027 | .050 | .053 |
| 117 | .071 | .224 | .008 | .091 |
| 118 | .081 | .115 | .242 | .118 |
| 119 | .149 | .200 | .034 | .013 |
| 120 | .090 | .228 | .171 | .150 |
| 121 | .115 | .158 | .124 | .000 |
| 122 | .094 | .046 | .204 | .045 |
| 123 | .098 | .210 | .214 | .054 |
| 124 | .162 | .166 | .140 | .006 |
| 125 | .200 | .108 | .091 | .034 |
| 126 | .114 | .108 | .086 | .139 |
| 127 | .171 | .120 | .000 | .074 |
| 128 | .231 | .190 | .267 | .104 |
| 129 | .081 | .180 | .075 | .201 |
| 130 | .089 | .038 | .019 | .134 |
| 131 | .268 | .277 | .082 | .055 |
| 132 | .187 | .272 | .156 | .067 |
| 133 | .154 | .161 | .186 | .100 |
| 134 | .094 | .023 | .038 | .065 |
| 135 | .087 | .143 | .047 | .204 |
| 136 | .201 | .060 | .153 | .158 |
| 137 | .236 | .100 | .010 | .085 |
| 138 | .080 | .150 | .126 | .067 |
| 139 | .075 | .175 | .083 | .058 |
| 140 | .209 | .293 | .059 | .011 |
| 141 | .052 | .068 | .190 | .185 |
| 142 | .197 | .095 | .056 | .055 |
| 143 | .130 | .105 | .256 | .048 |
| 144 | .092 | .057 | .030 | .266 |
| 145 | .265 | .117 | .034 | .096 |
| 146 | .295 | .100 | .005 | .064 |
| 147 | .165 | .051 | .128 | .019 |
| 148 | .126 | .005 | .128 | .206 |
| 149 | .297 | .114 | .049 | .051 |
| 150 | .245 | .105 | .030 | .142 |
| 151 | .116 | .106 | .145 | .191 |
| 152 | .126 | .081 | .090 | .154 |
| 153 | .039 | .026 | .168 | .206 |
| 154 | .066 | .096 | .185 | .127 |
| 155 | .111 | .150 | .109 | .282 |
| 156 | .013 | .022 | .160 | .249 |
| 157 | .082 | .074 | .127 | .191 |
| 158 | .091 | .026 | .253 | .083 |
| 159 | .175 | .079 | .106 | .088 |
| 160 | .160 | .151 | .157 | .222 |

L COORDINATE ANALYSIS (d) SAMPLE-II CONTINUOUS TYPE + EUCLIDEAN DIST.

25.861

| ROOTS | 2.675 | 1.826 | 1.628 | 1.594 |
|---|---|---|---|---|
| OF TRACE | 10.3 | 17.4 | 23.7 | 29.0 |

| | | | | |
|---|---|---|---|---|
| 1 | .085 | .091 | .122 | .090 |
| 2 | .165 | .071 | .119 | .130 |
| 3 | .124 | .165 | .087 | .138 |
| 4 | .286 | .077 | .227 | .128 |
| 5 | .037 | .023 | .126 | .070 |
| 6 | .046 | .131 | .029 | .032 |
| 7 | .017 | .240 | .023 | .056 |
| 8 | .183 | .173 | .027 | .851 |
| 9 | .196 | .062 | .076 | .820 |
| 10 | .050 | .084 | .129 | .018 |
| 11 | .251 | .001 | .039 | .135 |
| 12 | .107 | .155 | .070 | .012 |
| 13 | .165 | .125 | .187 | .129 |
| 14 | .122 | .100 | .096 | .096 |
| 15 | .036 | .056 | .065 | .016 |
| 16 | .019 | .173 | .029 | .141 |
| 17 | .137 | .013 | .037 | .071 |
| 18 | .080 | .028 | .026 | .140 |
| 19 | .027 | .151 | .039 | .135 |
| 20 | .122 | .295 | .030 | .092 |
| 21 | .085 | .066 | .093 | .021 |
| 22 | .026 | .006 | .145 | .023 |
| 23 | .240 | .026 | .151 | .023 |
| 24 | .112 | .111 | .086 | .128 |
| 25 | .147 | .020 | .094 | .096 |
| 26 | .191 | .035 | .147 | .008 |
| 27 | .144 | .207 | .031 | .105 |
| 28 | .222 | .002 | .039 | .050 |
| 29 | .141 | .042 | .007 | .086 |
| 30 | .270 | .103 | .080 | .071 |
| 31 | .123 | .064 | .123 | .014 |
| 32 | .180 | .079 | .152 | .127 |
| 33 | .056 | .104 | .093 | .017 |
| 34 | .013 | .157 | .008 | .112 |
| 35 | .015 | .111 | .038 | .203 |
| 36 | .111 | .137 | .073 | .046 |
| 37 | .127 | .170 | .073 | .192 |
| 38 | .038 | .112 | .118 | .086 |
| 39 | .080 | .050 | .128 | .078 |
| 40 | .031 | .046 | .075 | .110 |
| 41 | .040 | .061 | .078 | .118 |
| 42 | .186 | .008 | .221 | .004 |
| 43 | .068 | .055 | .126 | .054 |
| 44 | .053 | .083 | .002 | .165 |
| 45 | .062 | .103 | .022 | .058 |
| 46 | .018 | .036 | .031 | .059 |
| 47 | .031 | .072 | .084 | .001 |
| 48 | .014 | .141 | .042 | .097 |
| 49 | .139 | .117 | .022 | .082 |
| 50 | .018 | .125 | .049 | .034 |
| 51 | .115 | .047 | .017 | .049 |
| 52 | .267 | .141 | .208 | .051 |
| 53 | .246 | .124 | .089 | .014 |
| 54 | .165 | .077 | .070 | .092 |
| 55 | .029 | .143 | .059 | .008 |
| 56 | .203 | .051 | .103 | .026 |
| 57 | .195 | .038 | .131 | .127 |
| 58 | .277 | .074 | .005 | .010 |
| 59 | .249 | .100 | .220 | .040 |
| 60 | .154 | .021 | .057 | .081 |
| 61 | .223 | .070 | .808 | .805 |
| 62 | .223 | .070 | .808 | .805 |
| 63 | .013 | .110 | .022 | .063 |
| 64 | .037 | .153 | .172 | .148 |
| 65 | .099 | .086 | .028 | .039 |
| 66 | .130 | .066 | .060 | .058 |
| 67 | .086 | .091 | .112 | .220 |
| 68 | .077 | .044 | .149 | .073 |
| 69 | .062 | .026 | .118 | .082 |
| 70 | .050 | .034 | .171 | .012 |
| 71 | .006 | .109 | .027 | .084 |
| 72 | .206 | .206 | .007 | .053 |
| 73 | .079 | .204 | .006 | .012 |
| 74 | .130 | .211 | .074 | .023 |
| 75 | .100 | .611 | .024 | .080 |
| 76 | .058 | .355 | .070 | .042 |
| 77 | .124 | .120 | .034 | .065 |
| 78 | .013 | .176 | .010 | .021 |
| 79 | .081 | .106 | .106 | .067 |
| 80 | .087 | .030 | .115 | .002 |
| 81 | .173 | .037 | .078 | .064 |
| 82 | .139 | .060 | .059 | .060 |
| 83 | .147 | .041 | .104 | .040 |
| 84 | .041 | .045 | .148 | .124 |
| 85 | .140 | .115 | .137 | .027 |
| 86 | .136 | .144 | .107 | .062 |
| 87 | .042 | .053 | .042 | .070 |
| 88 | .125 | .126 | .090 | .121 |
| 89 | .171 | .010 | .074 | .158 |
| 90 | .193 | .010 | .026 | .092 |
| 91 | .137 | .011 | .126 | .001 |
| 92 | .182 | .015 | .067 | .103 |
| 93 | .155 | .002 | .122 | .032 |
| 94 | .001 | .056 | .113 | .172 |
| 95 | .104 | .108 | .128 | .025 |
| 96 | .140 | .105 | .077 | .033 |
| 97 | .129 | .050 | .129 | .028 |
| 98 | .129 | .050 | .150 | .119 |
| 99 | .071 | .137 | .167 | .050 |
| 100 | .017 | .141 | .087 | .039 |
| 101 | .182 | .018 | .029 | .256 |
| 102 | .087 | .020 | .091 | .053 |
| 103 | .110 | .080 | .103 | .012 |
| 104 | .114 | .051 | .013 | .078 |
| 105 | .155 | .016 | .162 | .118 |
| 106 | .121 | .092 | .054 | .070 |
| 107 | .035 | .090 | .090 | .076 |
| 108 | .078 | .114 | .133 | |
| 109 | .082 | .078 | .161 | |
| 110 | .115 | .083 | .118 | |
| 111 | .085 | .030 | .196 | |
| 112 | .128 | .085 | .195 | |
| 113 | .021 | .061 | .010 | .100 |
| 114 | .123 | .092 | .072 | .110 |
| 115 | .160 | .082 | .040 | .083 |
| 116 | .182 | .087 | .040 | .110 |
| 117 | .104 | .064 | .040 | .161 |
| 118 | .109 | .078 | .078 | .181 |
| 119 | .127 | .079 | .035 | .132 |
| 120 | .028 | .116 | .030 | .046 |
| 121 | .060 | .021 | .069 | .062 |
| 122 | .160 | .225 | .009 | .054 |
| 123 | .160 | .042 | .088 | .075 |
| 124 | .155 | .042 | .088 | .075 |
| 125 | .126 | .123 | .106 | .050 |
| 126 | .126 | .123 | .068 | .050 |
| 127 | .150 | .028 | .068 | .050 |
| 128 | .150 | .080 | .185 | .074 |
| 129 | .067 | .045 | .069 | .103 |
| 130 | .106 | .135 | .163 | .077 |
| 131 | .082 | .144 | .196 | .068 |
| 132 | .088 | .144 | .186 | .136 |
| 133 | .059 | .043 | .043 | .056 |
| 134 | .059 | .074 | .017 | .056 |
| 135 | .166 | .111 | .003 | .215 |
| 136 | .087 | .099 | .183 | .117 |
| 137 | .088 | .057 | .504 | .885 |
| 138 | .073 | .118 | .044 | .015 |
| 139 | .213 | .174 | .062 | .150 |
| 140 | .092 | .024 | .130 | .076 |
| 141 | .096 | .073 | .081 | .026 |
| 142 | .143 | .045 | .160 | .097 |
| 143 | .046 | .110 | .014 | .143 |
| 144 | .223 | .074 | .057 | .040 |
| 145 | .158 | .051 | .080 | .615 |
| 146 | .158 | .051 | .080 | .615 |
| 147 | .116 | .014 | .080 | .126 |
| 148 | .243 | .069 | .032 | .021 |
| 149 | .168 | .053 | .285 | .131 |
| 150 | .119 | .062 | .059 | .172 |
| 151 | .119 | .062 | .052 | .114 |
| 152 | .041 | .064 | .076 | .116 |
| 153 | .178 | .145 | .154 | .038 |
| 154 | .162 | .060 | .041 | .259 |
| 155 | .018 | .113 | .031 | .143 |
| 156 | .022 | .113 | .031 | .143 |
| 157 | .026 | .053 | .119 | .033 |
| 158 | .189 | .075 | .087 | .010 |
| 159 | .084 | .022 | .160 | .246 |
| 160 | | | | |

APPENDIX VIII : The first four component scores from PCA

| SAMPLE-I | | | | | SAMPLE-II | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Individual | Component 1 | 2 | 3 | 4 | Individual | Component 1 | 2 | 3 | 4 |
| 1 | 36.4 | 5.34 | 12.5 | -6.00 | 1 | 23.3 | -6.95 | -2.57 | -8.19 |
| 2 | 32.3 | 0.72 | 16.2 | -4.96 | 2 | 35.7 | -14.3 | -5.40 | -6.52 |
| 3 | 23.7 | -0.90 | 17.4 | 0.22 | 3 | 29.7 | -11.8 | -4.04 | -7.74 |
| 4 | 20.4 | 6.11 | 20.9 | 3.57 | 4 | 31.8 | 1.54 | 1.11 | -2.33 |
| 5 | 20.9 | 3.83 | 16.0 | -0.64 | 5 | 33.8 | -3.16 | -11.9 | -6.03 |
| 6 | 30.1 | 1.46 | 18.7 | -0.16 | 6 | 31.8 | -7.08 | -2.48 | -6.45 |
| 7 | 26.3 | -1.97 | 17.2 | -0.02 | 7 | 29.5 | -6.34 | -1.56 | -5.61 |
| 8 | 23.4 | 1.30 | 12.3 | -2.00 | 8 | 23.9 | -2.42 | 2.05 | -2.66 |
| 9 | 13.2 | 2.18 | 13.0 | 2.71 | 9 | 27.0 | -2.52 | -4.17 | -7.27 |
| 10 | 22.3 | 5.08 | 11.2 | 1.06 | 10 | 29.0 | -8.63 | -8.27 | -9.87 |
| 11 | 24.1 | -0.58 | 27.7 | -0.19 | 11 | 37.2 | -0.94 | -2.10 | -7.08 |
| 12 | 27.0 | 1.27 | 24.3 | -0.34 | 12 | 28.1 | -11.7 | -3.31 | -6.84 |
| 13 | 27.2 | -8.92 | 22.9 | 4.32 | 13 | 35.5 | -4.54 | 2.93 | -8.36 |
| 14 | 20.9 | -7.48 | 17.9 | 3.10 | 14 | 32.0 | -14.4 | -1.36 | -9.62 |
| 15 | 27.5 | -9.37 | 23.5 | -1.86 | 15 | 23.8 | -5.89 | -0.29 | -2.48 |
| 16 | 22.4 | -9.62 | 19.7 | 0.59 | 16 | 34.2 | -9.16 | 2.48 | -10.1 |
| 17 | 22.7 | -8.97 | 20.2 | 1.74 | 17 | 37.3 | -10.7 | -3.66 | -13.5 |
| 18 | 20.4 | -4.02 | 20.8 | 2.42 | 18 | 44.3 | -8.94 | -9.55 | -15.1 |
| 19 | 13.2 | -7.85 | 17.5 | 0.25 | 19 | 28.3 | -8.96 | -0.01 | -3.33 |
| 20 | 24.5 | -8.01 | 17.7 | 2.04 | 20 | 17.8 | -6.92 | 3.97 | -3.08 |
| 21 | 38.5 | -4.34 | 11.5 | 3.71 | 21 | 40.8 | -2.54 | -13.8 | -7.92 |
| 22 | 38.7 | -4.31 | 15.8 | 3.48 | 22 | 37.2 | -10.0 | -10.2 | -5.72 |
| 23 | 39.4 | 2.41 | 11.5 | -2.16 | 23 | 33.1 | -12.2 | -12.4 | -7.62 |
| 24 | 35.5 | -3.62 | 15.7 | 4.16 | 24 | 43.1 | -9.08 | -12.5 | -10.4 |
| 25 | 35.6 | -5.89 | 12.5 | 4.23 | 25 | 44.0 | -11.3 | -12.4 | -13.0 |

| Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 26 | 30.9 | -3.14 | 12.1 | 4.92 |
| 27 | 37.7 | -5.00 | 14.0 | 3.46 |
| 28 | 35.2 | -4.31 | 12.8 | 3.14 |
| 29 | 44.2 | -2.81 | 16.3 | 0.02 |
| 30 | 38.8 | -0.80 | 13.2 | 3.72 |
| 31 | 32.7 | -0.54 | 19.1 | 2.35 |
| 32 | 40.1 | -0.72 | 20.3 | -0.50 |
| 33 | 29.0 | -4.97 | 24.4 | -0.04 |
| 34 | 41.8 | -3.18 | 25.8 | -1.21 |
| 35 | 35.3 | -2.99 | 20.3 | 0.29 |
| 36 | 35.1 | -1.83 | 19.1 | 1.54 |
| 37 | 34.0 | -1.81 | 21.0 | -1.33 |
| 38 | 31.0 | -4.29 | 9.71 | 0.65 |
| 39 | 36.3 | -3.35 | 20.0 | 0.87 |
| 40 | 32.4 | -5.93 | 18.5 | 2.14 |
| 41 | 29.1 | -2.81 | 20.9 | -0.21 |
| 42 | 32.7 | -2.26 | 21.1 | -0.61 |
| 43 | 25.4 | 0.46 | 16.5 | 2.55 |
| 44 | 25.6 | -1.23 | 17.8 | 3.38 |
| 45 | 20.0 | 2.28 | 17.4 | 2.49 |
| 46 | 23.6 | -2.29 | 17.9 | 1.02 |
| 47 | 20.4 | 0.51 | 18.8 | 1.28 |
| 48 | 31.5 | -0.55 | 21.8 | 0.83 |
| 49 | 23.8 | -1.08 | 18.9 | 0.53 |
| 50 | 24.1 | -0.65 | 16.7 | 1.16 |
| 51 | 25.7 | 2.83 | 13.8 | -0.69 |
| 52 | 19.5 | 1.58 | 14.0 | 4.63 |
| 53 | 19.8 | 1.17 | 18.7 | 1.07 |

| Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 26 | 31.2 | -10.2 | -8.62 | -1.51 |
| 27 | 24.2 | -9.70 | -4.18 | -5.61 |
| 28 | 28.1 | -13.0 | -7.07 | -7.14 |
| 29 | 34.4 | -10.7 | -11.7 | -7.82 |
| 30 | 25.2 | -15.0 | -7.27 | -4.58 |
| 31 | 38.5 | -4.18 | -5.45 | -10.6 |
| 32 | 37.5 | -2.68 | -6.32 | -14.6 |
| 33 | 43.0 | -11.0 | -7.41 | -15.0 |
| 34 | 40.1 | -7.34 | -9.45 | -15.9 |
| 35 | 25.1 | -7.33 | -4.37 | -11.6 |
| 36 | 34.4 | 05.63 | -3.89 | -11.7 |
| 37 | 29.5 | -8.95 | -11.9 | -8.70 |
| 38 | 40.6 | -8.94 | -9.49 | -13.9 |
| 39 | 34.3 | -5.40 | -5.19 | -10.0 |
| 40 | 32.2 | -8.59 | -6.04 | -13.9 |
| 41 | 42.1 | -9.91 | -7.26 | -12.6 |
| 42 | 39.4 | -2.54 | -4.17 | -12.7 |
| 43 | 38.1 | -7.41 | -5.37 | -12.3 |
| 44 | 48.6 | -8.87 | -10.1 | -13.1 |
| 45 | 30.1 | -6.75 | -2.84 | -7.13 |
| 46 | 33.9 | -7.81 | -7.63 | -11.5 |
| 47 | 37.5 | -7.11 | -7.88 | -10.3 |
| 48 | 38.6 | -10.3 | -3.54 | -14.5 |
| 49 | 30.1 | -4.78 | -1.90 | -10.2 |
| 50 | 29.3 | -7.99 | -2.06 | -12.5 |
| 51 | 36.0 | -4.61 | -7.62 | -11.6 |
| 52 | 16.2 | 0.07 | 1.35 | -0.73 |
| 53 | 37.8 | 3.71 | -13.0 | -8.08 |

| Individual | Component 1 | 2 | 3 | 4 | Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|
| 54 | 17.8 | 2.17 | 10.7 | 1.52 | 54 | 31.8 | -2.50 | -6.18 | -8.05 |
| 55 | 18.3 | 1.81 | 13.0 | 1.36 | 55 | 39.3 | -3.14 | -12.9 | -8.24 |
| 56 | 14.6 | 3.87 | 12.4 | 2.03 | 56 | 23.9 | -2.00 | -1.22 | -2.63 |
| 57 | 23.7 | 1.77 | 14.1 | 1.63 | 57 | 25.4 | -0.39 | -2.28 | -5.66 |
| 58 | 22.2 | 1.80 | 20.4 | 1.06 | 58 | 31.0 | -1.99 | -2.63 | -7.55 |
| 59 | 28.5 | 2.17 | 20.6 | 1.71 | 59 | 21.7 | 0.34 | -2.45 | 0.19 |
| 60 | 19.2 | 2.32 | 14.2 | 0.66 | 60 | 28.3 | -1.69 | -6.49 | -3.90 |
| 61 | 27.9 | 2.42 | 11.2 | -1.55 | 61 | 29.6 | -3.33 | -5.99 | -6.90 |
| 62 | 26.6 | 1.88 | 14.0 | 1.01 | 62 | 37.6 | 2.63 | -8.83 | -12.9 |
| 63 | 29.0 | 0.13 | 13.3 | 2.33 | 63 | 30.8 | -5.37 | -8.58 | -6.60 |
| 64 | 33.0 | 0.89 | 16.5 | 3.10 | 64 | 43.0 | -2.31 | -17.7 | -2.37 |
| 65 | 30.7 | 3.90 | 16.7 | 2.02 | 65 | 38.0 | -5.76 | -15.5 | -6.05 |
| 66 | 26.1 | 4.65 | 11.3 | 3.96 | 66 | 36.4 | -0.49 | -9.87 | -8.45 |
| 67 | 30.2 | 2.03 | 13.0 | 1.55 | 67 | 30.3 | -7.57 | -14.4 | -11.2 |
| 68 | 32.4 | -2.66 | 13.3 | 2.10 | 68 | 29.8 | -6.88 | -8.29 | -5.97 |
| 69 | 26.1 | 0.09 | 14.1 | 4.27 | 69 | 25.5 | -2.03 | -9.93 | -2.01 |
| 70 | 31.6 | 1.77 | 17.7 | 2.74 | 70 | 34.3 | -4.45 | -7.82 | -6.55 |
| 71 | 31.9 | -2.86 | 17.8 | 2.77 | 71 | 35.8 | -8.08 | -7.71 | -11.5 |
| 72 | 25.2 | 3.35 | 17.8 | 3.58 | 72 | 40.1 | -11.7 | -12.9 | -11.8 |
| 73 | 41.7 | -0.46 | 19.2 | 1.52 | 73 | 40.1 | -6.18 | -12.9 | -14.1 |
| 74 | 31.8 | -4.24 | 17.8 | 2.45 | 74 | 39.8 | -1.54 | -12.3 | -11.9 |
| 75 | 33.2 | -2.18 | 15.2 | 0.80 | 75 | 43.9 | -3.10 | -12.5 | -13.2 |
| 76 | 35.9 | -2.80 | 19.2 | 0.88 | 76 | 51.1 | -1.80 | -18.3 | -14.0 |
| 77 | 32.3 | 3.24 | 11.2 | 1.68 | 77 | 38.3 | -1.68 | -15.8 | -11.1 |
| 78 | 32.7 | 1.92 | 12.2 | 2.24 | 78 | 40.9 | -4.23 | -9.39 | -9.44 |
| 79 | 29.2 | 0.65 | 13.3 | 2.51 | 79 | 36.8 | -5.90 | -14.1 | -8.78 |
| 80 | 24.9 | 1.30 | 16.1 | 4.41 | 80 | 32.6 | -4.67 | -7.42 | -5.65 |
| 81 | 25.2 | -7.57 | 14.7 | -2.12 | 81 | 34.1 | -12.0 | -5.11 | -12.8 |

| Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 82 | 30.2 | -9.80 | 14.7 | -4.00 |
| 83 | 26.8 | -7.56 | 12.9 | -1.78 |
| 84 | 34.2 | -5.61 | 19.9 | -4.70 |
| 85 | 26.2 | -8.33 | 18.1 | -3.50 |
| 86 | 23.6 | -9.75 | 12.9 | -1.70 |
| 87 | 24.5 | -7.69 | 14.6 | -3.35 |
| 88 | 28.4 | -3.48 | 12.4 | -9.23 |
| 89 | 34.8 | -8.71 | 18.1 | -3.54 |
| 90 | 21.6 | -10.00 | 11.9 | -2.26 |
| 91 | 28.1 | 0.62 | 19.1 | 4.55 |
| 92 | 31.1 | -4.79 | 19.4 | 4.62 |
| 93 | 28.2 | -2.65 | 16.9 | 5.21 |
| 94 | 34.2 | -3.00 | 18.7 | 5.69 |
| 95 | 29.5 | -2.70 | 19.7 | 6.86 |
| 96 | 31.8 | -7.22 | 19.4 | 5.95 |
| 97 | 33.9 | 0.02 | 18.7 | 3.55 |
| 98 | 29.8 | -4.52 | 22.6 | 5.01 |
| 99 | 34.3 | 0.73 | 16.8 | 5.42 |
| 100 | 29.5 | -0.73 | 15.9 | 5.13 |
| 101 | 28.0 | -3.89 | 15.2 | 6.39 |
| 102 | 25.4 | -0.99 | 18.2 | 8.39 |
| 103 | 27.2 | -3.89 | 16.5 | 5.79 |
| 104 | 27.1 | -5.93 | 16.7 | 6.52 |
| 105 | 30.4 | -5.24 | 15.5 | 3.68 |
| 106 | 31.1 | -6.71 | 19.7 | 2.59 |
| 107 | 34.7 | -7.50 | 20.6 | 3.62 |
| 108 | 24.5 | -4.85 | 17.2 | 6.67 |
| 109 | 29.4 | -5.19 | 15.2 | 4.93 |

| Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 82 | 47.0 | -10.6 | -10.4 | -18.2 |
| 83 | 33.0 | -13.2 | -5.08 | -13.8 |
| 84 | 29.9 | -7.41 | -3.14 | -15.4 |
| 85 | 25.1 | -4.86 | 0.20 | -12.2 |
| 86 | 24.2 | -12.5 | -1.22 | -9.14 |
| 87 | 39.7 | -10.0 | -6.64 | -12.1 |
| 88 | 30.4 | -11.2 | -2.67 | -13.4 |
| 89 | 26.2 | -11.9 | -5.71 | -10.9 |
| 90 | 27.7 | -11.8 | -2.33 | -10.9 |
| 91 | 35.8 | -4.95 | -5.54 | -10.1 |
| 92 | 39.3 | -14.3 | -5.95 | -6.08 |
| 93 | 35.9 | -13.4 | -6.83 | -8.65 |
| 94 | 37.1 | -8.13 | -6.41 | -3.31 |
| 95 | 41.1 | -4.62 | -9.84 | -9.72 |
| 96 | 27.0 | -12.3 | -3.51 | -5.24 |
| 97 | 22.7 | -14.0 | -5.52 | -3.16 |
| 98 | 34.9 | -11.1 | -9.31 | -4.54 |
| 99 | 30.4 | -5.73 | -2.98 | -4.31 |
| 100 | 25.2 | -8.55 | -1.27 | -4.69 |
| 101 | 39.4 | -13.5 | -6.24 | -3.27 |
| 102 | 44.5 | -11.3 | -6.39 | -3.52 |
| 103 | 33.0 | -10.5 | -4.26 | -7.51 |
| 104 | 30.6 | -9.76 | -5.00 | -4.71 |
| 105 | 35.9 | -11.6 | -6.47 | -10.5 |
| 106 | 28.3 | -1.76 | -2.87 | -0.06 |
| 107 | 32.8 | -8.85 | -6.13 | -6.51 |
| 108 | 30.3 | -6.28 | -3.71 | -5.10 |
| 109 | 30.3 | -10.2 | -1.92 | -2.34 |

| Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 110 | 18.9 | -5.09 | 12.9 | 5.71 |
| 111 | 23.2 | -4.52 | 13.7 | -0.27 |
| 112 | 24.4 | -8.75 | 10.6 | 3.01 |
| 113 | 27.8 | -8.68 | 12.1 | 4.70 |
| 114 | 23.3 | -7.39 | 14.6 | 5.52 |
| 115 | 27.6 | -6.06 | 14.6 | 1.64 |
| 116 | 32.9 | -8.95 | 12.9 | 1.83 |
| 117 | 32.7 | -6.60 | 12.3 | 0.37 |
| 118 | 24.0 | -7.04 | 11.0 | 4.06 |
| 119 | 28.1 | -5.81 | 13.3 | 1.28 |
| 120 | 25.9 | 10.4 | 14.5 | 4.52 |
| 121 | 27.3 | -0.02 | 17.9 | 2.60 |
| 122 | 28.3 | -1.65 | 20.4 | 0.13 |
| 123 | 37.2 | 0.35 | 15.4 | -5.51 |
| 124 | 26.6 | -3.71 | 17.2 | -2.02 |
| 125 | 27.5 | -3.43 | 18.8 | -4.41 |
| 126 | 26.5 | -1.61 | 10.6 | -0.93 |
| 127 | 32.5 | -0.24 | 12.4 | 0.32 |
| 128 | 26.6 | -3.84 | 15.8 | -1.57 |
| 129 | 26.6 | 0.46 | 12.7 | 1.88 |
| 130 | 25.7 | -0.13 | 12.2 | 1.93 |
| 131 | 43.8 | 0.49 | 18.2 | -3.04 |
| 132 | 36.5 | -3.14 | 19.4 | 1.41 |
| 133 | 32.6 | -2.51 | 18.2 | 0.99 |
| 134 | 41.4 | -1.59 | 19.0 | -2.45 |
| 135 | 43.3 | 1.60 | 13.8 | 0.55 |
| 136 | 31.9 | -2.62 | 15.7 | 0.63 |
| 137 | 34.2 | -3.27 | 17.5 | 3.14 |

| Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 110 | 40.1 | -6.62 | -11.7 | -4.28 |
| 111 | 29.6 | -8.00 | -8.65 | -8.73 |
| 112 | 25.9 | -5.71 | -5.83 | -9.92 |
| 113 | 30.8 | -6.29 | -7.76 | -7.91 |
| 114 | 24.8 | -12.5 | -4.24 | -6.82 |
| 115 | 30.6 | -9.67 | -7.58 | -11.4 |
| 116 | 37.2 | -11.4 | -10.6 | -8.96 |
| 117 | 25.2 | -7.13 | -2.28 | -2.72 |
| 118 | 36.9 | 0.09 | -17.0 | -11.2 |
| 119 | 20.0 | -9.67 | -5.30 | -6.78 |
| 120 | 22.3 | -8.64 | -1.26 | -7.65 |
| 121 | 42.2 | -9.46 | -6.42 | -11.4 |
| 122 | 30.5 | -7.22 | -3.92 | -12.6 |
| 123 | 42.4 | -1.92 | -3.50 | -6.61 |
| 124 | 36.7 | -2.91 | -7.15 | -12.9 |
| 125 | 39.5 | -0.79 | -12.1 | -14.7 |
| 126 | 37.8 | -7.60 | -6.98 | -14.4 |
| 127 | 41.3 | -7.05 | -1.97 | -9.04 |
| 128 | 23.8 | -6.75 | -1.08 | -9.92 |
| 129 | 25.6 | -3.23 | -4.08 | -3.94 |
| 130 | 28.4 | -4.36 | -6.54 | -6.63 |
| 131 | 47.5 | -5.44 | -8.07 | -16.5 |
| 132 | 37.7 | -5.92 | -1.47 | -12.0 |
| 133 | 43.1 | -6.62 | -8.81 | -12.0 |
| 134 | 39.5 | -8.71 | -8.30 | -10.5 |
| 135 | 52.5 | -4.42 | -12.7 | -14.8 |
| 136 | 36.5 | -7.48 | 1.96 | -8.44 |
| 137 | 32.8 | -3.77 | -5.79 | -10.6 |

| Individual | Component 1 | 2 | 3 | 4 | Individual | Component 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|
| 138 | 40.6 | 3.04 | 16.8 | -2.58 | 138 | 47.2 | - 5.01 | -13.1 | -13.7 |
| 139 | 44.5 | 0.50 | 19.3 | -2.96 | 139 | 26.7 | -5.01 | -5.23 | -5.97 |
| 140 | 32.5 | 0.07 | 16.2 | 2.24 | 140 | 16.0 | -0.71 | -0.97 | -5.56 |
| 141 | 32.4 | -8.36 | 13.6 | -1.43 | 141 | 36.8 | -7.43 | -9.25 | -1.56 |
| 142 | 31.7 | -6.44 | 14.9 | -2.79 | 142 | 34.2 | -11.8 | -10.4 | -9.98 |
| 143 | 33.0 | -8.39 | 15.3 | 0.92 | 143 | 29.6 | -6.49 | -3.27 | -12.6 |
| 144 | 32.3 | -6.41 | 13.2 | -1.73 | 144 | 30.1 | -8.78 | -6.04 | -13.2 |
| 145 | 28.3 | -11.9 | 16.8 | 0.84 | 145 | 34.6 | -13.4 | -9.62 | -9.21 |
| 146 | 29.0 | -6.23 | 14.7 | 0.38 | 146 | 32.5 | -13.0 | -9.54 | -11.4 |
| 147 | 31.8 | -9.29 | 20.0 | -0.84 | 147 | 32.9 | -3.66 | -4.66 | -10.6 |
| 148 | 34.2 | -9.09 | 16.7 | 0.15 | 148 | 29.4 | -11.1 | -5.93 | -10.0 |
| 149 | 35.7 | -8.72 | 16.2 | -0.55 | 149 | 37.8 | -13.1 | -11.2 | -11.1 |
| 150 | 30.4 | -10.6 | 16.8 | -0.54 | 150 | 24.7 | -11.3 | -8.48 | -7.32 |
| 151 | 31.3 | -8.08 | 21.7 | 4.09 | 151 | 32.9 | -8.95 | 0.62 | -7.34 |
| 152 | 30.4 | -2.70 | 21.4 | 1.82 | 152 | 44.5 | -14.8 | -1.39 | -10.9 |
| 153 | 20.8 | -9.53 | 16.8 | 2.57 | 153 | 36.4 | -10.6 | 0.04 | -10.3 |
| 154 | 28.5 | -8.72 | 22.7 | 1.59 | 154 | 25.0 | -13.3 | -0.34 | -5.44 |
| 155 | 29.5 | -7.51 | 25.8 | 2.95 | 155 | 35.1 | -12.7 | -3.30 | -3.92 |
| 156 | 28.9 | -5.92 | 23.7 | 1.18 | 156 | 29.4 | -9.72 | 2.22 | -5.33 |
| 157 | 27.8 | -9.43 | 24.0 | 1.00 | 157 | 26.7 | -8.96 | -0.75 | -3.39 |
| 158 | 26.1 | -10.5 | 21.4 | 3.62 | 158 | 32.2 | -9.46 | 0.36 | -11.2 |
| 159 | 23.7 | -8.68 | 16.3 | 3.73 | 159 | 26.0 | -13.7 | -2.67 | -5.01 |
| 160 | 21.6 | -7.48 | 16.3 | 5.19 | 160 | 39.4 | -7.13 | -2.35 | -5.53 |

APPENDIX IX : The results of "REGROUP" analysis for the tuber, plant and fresh leaf; leaf herbarium data analysed separately.

(a) SAMPLE I - tuber characters (mixed-mode)

Group 1 - 32 33 34 35 36 37 38 39 40

Group 2 - 11 31 58 62 65 70 77 78 79 80
95 99 102 110

Group 3 - 13 14 15 101 103 114 118 120 133 136
138 139 148 149

Group 4 - 81 82 83 84 85 86 87 88 89 90
112 115 116 117 119 142

Group 5 - 18 61 63 64 66 67 69 91 92 93
94 97 98 100 121 122 128

Group 6 - 41 42 43 44 45 46 47 48 49 50
72 140

Group 7 - 68 71 73 74 75 76 108 109 111 123
124 125 126 127 129 130 152

Group 8 - 1 2 3 4 5 6 7 8 9 10
12 23 51 53 54 55 56 59 60

Group 9 - 16 17 19 20 104 105 106 107 113 141
143 144 145 146 147 150 151 153 154 155
156 158

Group 10 - 21 22 24 25 26 27 28 29 30 52
57 96 131 132 134 135 137 157 159 160

(b) SAMPLE I - Plant and fresh leaf characters

Group 1 - 13 15 16 19 20 151 152 153 154 155
157 158 159 160

Group 2 - 64 70 72 73 74 75 78 79 80 91
98 111 121 126 127 129 130

Group 3 - 82 84 85 86 87 116 128 135 147 148

Group 4 - 38 89 112 113 120 137 141 142 143 144
145 149 150

Group 5 - 14 17 23 44 45 47 94 95 96 97
99 100 118 125 131 132 134 140

Group 6 - 11 12 18 31 32 33 34 40 41 42
43 46 48 49 50 65 71 88 90 122
133 136 138 139 156

Group 7 - 35 36 37 39 61 62 63 76 77 123
124

Group 8 - 1 2 3 4 5 6 7 8 9 10
51 52 53 54 55 56 57 58 59 60
67

Group 9 - 30 66 68 69 81 83 92 93 101 102
103 104 105 106 107 108 109 110 114 115
117 119 146

Group 10 - 21 22 24 25 26 27 28 29

(c) SAMPLE I - leaf herbarium characters

Group 1 - 11 12 18 33 34 37 40 84 95 151
152 155 156

Group 2 - 9 14 16 17 19 20 41 46 50 52
85 110 120 122 145 159 160

Group 3 - 5 62 67 68 69 75 78 79 105 109
117 119 130

Group 4 - 8 55 56 57 60 81 82 86 101 111
112 113 114 115 116 118

Group 5 - 6 24 32 35 36 39 72 74 80 97
100 121 132 137 140

Group 6 - 13 15 31 42 45 47 48 49 87 153
154 157 158

Group 7 - 2 7 10 38 44 51 54 70 76 83
88 89 90 123 124 125 126 128 129 141
142 146 147 148 149 150

Group 8 - 3 4 43 53 58 59 71 91 92 93
94 96 98 102 103 104 106 107 108 143

Group 9 - 1 21 22 25 26 27 28 29 30 61
63 64 65 66 77 99 127 133 136 144

Group 10 - 23 73 131 134 135 138 139

(d) SAMPLE II - tuber characters

Group 1 - 2 3 10 14 72 142 145 146 149 154

Group 2 - 13 20 32 36 40 50 61 62 85 87

Group 3 - 34 35 37 38 39 71 74 75 76 79
120 121 126 144 148 158

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group 4 - | 12 | 24 | 46 | 47 | 65 | 67 | 68 | 69 | 80 | 92 |
| | 96 | 97 | 98 | 104 | 114 | 117 | 129 | 150 | | |
| Group 5 - | 8 | 15 | 42 | 43 | 45 | 49 | 63 | 70 | 94 | 100 |
| | 122 | 125 | 128 | 131 | 133 | 136 | 137 | 141 | 143 | |
| Group 6 - | 1 | 5 | 6 | 9 | 16 | 18 | 48 | 103 | 107 | 119 |
| | 132 | 134 | 138 | 139 | | | | | | |
| Group 7 - | 7 | 17 | 19 | 21 | 31 | 33 | 51 | 60 | 64 | 73 |
| | 101 | 105 | 108 | 110 | 118 | 123 | 124 | 127 | 130 | 135 |
| | 140 | 147 | 151 | 153 | 156 | 157 | 160 | | | |
| Group 8 - | 4 | 11 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| | 66 | 77 | 91 | 95 | 99 | 102 | 106 | 109 | 112 | |
| Group 9 - | 81 | 82 | 83 | 84 | 86 | 88 | 89 | 90 | 111 | 113 |
| | 115 | 116 | | | | | | | | |
| Group 10 - | 22 | 23 | 25 | 26 | 27 | 28 | 29 | 30 | 41 | 44 |
| | 78 | 93 | 152 | 159 | | | | | | |

(e) SAMPLE II - plant and fresh leaf characters

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 - | 15 | 17 | 18 | 19 | 43 | 51 | 63 | 73 | 83 | 84 |
| | 107 | 125 | 126 | 133 | 153 | 155 | 156 | 157 | 158 | |
| Group 2 - | 10 | 29 | 40 | 44 | 47 | 50 | 71 | 87 | 90 | 100 |
| | 119 | | | | | | | | | |
| Group 3 - | 33 | 34 | 38 | 39 | 61 | 78 | 122 | 138 | 141 | 143 |
| Group 4 - | 3 | 12 | 14 | 25 | 79 | 86 | 92 | 93 | 94 | 96 |
| | 97 | 98 | 114 | 116 | 134 | 148 | 154 | 159 | | |
| Group 5 - | 1 | 6 | 8 | 13 | 16 | 20 | 41 | 45 | 48 | 80 |
| | 91 | 99 | 120 | 135 | 139 | 140 | 151 | 160 | | |
| Group 6 - | 4 | 9 | 11 | 31 | 32 | 52 | 53 | 57 | 58 | 59 |
| | 60 | 62 | 123 | 124 | | | | | | |
| Group 7 - | 5 | 21 | 36 | 42 | 56 | 74 | 75 | 76 | 77 | 95 |
| | 106 | 108 | 112 | 118 | 127 | 131 | 132 | 136 | 137 | 147 |
| Group 8 - | 35 | 46 | 49 | 54 | 66 | 69 | 85 | 111 | 113 | 117 |
| | 128 | 129 | 130 | | | | | | | |
| Group 9 - | 23 | 24 | 28 | 30 | 37 | 55 | 65 | 67 | 68 | 72 |
| | 81 | 82 | 89 | 102 | 121 | 142 | 144 | 145 | 146 | 149 |
| | 150 | | | | | | | | | |
| Group 10 - | 2 | 7 | 22 | 26 | 27 | 64 | 70 | 88 | 101 | 103 |
| | 104 | 105 | 109 | 110 | 115 | 152 | | | | |

(f) SAMPLE II - leaf herbarium characters

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 - | 2 | 9 | 16 | 26 | 34 | 54 | 70 | 93 | 98 | 101 |
| | 103 | 104 | 105 | 145 | | | | | | |
| Group 2 - | 1 | 4 | 10 | 15 | 40 | 51 | 57 | 59 | 68 | 71 |
| | 90 | 91 | 96 | 99 | 115 | 144 | | | | |
| Group 3 - | 11 | 18 | 22 | 24 | 36 | 44 | 78 | 82 | 94 | 107 |
| | 108 | 109 | 121 | 126 | 131 | 135 | 155 | | | |
| Group 4 - | 23 | 53 | 60 | 63 | 65 | 66 | 67 | 69 | 73 | 74 |
| | 77 | 111 | 113 | 118 | 130 | | | | | |
| Group 5 - | 3 | 7 | 8 | 12 | 14 | 19 | 20 | 43 | 45 | 49 |
| | 50 | 85 | 122 | 128 | 139 | 140 | 143 | 154 | 159 | |
| Group 6 - | 17 | 27 | 28 | 30 | 35 | 52 | 56 | 97 | 100 | 112 |
| | 114 | 119 | 120 | 150 | | | | | | |
| Group 7 - | 21 | 29 | 31 | 38 | 39 | 41 | 42 | 55 | 79 | 102 |
| | 125 | 133 | 134 | 138 | 142 | 146 | 147 | | | |
| Group 8 - | 5 | 25 | 62 | 64 | 72 | 75 | 76 | 80 | 95 | 106 |
| | 110 | 116 | 124 | | | | | | | |
| Group 9 - | 13 | 32 | 33 | 87 | 92 | 123 | 127 | 132 | 136 | 151 |
| | 152 | 153 | 156 | 158 | 160 | | | | | |
| Group 10 - | 6 | 37 | 46 | 47 | 48 | 58 | 61 | 81 | 83 | 84 |
| | 86 | 88 | 89 | 117 | 129 | 137 | 141 | 148 | 149 | 157 |

## APPENDIX X: The first four vector scores of the sixteen families analysed together using different character sets.

PRINCIPAL COORDINATE ANALYSIS (a) SAMPLE-I TUBER CHARACTERS

TRACE = 79,514

| | | | | |
|---|---|---|---|---|
| LATENT ROOTS | 8,445 | 6,230 | 5,099 | 4,284 |
| PERCENT OF TRACE | 10,6 | 16,5 | 24,9 | 30,3 |
| 1 | .000 | .416 | -.026 | .140 |
| 2 | -.094 | .531 | -.013 | .042 |
| 3 | -.109 | .403 | -.101 | -.127 |
| 4 | -.162 | .340 | .221 | .268 |
| 5 | -.150 | .565 | .069 | .130 |
| 6 | -.080 | .477 | .017 | .065 |
| 7 | .183 | .145 | .102 | -.066 |
| 8 | -.019 | .376 | .036 | .074 |
| 9 | .015 | .372 | .050 | .209 |
| 10 | .133 | .392 | .183 | .047 |
| 11 | -.228 | .115 | .010 | .090 |
| 12 | -.228 | .225 | .208 | .031 |
| 13 | -.085 | .336 | .166 | -.030 |
| 14 | .090 | .242 | .168 | -.143 |
| 15 | .178 | .452 | .223 | .119 |
| 16 | .284 | .203 | .232 | -.137 |
| 17 | -.215 | .101 | .294 | .190 |
| 18 | -.213 | .067 | -.230 | -.146 |
| 19 | .090 | .188 | .161 | -.154 |
| 20 | .221 | .153 | .124 | .255 |
| 21 | .323 | .052 | .364 | .131 |
| 22 | .264 | -.112 | .411 | .013 |
| 23 | -.044 | .356 | .041 | .062 |
| 24 | .173 | .206 | .337 | .210 |
| 25 | .165 | -.036 | .350 | .097 |
| 26 | .304 | -.044 | .306 | .158 |
| 27 | .374 | -.077 | .164 | .147 |
| 28 | .264 | -.013 | .266 | .105 |
| 29 | .206 | -.038 | .265 | .042 |
| 30 | .209 | .050 | .400 | .102 |
| 31 | -.219 | -.236 | .107 | .138 |
| 32 | -.110 | -.440 | -.133 | .011 |
| 33 | -.150 | -.320 | -.253 | .045 |
| 34 | -.220 | -.078 | -.253 | -.225 |
| 35 | -.081 | -.404 | -.162 | -.027 |
| 36 | -.111 | -.424 | -.078 | .010 |
| 37 | -.110 | -.287 | -.148 | -.059 |
| 38 | -.132 | -.266 | -.093 | .106 |
| 39 | -.177 | -.339 | -.099 | .014 |
| 40 | -.084 | -.308 | -.029 | .085 |
| 41 | -.199 | -.307 | -.070 | .276 |
| 42 | -.383 | -.047 | -.200 | .097 |
| 43 | -.373 | -.146 | -.088 | .191 |
| 44 | -.427 | -.032 | -.027 | .237 |
| 45 | -.436 | -.076 | -.098 | .266 |
| 46 | -.385 | -.014 | -.125 | .185 |
| 47 | -.341 | -.108 | -.072 | .306 |
| 48 | -.387 | -.165 | -.015 | .247 |
| 49 | -.271 | -.166 | -.222 | .270 |
| 50 | -.370 | -.050 | -.052 | .322 |
| 51 | -.076 | -.271 | -.117 | .223 |
| 52 | -.114 | -.015 | -.247 | .313 |
| 53 | -.011 | -.212 | -.042 | .226 |
| 54 | -.040 | -.036 | -.143 | .445 |
| 55 | -.091 | -.217 | -.070 | .274 |
| 56 | -.205 | -.338 | -.151 | .259 |
| 57 | -.003 | -.055 | -.260 | .240 |
| 58 | -.044 | -.018 | -.023 | .282 |
| 59 | -.252 | -.103 | -.038 | .173 |
| 60 | -.017 | -.097 | -.036 | -.455 |
| 61 | -.207 | -.201 | -.131 | -.076 |
| 62 | -.301 | -.090 | -.075 | -.335 |
| 63 | -.277 | -.141 | -.010 | -.226 |
| 64 | -.262 | -.006 | -.141 | -.236 |
| 65 | -.236 | -.111 | -.001 | -.106 |
| 66 | -.286 | -.123 | -.061 | -.040 |
| 67 | -.289 | -.214 | -.074 | -.050 |
| 68 | -.027 | -.177 | -.050 | -.049 |
| 69 | -.371 | -.191 | -.018 | -.150 |
| 70 | -.279 | -.061 | -.057 | -.133 |
| 71 | -.020 | -.290 | -.125 | -.004 |
| 72 | -.381 | -.050 | -.022 | -.163 |
| 73 | -.020 | -.170 | -.133 | -.080 |
| 74 | -.051 | -.202 | -.015 | -.027 |
| 75 | -.044 | -.104 | -.075 | -.046 |
| 76 | -.016 | -.213 | -.023 | -.040 |
| 77 | -.263 | -.211 | -.225 | -.050 |
| 78 | -.282 | -.137 | -.063 | -.151 |
| 79 | -.184 | -.003 | -.064 | -.063 |
| 80 | -.277 | -.117 | -.056 | -.054 |
| 81 | -.189 | -.106 | -.426 | -.084 |
| 82 | -.342 | -.151 | -.407 | -.069 |
| 83 | -.181 | -.220 | -.393 | -.089 |
| 84 | -.153 | -.095 | -.518 | -.074 |
| 85 | -.271 | -.013 | -.440 | -.060 |
| 86 | -.337 | -.165 | -.332 | -.036 |
| 87 | -.326 | -.105 | -.455 | -.220 |
| 88 | -.275 | -.145 | -.484 | -.212 |
| 89 | -.359 | -.026 | -.272 | -.016 |
| 90 | -.328 | -.092 | -.333 | -.009 |
| 91 | -.304 | -.328 | -.022 | -.177 |
| 92 | -.208 | -.215 | -.050 | -.192 |
| 93 | -.344 | -.043 | -.006 | -.356 |
| 94 | -.160 | -.063 | -.093 | -.091 |
| 95 | -.262 | -.251 | -.131 | -.027 |
| 96 | -.135 | -.026 | -.250 | -.050 |
| 97 | -.382 | -.114 | -.002 | -.154 |
| 98 | -.315 | -.115 | -.030 | -.345 |
| 99 | -.383 | -.087 | -.066 | -.077 |
| 100 | -.323 | -.044 | -.040 | -.388 |
| 101 | -.006 | -.003 | -.006 | -.004 |
| 102 | -.216 | -.241 | -.166 | -.121 |
| 103 | -.080 | -.042 | -.002 | -.007 |
| 104 | -.112 | -.168 | -.074 | -.114 |
| 105 | -.131 | -.088 | -.204 | -.007 |
| 106 | -.190 | -.115 | -.109 | -.131 |
| 107 | -.204 | -.106 | -.096 | -.077 |
| 108 | -.154 | -.127 | -.125 | -.033 |
| 109 | -.029 | -.152 | -.261 | -.040 |
| 110 | -.143 | -.221 | -.190 | -.057 |
| 111 | -.050 | -.258 | -.282 | -.123 |
| 112 | -.239 | -.132 | -.261 | -.250 |
| 113 | -.279 | -.201 | -.004 | -.020 |
| 114 | -.079 | -.121 | -.091 | -.020 |
| 115 | -.213 | -.034 | -.209 | -.010 |
| 116 | -.211 | -.038 | -.156 | -.037 |
| 117 | -.324 | -.056 | -.284 | -.170 |
| 118 | -.255 | -.018 | -.026 | -.025 |
| 119 | -.263 | -.107 | -.204 | -.091 |
| 120 | -.190 | -.123 | -.140 | -.084 |
| 121 | -.293 | -.006 | -.036 | -.174 |
| 122 | -.247 | -.020 | -.211 | -.270 |
| 123 | -.026 | -.077 | -.105 | -.151 |
| 124 | -.065 | -.006 | -.145 | -.320 |
| 125 | -.132 | -.008 | -.039 | -.065 |
| 126 | -.037 | -.247 | -.091 | -.050 |
| 127 | -.072 | -.340 | -.051 | -.035 |
| 128 | -.286 | -.018 | -.063 | -.330 |
| 129 | -.145 | -.014 | -.058 | -.082 |
| 130 | -.070 | -.206 | -.004 | -.115 |
| 131 | -.164 | -.124 | -.134 | -.203 |
| 132 | -.020 | -.002 | -.280 | -.559 |
| 133 | -.001 | -.100 | -.128 | -.252 |
| 134 | -.106 | -.006 | -.078 | -.232 |
| 135 | -.114 | -.100 | -.353 | -.168 |
| 136 | -.001 | -.070 | -.000 | -.049 |
| 137 | -.075 | -.053 | -.256 | -.218 |
| 138 | -.086 | -.072 | -.152 | -.217 |
| 139 | -.109 | -.277 | -.194 | -.065 |
| 140 | -.188 | -.012 | -.166 | -.120 |
| 141 | -.359 | -.021 | -.118 | -.015 |
| 142 | -.298 | -.077 | -.200 | -.076 |
| 143 | -.230 | -.135 | -.044 | -.227 |
| 144 | -.177 | -.150 | -.028 | -.178 |
| 145 | -.359 | -.054 | -.139 | -.119 |
| 146 | -.210 | -.081 | -.281 | -.120 |
| 147 | -.271 | -.029 | -.040 | -.051 |
| 148 | -.172 | -.273 | -.089 | -.200 |
| 149 | -.266 | -.004 | -.090 | -.051 |
| 150 | -.439 | -.021 | -.125 | -.021 |
| 151 | -.181 | -.278 | -.004 | -.111 |
| 152 | -.036 | -.450 | -.003 | -.113 |
| 153 | -.246 | -.017 | -.003 | -.032 |
| 154 | -.247 | -.007 | -.090 | -.066 |
| 155 | -.094 | -.265 | -.037 | -.153 |
| 156 | -.199 | -.006 | -.003 | -.043 |
| 157 | -.366 | -.104 | -.077 | -.127 |
| 158 | -.382 | -.154 | -.045 | -.005 |
| 159 | -.335 | -.051 | -.107 | -.054 |
| 160 | -.308 | -.153 | -.158 | -.043 |

PRINCIPAL COORDINATE ANALYSIS (b) SAMPLE-I PLANT AND FRESH LEAF CHARACTERS

TRACE = 91,273

| | | | | |
|---|---|---|---|---|
| LATENT ROOTS | 7,869 | 6,218 | 4,539 | 4,002 |
| PERCENT OF TRACE | 8,6 | 15,4 | 20,4 | 24,8 |
| 1 | -.292 | -.318 | .411 | -.001 |
| 2 | -.198 | -.068 | .324 | -.135 |
| 3 | -.188 | -.248 | .138 | -.023 |
| 4 | .275 | -.502 | .145 | .140 |
| 5 | .304 | -.468 | .316 | .029 |
| 6 | .234 | -.377 | .322 | .087 |
| 7 | .252 | -.377 | .097 | .148 |
| 8 | .219 | -.348 | .027 | -.025 |
| 9 | .270 | -.548 | .165 | .196 |
| 10 | .240 | -.355 | .038 | .074 |
| 11 | .355 | -.028 | .034 | .165 |
| 12 | .291 | -.228 | .132 | .054 |
| 13 | .258 | -.076 | .042 | .302 |
| 14 | .131 | -.073 | .174 | .132 |
| 15 | .060 | -.066 | .276 | .368 |
| 16 | .057 | -.015 | .158 | .051 |
| 17 | .050 | -.092 | .247 | .051 |
| 18 | .240 | -.084 | .153 | .244 |
| 19 | .174 | -.163 | .133 | .302 |
| 20 | .138 | -.051 | .145 | .313 |
| 21 | .398 | -.053 | .070 | .271 |
| 22 | .217 | -.183 | .160 | .230 |
| 23 | .159 | -.134 | .059 | .085 |
| 24 | .152 | -.068 | .008 | .347 |
| 25 | .281 | -.183 | .034 | .237 |
| 26 | .227 | -.020 | .038 | .191 |
| 27 | .293 | -.203 | .007 | .136 |
| 28 | .386 | -.201 | .037 | .172 |
| 29 | .244 | -.163 | .154 | .116 |
| 30 | .365 | -.170 | .123 | .155 |
| 31 | .294 | -.313 | .149 | .181 |
| 32 | .172 | -.385 | .104 | .101 |
| 33 | .334 | -.205 | .000 | .094 |
| 34 | .086 | -.306 | .036 | .170 |
| 35 | .125 | -.155 | .143 | .153 |
| 36 | .142 | -.313 | .176 | .323 |
| 37 | .250 | -.313 | .177 | .110 |
| 38 | .254 | -.277 | .145 | .157 |
| 39 | .032 | -.178 | .121 | .000 |
| 40 | .024 | -.144 | .009 | .102 |
| 41 | .253 | -.336 | .086 | .030 |
| 42 | .124 | -.187 | .064 | .041 |
| 43 | .200 | -.183 | .083 | .083 |
| 44 | .082 | -.057 | .325 | .110 |
| 45 | .176 | -.265 | .150 | .027 |
| 46 | .250 | -.105 | .231 | .091 |
| 47 | .211 | -.052 | .330 | .261 |
| 48 | .143 | -.146 | .328 | .121 |
| 49 | .188 | -.031 | .001 | .047 |
| 50 | .247 | -.105 | .202 | .084 |
| 51 | .222 | -.030 | .165 | .160 |
| 52 | .199 | -.306 | .038 | .187 |
| 53 | .294 | -.180 | .343 | .097 |
| 54 | .164 | -.334 | .123 | .297 |
| 55 | .199 | -.360 | .182 | .083 |
| 56 | .193 | -.390 | .033 | .204 |
| 57 | .347 | -.174 | .252 | .068 |
| 58 | .290 | -.423 | .185 | .003 |
| 59 | .215 | -.401 | .282 | .034 |
| 60 | .216 | -.406 | .225 | .000 |
| 61 | .317 | -.255 | .135 | .088 |
| 62 | .307 | -.232 | .155 | .052 |
| 63 | .120 | -.226 | .066 | .167 |
| 64 | .144 | -.072 | .099 | .107 |
| 65 | .319 | -.168 | .316 | .189 |
| 66 | .127 | -.068 | .026 | .205 |
| 67 | .191 | -.247 | .135 | .104 |
| 68 | .011 | -.093 | .069 | .211 |
| 69 | .120 | -.087 | .111 | .117 |
| 70 | .145 | -.048 | .212 | .158 |
| 71 | .078 | -.235 | .136 | .223 |
| 72 | .134 | -.068 | .390 | .080 |
| 73 | .012 | -.121 | .186 | .392 |
| 74 | .055 | -.309 | .312 | .007 |
| 75 | .033 | -.083 | .316 | .090 |
| 76 | .177 | -.227 | .174 | .017 |
| 77 | .285 | -.185 | .054 | .012 |
| 78 | .150 | -.029 | .203 | .143 |
| 79 | .248 | -.080 | .152 | .134 |
| 80 | .318 | -.054 | .283 | .024 |
| 81 | .108 | -.143 | .077 | -.200 |
| 82 | .314 | .073 | .223 | .175 |
| 83 | .251 | -.206 | .137 | .029 |
| 84 | .177 | -.225 | .293 | .153 |
| 85 | .284 | -.169 | .233 | .199 |
| 86 | .169 | -.052 | .242 | .200 |
| 87 | .273 | -.120 | .137 | -.261 |
| 88 | .064 | -.260 | .250 | .039 |
| 89 | .382 | -.231 | .120 | .039 |
| 90 | .057 | .114 | .032 | .039 |
| 91 | .028 | -.100 | .214 | .033 |
| 92 | .178 | -.173 | .146 | .311 |
| 93 | .372 | -.214 | .242 | .043 |
| 94 | .297 | -.167 | .294 | .156 |
| 95 | .195 | -.127 | .237 | .081 |
| 96 | .053 | -.113 | .120 | .039 |
| 97 | .147 | -.093 | .130 | .039 |
| 98 | .041 | -.033 | .315 | .158 |
| 99 | .076 | -.113 | .080 | .082 |
| 100 | .103 | -.157 | .057 | .014 |
| 101 | .289 | -.118 | .030 | .197 |
| 102 | .253 | -.029 | .214 | .103 |
| 103 | .158 | -.213 | .314 | .103 |
| 104 | .290 | -.070 | .057 | .014 |
| 105 | .277 | -.129 | .065 | .054 |
| 106 | .239 | -.181 | .233 | .125 |
| 107 | .235 | -.038 | .297 | .083 |
| 108 | .231 | -.275 | .022 | .046 |
| 109 | .256 | -.040 | .016 | .110 |
| 110 | .339 | -.143 | .045 | .157 |
| 111 | .020 | -.032 | .328 | .033 |
| 112 | .313 | -.047 | .107 | .033 |
| 113 | .304 | -.044 | .056 | .054 |
| 114 | .295 | -.027 | .148 | .148 |
| 115 | .281 | -.072 | .050 | .148 |
| 116 | .307 | -.028 | .095 | .190 |
| 117 | .352 | -.027 | .084 | .018 |
| 118 | .128 | -.055 | .065 | .051 |
| 119 | .169 | -.055 | .081 | .081 |
| 120 | .403 | .135 | .114 | .222 |
| 121 | .103 | -.106 | .331 | .008 |
| 122 | .309 | .294 | .091 | .047 |
| 123 | .440 | -.385 | .028 | .020 |
| 124 | .132 | -.036 | .020 | .153 |
| 125 | .132 | -.036 | .290 | .153 |
| 126 | .211 | .070 | .039 | .227 |
| 127 | .236 | -.182 | .093 | .093 |
| 128 | .172 | -.053 | .040 | .313 |
| 129 | .172 | -.054 | .276 | .313 |
| 130 | .153 | -.055 | .353 | .268 |
| 131 | .141 | .111 | .179 | .169 |
| 132 | .100 | -.028 | .147 | .155 |
| 133 | .172 | -.157 | .097 | .000 |
| 134 | .176 | .054 | .140 | .026 |
| 135 | .132 | -.156 | .213 | .022 |
| 136 | .156 | -.253 | .062 | .022 |
| 137 | .253 | -.384 | .148 | .032 |
| 138 | .228 | .141 | .066 | .066 |
| 139 | .075 | -.163 | .141 | .066 |
| 140 | .504 | -.156 | .293 | .032 |
| 141 | .333 | -.252 | .218 | .132 |
| 142 | .355 | -.247 | .085 | .060 |
| 143 | .188 | -.196 | .114 | .114 |
| 144 | .292 | -.255 | .118 | .114 |
| 145 | .193 | -.089 | .158 | .158 |
| 146 | .223 | -.240 | .060 | .077 |
| 147 | .240 | -.423 | .266 | .111 |
| 148 | .205 | -.252 | .304 | .114 |
| 149 | .352 | -.282 | .336 | .233 |
| 150 | .265 | -.186 | .248 | .324 |
| 151 | .186 | -.098 | .026 | .019 |
| 152 | .080 | .084 | .252 | .281 |
| 153 | .392 | -.198 | .184 | .053 |
| 154 | .007 | -.205 | .103 | .221 |
| 155 | .090 | -.005 | .073 | .102 |
| 156 | .174 | -.227 | .139 | .189 |
| 157 | .017 | -.185 | .004 | .171 |
| 158 | .012 | -.054 | .113 | .354 |
| 159 | .143 | -.203 | .087 | .087 |
| 160 | .139 | -.021 | .036 | .087 |

PRINCIPAL COORDINATE ANALYSIS (c) SAMPLE-I LEAF HERBARIUM CHARACTERS

TRACE = 43.286

| | | | | |
|---|---|---|---|---|
| LATENT ROOTS | 5.392 | 3.931 | 3.576 | 2.300 |
| PERCENT OF TRACE | 12.5 | 21.5 | 29.8 | 35.1 |

| | | | | |
|---|---|---|---|---|
| 1 | -.344 | -.160 | .049 | .139 |
| 2 | .032 | -.042 | .118 | .164 |
| 3 | .043 | -.066 | .116 | .151 |
| 4 | .106 | -.001 | .243 | .088 |
| 5 | .002 | .358 | .057 | .051 |
| 6 | .193 | .018 | .153 | .017 |
| 7 | .073 | .016 | .054 | .144 |
| 8 | .019 | .189 | .001 | .124 |
| 9 | .234 | .021 | .027 | .136 |
| 10 | .078 | .156 | .250 | .134 |
| 11 | .197 | .564 | .042 | .077 |
| 12 | .073 | .264 | .058 | .393 |
| 13 | .184 | .275 | .045 | .139 |
| 14 | .276 | .066 | .102 | .055 |
| 15 | .193 | .170 | .091 | .170 |
| 16 | .222 | .122 | .045 | .085 |
| 17 | .214 | .186 | .103 | .037 |
| 18 | .259 | .054 | .076 | .160 |
| 19 | .312 | .023 | .073 | .002 |
| 20 | .131 | .205 | .026 | .010 |
| 21 | .332 | .024 | .030 | .012 |
| 22 | .312 | .082 | .019 | .051 |
| 23 | .293 | .108 | .305 | .169 |
| 24 | .242 | .008 | .083 | .040 |
| 25 | .220 | .118 | .115 | .080 |
| 26 | .282 | .095 | .032 | .174 |
| 27 | .272 | .083 | .055 | .166 |
| 28 | .273 | .032 | .056 | .210 |
| 29 | .337 | .093 | .066 | .024 |
| 30 | .326 | .081 | .009 | .093 |
| 31 | .049 | .290 | .108 | .044 |
| 32 | .123 | .152 | .038 | .113 |
| 33 | .219 | .111 | .171 | .287 |
| 34 | .126 | .167 | .291 | .182 |
| 35 | .051 | .067 | .224 | .060 |
| 36 | .180 | .082 | .109 | .025 |
| 37 | .043 | .287 | .153 | .078 |
| 38 | .060 | .178 | .271 | .087 |
| 39 | .150 | .198 | .037 | .067 |
| 40 | .024 | .187 | .044 | .167 |
| 41 | .180 | .166 | .016 | .038 |
| 42 | .033 | .232 | .062 | .108 |
| 43 | .081 | .050 | .111 | .154 |
| 44 | .175 | .111 | .113 | .097 |
| 45 | .253 | .156 | .227 | .052 |
| 46 | .250 | .028 | .089 | .037 |
| 47 | .297 | .222 | .209 | .107 |
| 48 | .078 | .522 | .183 | .164 |
| 49 | .239 | .132 | .159 | .114 |
| 50 | .184 | .071 | .235 | .120 |
| 51 | .007 | .143 | .034 | .175 |
| 52 | .172 | .054 | .091 | .008 |
| 53 | .102 | .007 | .268 | .144 |
| 54 | .167 | .018 | .121 | .247 |
| 55 | .175 | .131 | .037 | .141 |
| 56 | .221 | .160 | .250 | .007 |
| 57 | .140 | .133 | .015 | .118 |
| 58 | .151 | .110 | .125 | .171 |
| 59 | .042 | .054 | .248 | .137 |
| 60 | .214 | .202 | .017 | .169 |
| 61 | .102 | .215 | .111 | .021 |
| 62 | .027 | .233 | .081 | .127 |
| 63 | .118 | .105 | .001 | .062 |
| 64 | .229 | .060 | .083 | .062 |
| 65 | .266 | .075 | .134 | .025 |
| 66 | .212 | .150 | .019 | .111 |
| 67 | .167 | .310 | .038 | .056 |
| 68 | .128 | .237 | .018 | .082 |
| 69 | .015 | .255 | .012 | .022 |
| 70 | .111 | .017 | .073 | .115 |
| 71 | .056 | .077 | .153 | .118 |
| 72 | .029 | .007 | .056 | .141 |
| 73 | .084 | .086 | .040 | .059 |
| 74 | .032 | .015 | .200 | .067 |
| 75 | .036 | .262 | .076 | .046 |
| 76 | .054 | .021 | .006 | .139 |
| 77 | .269 | .146 | .045 | .062 |
| 78 | .135 | .248 | .081 | .263 |
| 79 | .150 | .160 | .059 | .282 |
| 80 | .011 | .087 | .111 | .033 |
| 81 | .232 | .268 | .045 | .095 |
| 82 | .065 | .228 | .067 | .083 |
| 83 | .110 | .093 | .136 | .086 |
| 84 | .022 | .083 | .118 | .265 |
| 85 | .124 | .042 | .100 | .189 |
| 86 | .117 | .246 | .257 | .090 |
| 87 | .129 | .516 | .126 | .095 |
| 88 | .178 | .033 | .270 | .034 |
| 89 | .092 | .171 | .149 | .139 |
| 90 | .150 | .052 | .232 | .032 |
| 91 | .009 | .055 | .287 | .185 |
| 92 | .059 | .016 | .219 | .176 |
| 93 | .003 | .052 | .282 | .055 |
| 94 | .109 | .044 | .321 | .031 |
| 95 | .003 | .011 | .358 | .230 |
| 96 | .018 | .023 | .270 | .053 |
| 97 | .137 | .149 | .077 | .033 |
| 98 | .104 | .048 | .239 | .093 |
| 99 | .286 | .070 | .156 | .052 |
| 100 | .286 | .041 | .221 | .072 |
| 101 | .091 | .104 | .056 | .138 |
| 102 | .082 | .015 | .298 | .158 |
| 103 | .045 | .070 | .312 | .030 |
| 104 | .180 | .040 | .086 | .085 |
| 105 | .087 | .174 | .089 | .205 |
| 106 | .041 | .026 | .113 | .007 |
| 107 | .043 | .101 | .237 | .013 |
| 108 | .139 | .017 | .207 | .200 |
| 109 | .092 | .212 | .060 | .120 |
| 110 | .348 | .054 | .141 | .072 |
| 111 | .222 | .256 | .025 | .104 |
| 112 | .200 | .321 | .048 | .063 |
| 113 | .131 | .277 | .095 | .031 |
| 114 | .234 | .124 | .028 | .030 |
| 115 | .160 | .250 | .035 | .187 |
| 116 | .147 | .144 | .152 | .085 |
| 117 | .042 | .247 | .114 | .108 |
| 118 | .103 | .550 | .089 | .004 |
| 119 | .050 | .330 | .114 | .134 |
| 120 | .250 | .051 | .028 | .181 |
| 121 | .041 | .007 | .014 | .071 |
| 122 | .085 | .134 | .070 | .060 |
| 123 | .200 | .022 | .128 | .162 |
| 124 | .119 | .098 | .118 | .087 |
| 125 | .001 | .048 | .252 | .124 |
| 126 | .011 | .090 | .218 | .093 |
| 127 | .145 | .055 | .153 | .060 |
| 128 | .063 | .136 | .143 | .119 |
| 129 | .092 | .063 | .213 | .060 |
| 130 | .063 | .315 | .021 | .048 |
| 131 | .417 | .188 | .130 | .084 |
| 132 | .153 | .074 | .130 | .084 |
| 133 | .200 | .076 | .060 | .032 |
| 134 | .313 | .140 | .239 | .156 |
| 135 | .424 | .061 | .024 | .038 |
| 136 | .243 | .155 | .101 | .017 |
| 137 | .245 | .105 | .042 | .072 |
| 138 | .315 | .226 | .270 | .103 |
| 139 | .327 | .241 | .267 | .104 |
| 140 | .265 | .034 | .112 | .124 |
| 141 | .150 | .078 | .161 | .013 |
| 142 | .014 | .038 | .323 | .083 |
| 143 | .103 | .072 | .148 | .124 |
| 144 | .246 | .068 | .026 | .073 |
| 145 | .266 | .017 | .063 | .133 |
| 146 | .069 | .009 | .134 | .014 |
| 147 | .083 | .077 | .160 | .046 |
| 148 | .054 | .038 | .027 | .155 |
| 149 | .095 | .111 | .106 | .018 |
| 150 | .162 | .046 | .236 | .110 |
| 151 | .141 | .120 | .103 | .027 |
| 152 | .046 | .232 | .145 | .052 |
| 153 | .335 | .135 | .177 | .084 |
| 154 | .175 | .304 | .063 | .080 |
| 155 | .118 | .283 | .078 | .175 |
| 156 | .231 | .088 | .178 | .284 |
| 157 | .266 | .307 | .075 | .050 |
| 158 | .289 | .322 | .078 | .018 |
| 159 | .269 | .254 | .079 | .007 |
| 160 | .311 | .031 | .070 | .114 |

COORDINATE ANALYSIS (d) SAMPLE-II TUBER CHARACTERS

.180

| | | | | |
|---|---|---|---|---|
| TS | 6.519 | 5.607 | 4.874 | 4.132 |
| TRACE | 8.2 | 15.3 | 21.5 | 26.7 |

| | | | | |
|---|---|---|---|---|
| 1 | .089 | -.086 | -.202 | .101 |
| 2 | .288 | .153 | .058 | .070 |
| 3 | .206 | .080 | .159 | .363 |
| 4 | .103 | .541 | .100 | .088 |
| 5 | .103 | .164 | .199 | .189 |
| 6 | .132 | .035 | .299 | .040 |
| 7 | .101 | .314 | .059 | .102 |
| 8 | .299 | .378 | .223 | .091 |
| 9 | .100 | .202 | .245 | .153 |
| 10 | .223 | .110 | .019 | .133 |
| 11 | .300 | .352 | .093 | .180 |
| 12 | .081 | .194 | .170 | .042 |
| 13 | .356 | .086 | .087 | .170 |
| 14 | .105 | .186 | .034 | .313 |
| 15 | .155 | .250 | .148 | .046 |
| 16 | .120 | .257 | .310 | .067 |
| 17 | .055 | .140 | .151 | .302 |
| 18 | .076 | .105 | .312 | .074 |
| 19 | .173 | .136 | .041 | .200 |
| 20 | .378 | .141 | .003 | .013 |
| 21 | .045 | .265 | .082 | .152 |
| 22 | .360 | .086 | .273 | .066 |
| 23 | .398 | .068 | .160 | .089 |
| 24 | .095 | .114 | .239 | .038 |
| 25 | .360 | .014 | .125 | .073 |
| 26 | .362 | .012 | .097 | .020 |
| 27 | .347 | .015 | .217 | .052 |
| 28 | .371 | .001 | .094 | .026 |
| 29 | .319 | .143 | .077 | .056 |
| 30 | .418 | .052 | .214 | .062 |
| 31 | .032 | .053 | .147 | .260 |
| 32 | .341 | .205 | .055 | .053 |
| 33 | .254 | .000 | .020 | .011 |
| 34 | .094 | .383 | .034 | .274 |
| 35 | .140 | .359 | .021 | .177 |
| 36 | .409 | .173 | .183 | .078 |
| 37 | .184 | .330 | .009 | .105 |
| 38 | .188 | .394 | .102 | .190 |
| 39 | .089 | .229 | .045 | .035 |
| 40 | .238 | .211 | .129 | .128 |
| 41 | .262 | .008 | .064 | .039 |
| 42 | .274 | .063 | .070 | .088 |
| 43 | .220 | .053 | .011 | .075 |
| 44 | .244 | .010 | .014 | .032 |
| 45 | .392 | .070 | .247 | .011 |
| 46 | .021 | .315 | .215 | .031 |
| 47 | .057 | .037 | .318 | .076 |
| 48 | .141 | .054 | .056 | .217 |
| 49 | .327 | .011 | .118 | .053 |
| 50 | .149 | .103 | .088 | .301 |
| 51 | .004 | .583 | .020 | .024 |
| 52 | .148 | .544 | .039 | .107 |
| 53 | .116 | .484 | .082 | .092 |
| 54 | .168 | .016 | .412 | .142 |
| 55 | .094 | .368 | .121 | .228 |
| 56 | .108 | .528 | .065 | .046 |
| 57 | .033 | .366 | .050 | .153 |
| 58 | .304 | .196 | .271 | .064 |
| 59 | .122 | .460 | .122 | .080 |
| 60 | .032 | .150 | .144 | .060 |
| 61 | .338 | .125 | .070 | .060 |
| 62 | .327 | .058 | .063 | .381 |
| 63 | .235 | .177 | .051 | .012 |
| 64 | .024 | .068 | .138 | .136 |
| 65 | .062 | .142 | .204 | .157 |
| 66 | .251 | .089 | .260 | .243 |
| 67 | .037 | .182 | .421 | .028 |
| 68 | .033 | .076 | .329 | .065 |
| 69 | .136 | .172 | .081 | .249 |
| 70 | .291 | .095 | .022 | .641 |
| 71 | .055 | .096 | .040 | .345 |
| 72 | .252 | .165 | .027 | .155 |
| 73 | .036 | .043 | .130 | .236 |
| 74 | .209 | .118 | .087 | .231 |
| 75 | .163 | .253 | .173 | .333 |
| 76 | .071 | .256 | .030 | .301 |
| 77 | .023 | .290 | .033 | .148 |
| 78 | .127 | .094 | .083 | .318 |
| 79 | .128 | .127 | .135 | .264 |
| 80 | .139 | .041 | .199 | .157 |
| 81 | .301 | .246 | .159 | .210 |
| 82 | .181 | .085 | .124 | .233 |
| 83 | .190 | .124 | .159 | .220 |
| 84 | .114 | .270 | .092 | .068 |
| 85 | .293 | .218 | .275 | .127 |
| 86 | .152 | .152 | .786 | .068 |
| 87 | .085 | .105 | .093 | .390 |
| 88 | .085 | .315 | .087 | .269 |
| 89 | .205 | .136 | .280 | .207 |
| 90 | .272 | .170 | .182 | .174 |
| 91 | .179 | .128 | .294 | .224 |
| 92 | .084 | .108 | .563 | .287 |
| 93 | .241 | .037 | .122 | .119 |
| 94 | .290 | .033 | .055 | .145 |
| 95 | .157 | .002 | .271 | .031 |
| 96 | .110 | .168 | .364 | .026 |
| 97 | .189 | .108 | .026 | .066 |
| 98 | .036 | .027 | .343 | .017 |
| 99 | .214 | .243 | .773 | .038 |
| 100 | .280 | .029 | .149 | .056 |
| 101 | .124 | .022 | .351 | .003 |
| 102 | .025 | .002 | .221 | .196 |
| 103 | .085 | .013 | .155 | .021 |
| 104 | .082 | .156 | .124 | .091 |
| 105 | .147 | .055 | .105 | .011 |
| 106 | .001 | .262 | .155 | .170 |
| 107 | .076 | .008 | .093 | .166 |
| 108 | .022 | .141 | .268 | .014 |
| 109 | .038 | .307 | .187 | .001 |
| 110 | .141 | .088 | .357 | .037 |
| 111 | .185 | .010 | .503 | .044 |
| 112 | .109 | .044 | .042 | .054 |
| 113 | .073 | .326 | .064 | .129 |
| 114 | .136 | .242 | .110 | .166 |
| 115 | .214 | .141 | .105 | .113 |
| 116 | .019 | .148 | .146 | .141 |
| 117 | .024 | .013 | .121 | .110 |
| 118 | .019 | .121 | .064 | .115 |
| 119 | .047 | .343 | .043 | .146 |
| 120 | .055 | .093 | .312 | .064 |
| 121 | .074 | .142 | .351 | .035 |
| 122 | .115 | .006 | .168 | .031 |
| 123 | .257 | .099 | .173 | .034 |
| 124 | .141 | .198 | .091 | .004 |
| 125 | .026 | .129 | .004 | .195 |
| 126 | .312 | .204 | .230 | .040 |
| 127 | .208 | .010 | .158 | .231 |
| 128 | .170 | .012 | .187 | .228 |
| 129 | .037 | .085 | .124 | .264 |
| 130 | .043 | .037 | .246 | .175 |
| 131 | .170 | .042 | .034 | .224 |
| 132 | .085 | .049 | .167 | .249 |
| 133 | .250 | .057 | .129 | .019 |
| 134 | .056 | .126 | .297 | .156 |
| 135 | .084 | .251 | .179 | .079 |
| 136 | .220 | .110 | .033 | .133 |
| 137 | .151 | .005 | .307 | .055 |
| 138 | .064 | .011 | .055 | .047 |
| 139 | .129 | .120 | .024 | .266 |
| 140 | .274 | .098 | .021 | .061 |
| 141 | .140 | .047 | .230 | .122 |
| 142 | .286 | .081 | .172 | .126 |
| 143 | .066 | .213 | .266 | .026 |
| 144 | .362 | .178 | .298 | .163 |
| 145 | .274 | .266 | .005 | .271 |
| 146 | .140 | .208 | .177 | .090 |
| 147 | .066 | .064 | .022 | .286 |
| 148 | .371 | .025 | .160 | .407 |
| 149 | .286 | .240 | .206 | .013 |
| 150 | .133 | .192 | .004 | .092 |
| 151 | .020 | .150 | .104 | .135 |
| 152 | .298 | .060 | .206 | .022 |
| 153 | .057 | .206 | .208 | .177 |
| 154 | .174 | .033 | .064 | .022 |
| 155 | .280 | .007 | .025 | .286 |
| 156 | .095 | .240 | .160 | .135 |
| 157 | .265 | .192 | .206 | .407 |
| 158 | .034 | .004 | .092 | .013 |
| 159 | .369 | .104 | .190 | .270 |
| 160 | .086 | .101 | | |

PRINCIPAL COORDINATE ANALYSIS (e) SAMPLE-II PLANT AND FRESH LEAF CHARACTERS

TRACE = 93,422

| | | | | |
|---|---|---|---|---|
| LATENT ROOTS | 7,259 | 5,065 | 4,830 | 4,210 |
| PERCENT OF TRACE | 7.8 | 13.2 | 18.4 | 22.9 |

| | | | | |
|---|---|---|---|---|
| 1 | .056 | .189 | .118 | .224 |
| 2 | .128 | .198 | .257 | .058 |
| 3 | .155 | .005 | .145 | .120 |
| 4 | .305 | .099 | .433 | .080 |
| 5 | .163 | .116 | .305 | .173 |
| 6 | .253 | .318 | .229 | .076 |
| 7 | .107 | .350 | .209 | .056 |
| 8 | .242 | .272 | .043 | .005 |
| 9 | .335 | .503 | .227 | .021 |
| 10 | .065 | .248 | .047 | .062 |
| 11 | .299 | .012 | .270 | .037 |
| 12 | .062 | .025 | .098 | .326 |
| 13 | .192 | .230 | .326 | .031 |
| 14 | .211 | .034 | .058 | .294 |
| 15 | .102 | .028 | .051 | .061 |
| 16 | .151 | .177 | .002 | .403 |
| 17 | .096 | .008 | .341 | .144 |
| 18 | .011 | .105 | .215 | .295 |
| 19 | .040 | .168 | .200 | .048 |
| 20 | .057 | .516 | .114 | .173 |
| 21 | .210 | .031 | .115 | .039 |
| 22 | .205 | .308 | .005 | .181 |
| 23 | .372 | .109 | .130 | .080 |
| 24 | .114 | .015 | .021 | .239 |
| 25 | .176 | .076 | .180 | .221 |
| 26 | .315 | .182 | .149 | .027 |
| 27 | .316 | .181 | .265 | .067 |
| 28 | .269 | .147 | .089 | .022 |
| 29 | .290 | .250 | .151 | .229 |
| 30 | .435 | .050 | .131 | .067 |
| 31 | .266 | .247 | .163 | .253 |
| 32 | .275 | .242 | .291 | .170 |
| 33 | .126 | .044 | .288 | .390 |
| 34 | .036 | .114 | .042 | .247 |
| 35 | .096 | .277 | .034 | .309 |
| 36 | .262 | .307 | .040 | .091 |
| 37 | .339 | .236 | .080 | .272 |
| 38 | .041 | .151 | .130 | .244 |
| 39 | .230 | .078 | .112 | .335 |
| 40 | .025 | .067 | .086 | .380 |
| 41 | .114 | .134 | .075 | .346 |
| 42 | .322 | .128 | .058 | .308 |
| 43 | .030 | .046 | .183 | .042 |
| 44 | .011 | .172 | .130 | .098 |
| 45 | .062 | .268 | .019 | .105 |
| 46 | .105 | .237 | .022 | .093 |
| 47 | .042 | .119 | .039 | .005 |
| 48 | .171 | .143 | .227 | .256 |
| 49 | .143 | .096 | .077 | .334 |
| 50 | .054 | .347 | .013 | .116 |
| 51 | .219 | .008 | .371 | .064 |
| 52 | .248 | .058 | .346 | .026 |
| 53 | .207 | .342 | .084 | .123 |
| 54 | .115 | .016 | .053 | .158 |
| 55 | .286 | .157 | .045 | .082 |
| 56 | .338 | .034 | .175 | .122 |
| 57 | .259 | .038 | .410 | .091 |
| 58 | .245 | .173 | .237 | .263 |
| 59 | .272 | .043 | .437 | .014 |
| 60 | .241 | .044 | .344 | .169 |
| 61 | .262 | .218 | .265 | .042 |
| 62 | .331 | .135 | .181 | .075 |
| 63 | .014 | .158 | .296 | .122 |
| 64 | .178 | .058 | .032 | .076 |
| 65 | .257 | .054 | .101 | .049 |
| 66 | .134 | .006 | .044 | .006 |
| 67 | .308 | .100 | .102 | .531 |
| 68 | .292 | .021 | .062 | .126 |
| 69 | .061 | .087 | .140 | .018 |
| 70 | .172 | .104 | .091 | .084 |
| 71 | .095 | .043 | .090 | .200 |
| 72 | .287 | .375 | .114 | .013 |
| 73 | .050 | .215 | .426 | .042 |
| 74 | .281 | .204 | .200 | .028 |
| 75 | .175 | .323 | .137 | .107 |
| 76 | .298 | .373 | .130 | .083 |
| 77 | .200 | .195 | .067 | .025 |
| 78 | .080 | .051 | .233 | .255 |
| 79 | .155 | .184 | .134 | .020 |
| 80 | .187 | .152 | .100 | .069 |
| 81 | .073 | .166 | .168 | .041 |
| 82 | .216 | .145 | .013 | .114 |
| 83 | .177 | .154 | .094 | .106 |
| 84 | .120 | .182 | .335 | .035 |
| 85 | .273 | .088 | .032 | .065 |
| 86 | .245 | .043 | .202 | .162 |
| 87 | .244 | .106 | .083 | .141 |
| 88 | .254 | .202 | .019 | .017 |
| 89 | .170 | .508 | .002 | .072 |
| 90 | .169 | .012 | .132 | .118 |
| 91 | .184 | .092 | .016 | .118 |
| 92 | .328 | .011 | .108 | .070 |
| 93 | .065 | .183 | .183 | .164 |
| 94 | .006 | .002 | .107 | .201 |
| 95 | .187 | .090 | .034 | .064 |
| 96 | .275 | .000 | .303 | .084 |
| 97 | .279 | .085 | .198 | .134 |
| 98 | .230 | .005 | .209 | .090 |
| 99 | .030 | .331 | .036 | .028 |
| 100 | .088 | .311 | .014 | .160 |
| 101 | .306 | .010 | .063 | .062 |
| 102 | .193 | .000 | .045 | .142 |
| 103 | .339 | .023 | .040 | .124 |
| 104 | .094 | .115 | .130 | .221 |
| 105 | .155 | .017 | .022 | .130 |
| 106 | .106 | .122 | .069 | .051 |
| 107 | .021 | .001 | .214 | .073 |
| 108 | .153 | .027 | .336 | .136 |
| 109 | .360 | .293 | .114 | .024 |
| 110 | .109 | .294 | .052 | .024 |
| 111 | .059 | .123 | .092 | .073 |
| 112 | .190 | .167 | .002 | .086 |
| 113 | .092 | .133 | .005 | .201 |
| 114 | .241 | .192 | .056 | .153 |
| 115 | .237 | .010 | .074 | .266 |
| 116 | .248 | .225 | .093 | .031 |
| 117 | .108 | .092 | .024 | .269 |
| 118 | .082 | .207 | .042 | .152 |
| 119 | .182 | .288 | .037 | .017 |
| 120 | .255 | .410 | .178 | .010 |
| 121 | .232 | .062 | .118 | .123 |
| 122 | .097 | .184 | .157 | .075 |
| 123 | .174 | .359 | .115 | .389 |
| 124 | .358 | .256 | .129 | .021 |
| 125 | .220 | .056 | .102 | .103 |
| 126 | .146 | .188 | .230 | .065 |
| 127 | .255 | .055 | .020 | .090 |
| 128 | .273 | .192 | .167 | .117 |
| 129 | .050 | .241 | .052 | .217 |
| 130 | .078 | .153 | .008 | .252 |
| 131 | .339 | .263 | .127 | .146 |
| 132 | .315 | .476 | .203 | .049 |
| 133 | .116 | .049 | .277 | .188 |
| 134 | .144 | .093 | .141 | .088 |
| 135 | .237 | .256 | .152 | .042 |
| 136 | .136 | .052 | .002 | .201 |
| 137 | .215 | .023 | .293 | .028 |
| 138 | .195 | .044 | .357 | .036 |
| 139 | .255 | .042 | .042 | .051 |
| 140 | .239 | .203 | .157 | .206 |
| 141 | .050 | .060 | .321 | .237 |
| 142 | .304 | .200 | .071 | .073 |
| 143 | .021 | .155 | .268 | .144 |
| 144 | .063 | .236 | .099 | .013 |
| 145 | .449 | .122 | .114 | .012 |
| 146 | .454 | .171 | .017 | .193 |
| 147 | .354 | .018 | .074 | .172 |
| 148 | .235 | .019 | .131 | .245 |
| 149 | .425 | .228 | .128 | .224 |
| 150 | .312 | .078 | .124 | .046 |
| 151 | .124 | .041 | .104 | .175 |
| 152 | .096 | .075 | .029 | .034 |
| 153 | .038 | .110 | .277 | .185 |
| 154 | .071 | .219 | .027 | .268 |
| 155 | .103 | .094 | .044 | .320 |
| 156 | .035 | .113 | .089 | .369 |
| 157 | .211 | .167 | .133 | .153 |
| 158 | .121 | .042 | .348 | .180 |
| 159 | .167 | .157 | .020 | .007 |
| 160 | .213 | .252 | .229 | .008 |

PAL COORDINATE ANALYSIS (f) SAMPLE-II LEAF HERBARIUM CHARACTERS

43,365

| | | | | |
|---|---|---|---|---|
| ROOTS | 5,713 | 4,074 | 3,467 | 2,445 |
| OF TRACE | 13.2 | 22.6 | 30.6 | 36.2 |

| | | | | |
|---|---|---|---|---|
| 1 | .302 | .218 | .109 | .020 |
| 2 | .009 | .005 | .282 | .052 |
| 3 | .067 | .108 | .064 | .283 |
| 4 | .120 | .034 | .239 | .158 |
| 5 | .188 | .290 | .033 | .092 |
| 6 | .048 | .013 | .077 | .004 |
| 7 | .258 | .146 | .135 | .091 |
| 8 | .188 | .018 | .190 | .084 |
| 9 | .017 | .118 | .014 | .089 |
| 10 | .109 | .314 | .002 | .079 |
| 11 | .314 | .029 | .034 | .042 |
| 12 | .308 | .145 | .090 | .062 |
| 13 | .072 | .302 | .695 | .070 |
| 14 | .115 | .227 | .020 | .324 |
| 15 | .181 | .148 | .174 | .214 |
| 16 | .024 | .142 | .088 | .214 |
| 17 | .128 | .096 | .154 | .007 |
| 18 | .182 | .083 | .106 | .061 |
| 19 | .245 | .270 | .037 | .066 |
| 20 | .302 | .196 | .076 | .113 |
| 21 | .242 | .194 | .219 | .153 |
| 22 | .264 | .068 | .012 | .011 |
| 23 | .102 | .263 | .068 | .216 |
| 24 | .318 | .006 | .052 | .048 |
| 25 | .162 | .067 | .169 | .023 |
| 26 | .157 | .154 | .004 | .099 |
| 27 | .368 | .053 | .124 | .191 |
| 28 | .194 | .184 | .060 | .124 |
| 29 | .133 | .008 | .151 | .016 |
| 30 | .210 | .100 | .010 | .025 |
| 31 | .131 | .209 | .155 | .116 |
| 32 | .065 | .161 | .050 | .067 |
| 33 | .104 | .136 | .173 | .120 |
| 34 | .011 | .166 | .135 | .091 |
| 35 | .411 | .033 | .048 | .021 |
| 36 | .127 | .107 | .136 | .216 |
| 37 | .011 | .056 | .190 | .246 |
| 38 | .109 | .082 | .148 | .053 |
| 39 | .010 | .254 | .160 | .066 |
| 40 | .073 | .124 | .159 | .196 |
| 41 | .064 | .070 | .120 | .080 |
| 42 | .100 | .180 | .242 | .168 |
| 43 | .014 | .249 | .659 | .197 |
| 44 | .412 | .008 | .332 | .079 |
| 45 | .148 | .165 | .032 | .030 |
| 46 | .074 | .070 | .224 | .027 |
| 47 | .044 | .102 | .125 | .053 |
| 48 | .152 | .015 | .036 | .006 |
| 49 | .239 | .104 | .125 | .096 |
| 50 | .271 | .087 | .075 | .071 |
| 51 | .039 | .180 | .030 | .035 |
| 52 | .351 | .240 | .072 | .000 |
| 53 | .152 | .136 | .271 | .062 |
| 54 | .112 | .191 | .018 | .154 |
| 55 | .241 | .035 | .262 | .197 |
| 56 | .163 | .031 | .022 | .012 |
| 57 | .258 | .223 | .114 | .025 |
| 58 | .128 | .141 | .136 | .031 |
| 59 | .131 | .311 | .034 | .056 |
| 60 | .061 | .192 | .045 | .212 |
| 61 | .006 | .126 | .358 | .195 |
| 62 | .206 | .209 | .027 | .063 |
| 63 | .003 | .124 | .103 | .200 |
| 64 | .373 | .087 | .019 | .105 |
| 65 | .231 | .163 | .231 | .113 |
| 66 | .164 | .224 | .100 | .001 |
| 67 | .038 | .350 | .071 | .017 |
| 68 | .049 | .225 | .030 | .010 |
| 69 | .181 | .276 | .112 | .138 |
| 70 | .099 | .210 | .057 | .122 |
| 71 | .055 | .091 | .110 | .091 |
| 72 | .067 | .134 | .173 | .095 |
| 73 | .115 | .275 | .010 | .002 |
| 74 | .194 | .141 | .012 | .198 |
| 75 | .160 | .106 | .102 | .108 |
| 76 | .417 | .053 | .015 | .096 |
| 77 | .075 | .098 | .259 | .162 |
| 78 | .204 | .072 | .110 | .149 |
| 79 | .204 | .091 | .322 | .066 |
| 80 | .057 | .111 | .054 | .224 |
| 81 | .062 | .015 | .118 | .258 |
| 82 | .209 | .025 | .069 | .041 |
| 83 | .112 | .033 | .053 | .055 |
| 84 | .100 | .016 | .170 | .037 |
| 85 | .185 | .153 | .206 | .007 |
| 86 | .198 | .031 | .107 | .187 |
| 87 | .105 | .180 | .272 | .073 |
| 88 | .140 | .075 | .230 | .279 |
| 89 | .286 | .014 | .213 | .127 |
| 90 | .217 | .042 | .271 | .057 |
| 91 | .045 | .123 | .323 | .057 |
| 92 | .038 | .191 | .160 | .030 |
| 93 | .050 | .126 | .168 | .139 |
| 94 | .090 | .068 | .147 | .189 |
| 95 | .139 | .133 | .135 | .153 |
| 96 | .217 | .042 | .115 | .095 |
| 97 | .302 | .068 | .112 | .130 |
| 98 | .255 | .123 | .149 | .009 |
| 99 | .251 | .042 | .188 | .164 |
| 100 | .285 | .040 | .322 | .221 |
| 101 | .156 | .007 | .097 | .143 |
| 102 | .273 | .308 | .097 | .140 |
| 103 | .100 | .093 | .187 | .229 |
| 104 | .082 | .156 | .133 | .127 |
| 105 | .041 | .052 | .012 | .133 |
| 106 | .078 | .187 | .034 | .145 |
| 107 | .048 | .020 | .044 | .105 |
| 108 | .123 | .145 | .032 | .158 |
| 109 | .264 | .042 | .057 | .101 |
| 110 | .318 | .040 | .133 | .133 |
| 111 | .234 | .250 | .044 | .032 |
| 112 | .193 | .025 | .031 | .057 |
| 113 | .093 | .190 | .132 | .227 |
| 114 | .216 | .168 | .045 | .109 |
| 115 | .042 | .098 | .053 | .130 |
| 116 | .264 | .061 | .134 | .151 |
| 117 | .343 | .171 | .068 | .127 |
| 118 | .111 | .342 | .053 | .088 |
| 119 | .210 | .123 | .325 | .070 |
| 120 | .130 | .155 | .332 | .157 |
| 121 | .254 | .008 | .361 | .213 |
| 122 | .104 | .151 | .074 | .101 |
| 123 | .111 | .123 | .107 | .096 |
| 124 | .130 | .155 | .168 | .175 |
| 125 | .254 | .008 | .124 | .095 |
| 126 | .012 | .267 | .087 | .149 |
| 127 | .152 | .142 | .048 | .111 |
| 128 | .320 | .142 | .065 | .132 |
| 129 | .186 | .084 | .207 | .087 |
| 130 | .040 | .258 | .048 | .140 |
| 131 | .344 | .142 | .123 | .213 |
| 132 | .128 | .207 | .065 | .111 |
| 133 | .292 | .201 | .123 | .132 |
| 134 | .129 | .066 | .201 | .087 |
| 135 | .402 | .081 | .087 | .084 |
| 136 | .157 | .376 | .161 | .087 |
| 137 | .093 | .088 | .220 | .181 |
| 138 | .314 | .244 | .122 | .095 |
| 139 | .209 | .112 | .141 | .035 |
| 140 | .255 | .012 | .281 | .024 |
| 141 | .035 | .047 | .168 | .101 |
| 142 | .073 | .055 | .159 | .113 |
| 143 | .167 | .143 | .225 | .091 |
| 144 | .098 | .191 | .225 | .203 |
| 145 | .090 | .000 | .058 | .203 |
| 146 | .089 | .043 | .254 | .144 |
| 147 | .035 | .000 | .111 | .173 |
| 148 | .061 | .006 | .173 | .186 |
| 149 | .001 | .153 | .011 | .030 |
| 150 | .188 | .164 | .036 | .093 |
| 151 | .068 | .183 | .142 | .007 |
| 152 | .010 | .278 | .380 | .038 |
| 153 | .152 | .151 | .289 | .146 |
| 154 | .278 | .235 | .127 | .057 |
| 155 | .247 | .146 | .192 | .022 |
| 156 | .149 | .104 | .229 | .119 |
| 157 | .062 | .173 | .116 | .079 |
| 158 | .106 | .154 | .178 | .085 |
| 159 | .259 | .232 | .011 | .075 |
| 160 | .241 | .425 | .042 | .018 |

APPENDIX XI : Pseudo-F values (>10) for all the 99 characters on the first four vectors of PCO analysis of SAMPLE-I and SAMPLE-II.

| Character no. | SAMPLE-I | | | SAMPLE-II | | |
|---|---|---|---|---|---|---|
| | A* | B | C | A | B | C |
| 1 | 23.4 (1)<br>25.2 (2) | 35.7 (4) | 39.8 (1) | 20.9 (3) | 37.4 (2) | 23.2 (1) |
| 2 | 26.5 (1) | 26.2 (1) | 34.3 (1) | 19.2 (1)<br>16.9 (2) | 19.6 (1)<br>22.0 (2) | 30.5 (1) |
| 3 | 10.6 (1) | 13.6 (1) | - | - | - | - |
| 4 | - | - | - | 10.8 (2)<br>14.0 (4) | 12.5 (3) | 17.1 (2)<br>10.3 (4) |
| 5 | 13.3 (2)<br>26.8 (3) | 23.4 (4) | 25.8 (3) | 15.1 (4) | 31.5 (2) | - |
| 6 | 60.1 (3) | 21.5 (1)<br>58.9 (3) | 47.3 (3) | 19.1 (3) | 82.5 (3) | 26.5 (3) |
| 7 | 30.8 (3) | 30.2 (3) | 14.8 (1)<br>41.3 (3) | - | 33.8 (3) | 20.3 (3) |
| 8 | - | 30.4 (2)<br>20.3 (3)<br>11.6 (4) | 12.2 (3) | - | 18.8 (3)<br>18.0 (4) | 14.0 (3) |
| 9 | 16.0 (2)<br>11.5 (3) | 29.5 (2)<br>11.4 (4) | 20.8 (1) | - | 12.2 (4) | - |
| 10 | 87.4 (1) | 70.5 (1) | 199.5 (1)<br>13.8 (4) | 56.1 (1) | 50.5 (1) | 190.3 (1) |
| 11 | 10.6 (2)<br>11.3 (3) | 13.5 (2)<br>33.0 (4) | 22.6 (1) | 11.5 (3) | 22.8 (2)<br>23.7 (4) | - |
| 12 | 19.9 (1)<br>16.8 (2) | 35.7 (1)<br>15.8 (2) | 22.5 (1) | - | 16.2 (1)<br>13.6 (4) | 12.6 (3) |
| 13 | 17.3 (2) | 15.4 (1)<br>12.7 (4) | 16.6 (2) | 10.4 (4) | 13.5 (1) | 10.7 (3) |
| 14 | 13.8 (1) | 22.1 (1)<br>33.4 (2) | 22.0 (1)<br>13.5 (4) | - | 22.4 (1) | 15.2 (1) |

| Character no. | SAMPLE-I | | | SAMPLE-II | | |
|---|---|---|---|---|---|---|
| | A* | B | C | A | B | C |
| 15 | 34.6 (3) | 60.1 (3) | 12.4 (2)<br>27.2 (3) | 37.9 (4) | 48.3 (2) | 53.3 (4) |
| 16 | 10.2 (1) | 15.9 (1)<br>12.5 (2)<br>12.3 (4) | 32.1 (1)<br>30.4 (4) | - | 11.7 (2) | 11.0 (2)<br>27.7 (4) |
| 17 | 12.5 (1) | 21.0 (1) | 20.0 (1)<br>46.3 (4) | 12.6 (4) | 20.8 (2) | 10.4 (2)<br>36.7 (4) |
| 18 | - | 15.3 (2)<br>14.2 (3) | - | - | 10.0 (4) | 11.8 (3) |
| 19 | 12.8 (1) | 14.3 (3) | 14.2 (1)<br>37.4 (2) | - | 14.1 (3) | 32.9 (3) |
| 20 | 48.2 (1) | 49.9 (1)<br>10.3 (4) | 76.7 (1) | 16.4 (1)<br>14.1 (3) | 23.2 (1) | 58.7 (1)<br>10.9 (4) |
| 21 | 13.4 (2) | - | 18.8 (2)<br>27.1 (3) | - | - | 11.9 (3) |
| 22 | 15.4 (1)<br>16.8 (4) | 36.3 (1)<br>15.3 (4) | 82.3 (1)<br>12.7 (3) | 34.1 (4) | 26.3 (1)<br>24.2 (2)<br>11.9 (3) | 38.8 (1) |
| 23 | 22.0 (1)<br>20.8 (4) | 56.6 (1)<br>20.2 (3) | 48.7 (1)<br>15.8 (3)<br>20.6 (4) | 38.4 (4) | 32.8 (1)<br>21.5 (2)<br>15.0 (3) | 13.4 (1) |
| 24 | 23.4 (3) | 10.6 (1)<br>23.1 (2)<br>86.8 (3) | 21.6 (3) | - | 16.7 (2)<br>22.7 (3)<br>46.2 (4) | 11.8 (3)<br>11.5 (4) |
| 25 | 24.3 (3) | 66.0 (2)<br>25.9 (3) | 30.5 (3) | 12.7 (2)<br>11.2 (4) | 17.1 (2)<br>29.3 (3)<br>26.0 (4) | 18.4 (2) |
| 26 | 44.0 (1)<br>23.0 (2)<br>13.0 (4) | 25.9 (1)<br>29.0 (2)<br>31.4 (3) | 133.4 (1) | 22.1 (1)<br>15.6 (3) | 11.2 (1)<br>13.9 (4) | 67.6 (1) |
| 27 | 18.8 (1) | 11.6 (1)<br>20.2 (4) | 92.0 (1)<br>12.0 (4) | 22.6 (1) | 13.0 (1)<br>14.2 (2) | 130.4 (1) |

| Character no. | SAMPLE-I | | | SAMPLE-II | | |
|---|---|---|---|---|---|---|
| | A* | B | C | A | B | C |
| 28 | 16.1 (1) | 20.9 (4) | 86.9 (1)<br>22.0 (3) | 22.1 (1) | 16.5 (1)<br>17.0 (2) | 124.5 (1) |
| 29 | - | - | - | - | - | - |
| 30 | 10.9 (2) | 15.5 (2) | - | 44.3 (2) | 32.8 (1) | 27.9 (2) |
| 31 | - | 10.1 (3) | - | 12.0 (2) | - | 18.7 (2)<br>14.9 (4) |
| 32 | 10.3 (2) | 13.4 (2)<br>16.7 (4) | 18.8 (1)<br>12.5 (2) | - | - | - |
| 33 | - | - | 10.5 (2) | - | - | - |
| 34 | 17.7 (2)<br>12.2 (4) | 34.2 (2)<br>14.0 (3) | 24.1 (2)<br>18.3 (3) | 34.1 (2) | 18.6 (2)<br>19.8 (3) | 57.2 (2) |
| 35 | - | - | 10.3 (4) | - | 10.7 (2) | 16.0 (2) |
| 36 | - | - | - | - | - | - |
| 37 | - | - | 20.5 (4) | - | 22.5 (2) | 50.8 (2) |
| 38 | - | - | 14.0 (3) | - | 11.2 (2) | 10.6 (2) |
| 39 | 10.8 (2) | - | - | - | - | 25.4 (1) |
| 40 | 48.2 (1) | 29.1 (1) | 166.7 (1) | 68.4 (1)<br>12.2 (3) | 61.8 (1)<br>10.0 (3) | 280.3(1) |
| 41 | 25.6 (1)<br>20.6 (2) | 19.3 (1)<br>27.0 (2)<br>10.1 (3) | 88.5 (1) | 29.5 (1)<br>15.3 (3) | 38.4 (1)<br>12.2 (3)<br>10.2 (4) | 87.8 (1) |
| 42 | 21.3 (1) | 25.4 (1)<br>13.2 (4) | 38.6 (1)<br>22.6 (4) | 26.8 (1) | 33.2 (1) | 47.6 (1)<br>11.3 (4) |
| 43 | 16.3 (1) | 32.5 (1) | 24.0 (1)<br>35.8 (2) | 22.8 (1) | 26.3 (1) | 27.2 (1)<br>26.6 (3) |
| 44 | - | - | 13.5 (4) | - | - | - |
| 45 | 13.4 (4) | 33.8 (3) | - | - | 14.2 (2) | - |
| 46 | - | - | - | - | 10.1 (3) | 19.8 (3) |
| 47 | 15.8 (4) | - | 33.8 (4) | 21.8 (4) | 15.1 (2) | 10.3 (1)<br>44.1 (20<br>12.1 (3)<br>22.3 (4) |

| Character no. | SAMPLE-I | | | SAMPLE-II | | |
|---|---|---|---|---|---|---|
| | A* | B | C | A | B | C |
| 48 | 17.2 (2) | 18.2 (3) | - | 16.0 (3) | 10.0 (1) | - |
| | | 16.0 (4) | | | 10.9 (3) | |
| | | | | | 23.4 (4) | |
| 49 | 28.2 (3) | 20.7 (3) | 15.5 (2) | - | - | 12.0 (3) |
| | | 22.1 (4) | 10.0 (3) | | | |
| | | | 10.4 (4) | | | |
| 50 | 24.2 (3) | 11.0 (2) | 20.8 (2) | 25.4 (3) | 11.4 (1) | 34.4 (3) |
| | | 62.8 (4) | 26.5 (4) | 10.5 (4) | 40.6 (3) | 27.2 (4) |
| | | | | | 45.2 (4) | |
| 51 | - | - | 15.3 (4) | 11.6 (4) | 18.1 (2) | 47.7 (2) |
| | | | | | | 12.2 (4) |
| 52 | - | - | - | 11.8 (4) | - | 53.2 (4) |
| 53 | 18.3 (2) | 23.3 (2) | 20.3 (1) | 29.4 (4) | 11.0 (2) | 21.5 (2) |
| | | | 45.3 (2) | | 15.5 (4) | 28.4 (3) |
| | | | 27.3 (4) | | | 42.1 (4) |
| 54 | 14.6 (2) | 40.2 (2) | 81.8 (2) | 14.2 (2) | 18.0 (2) | 22.9 (2) |
| | | | | 10.5 (3) | 23.3 (3) | 35.2 (3) |
| 55 | 21.5 (2) | 36.0 (2) | 65.3 (2) | 16.2 (2) | 24.7 (2) | 40.6 (2) |
| | | | 25.0 (3) | | | 12.6 (3) |
| 56 | - | - | 20.2 (2) | - | - | - |
| 57 | 38.2 (2) | 64.9 (2) | 57.6 (2) | 15.3 (2) | 14.1 (2) | 30.9 (2) |
| | 15.2 (4) | 18.5 (4) | | | | |
| 58 | 53.4 (1) | 118.5 (1) | 136.3 (1) | 57.2 (1) | 72.7 (1) | 179.2 (1) |
| | 62.8 (2) | 44.4 (2) | 21.6 (2) | 14.3 (3) | 16.8 (2) | |
| | | | | | 15.5 (3) | |
| 59 | 88.8 (1) | 161.3 (1) | 248.6 (1) | 72.4 (1) | 93.2 (1) | 295.0 (1) |
| | 59.7 (2) | 43.2 (2) | | 18.6 (3) | 16.5 (2) | |
| | | 14.1 (3) | | | 22.9 (3) | |
| 60 | 42.6 (1) | 63.3 (1) | 129.2 (1) | 19.1 (1) | 21.5 (1) | 101.0 (1) |
| | 53.6 (2) | 30.3 (2) | 16.7 (2) | 18.5 (3) | 15.2 (2) | |
| | | | | | 20.1 (3) | |
| | | | | | 12.8 (4) | |

| Character no. | SAMPLE-I | | | SAMPLE-II | | |
|---|---|---|---|---|---|---|
| | A | B | C | A | B | C |
| 61 | 68.8 (1) | 122.5 (1) | 209.4 (1) | 75.7 (1) | 87.1 (1) | 366.7 (1) |
| | 45.0 (2) | 25.0 (2) | | 23.8 (3) | 24.6 (2) | |
| | | 14.2 (3) | | | 25.0 (3) | |
| 62 | 27.4 (1) | 31.9 (1) | 142.7 (1) | 44.5 (1) | 54.5 (1) | 166.6 (1) |
| | 14.3 (2) | 14.2 (2) | | 11.4 (3) | | |
| 63 | 21.2 (1) | 25.6 (1) | 36.4 (1) | 19.4 (1) | 23.3 (1) | 36.3 (1) |
| | | | 16.1 (2) | | | |
| 64 | - | - | - | - | - | 11.6 (2) |
| 65 | 23.7 (2) | 65.5 (1) | 86.3 (3) | 90.7 (2) | 111.5 (1) | 27.0 (2) |
| | 38.2 (3) | 33.8 (2) | | 30.4 (4) | 35.6 (2) | 126.0 (4) |
| | 13.8 (4) | 27.5 (3) | | | 33.1 (3) | |
| | | 13.6 (4) | | | | |
| 66 | 35.8 (2) | 67.0 (1) | 12.1 (2) | 108.9 (2) | 104.1 (1) | 43.6 (2) |
| | 21.9 (3) | 52.0 (2) | 95.7 (3) | 13.9 (4) | 38.2 (2) | 64.5 (4) |
| | 35.1 (4) | | | | 28.2 (3) | |
| 67 | 18.2 (3) | 13.6 (1) | 15.5 (3) | 31.6 (2) | 39.5 (1) | 73.2 (4) |
| | | 19.8 (3) | | 23.4 (4) | 29.4 (2) | |
| | | | | | 27.0 (3) | |
| 68 | - | 19.9 (2) | 12.0 (4) | 13.8 (3) | 56.4 (2) | 12.4 (3) |
| | | | | 47.8 (4) | 13.6 (3) | 41.4 (4) |
| 69 | 54.9 (3) | 45.1 (1) | 34.2 (3) | 49.0 (2) | 55.4 (1) | 52.2 (2) |
| | | | 16.1 (4) | | | |
| 70 | 46.2 (3) | 218.9 (1) | 67.7 (3) | 99.8 (2) | 194.9 (1) | 115.8 (2) |
| | 21.7 (4) | | 24.3 (4) | 20.9 (3) | | |
| 71 | 60.0 (3) | 340.0 (1) | 146.5 (3) | 118.9 (2) | 188.9 (1) | 150.9 (2) |
| | 52.6 (4) | | 11.9 (4) | 15.5 (3) | | |
| 72 | 13.0 (3) | 120.6 (1) | 10.0 (2) | 50.1 (2) | 89.3 (1) | 52.8 (2) |
| | 67.8 (4) | 31.0 (3) | 49.7 (3) | | 12.2 (3) | |
| 73 | 27.3 (3) | 88.3 (1) | 33.4 (3) | 50.0 (2) | 101.7 (1) | 60.4 (2) |
| | 15.0 (4) | | | 13.5 (3) | | |
| 74 | 23.3 (3) | 65.3 (1) | 26.6 (3) | 30.7 (2) | 33.6 (1) | 32.0 (2) |
| | | 10.8 (2) | 17.1 (4) | | | |

| Character no. | SAMPLE-I | | | SAMPLE-II | | |
|---|---|---|---|---|---|---|
| | A | B | C | A | B | C |
| 75 | 12.1 (3) | 107.0 (1) | 54.7 (3) | 33.7 (2) | 98.5 (1) | 18.3 (2) |
| | 73.4 (4) | 15.2 (3) | | | 10.7 (3) | 15.9 (4) |
| 76 | 27.6 (3) | 20.7 (1) | 18.3 (2) | 29.7 (3) | 18.1 (1) | 17.5 (2) |
| | | 38.5 (3) | 48.4 (3) | | 36.2 (2) | 39.6 (3) |
| | | 12.2 (4) | | | 28.2 (4) | |
| 77 | 24.7 (3) | 15.4 (1) | 27.3 (2) | 11.0 (3) | 55.2 (4) | 21.6 (3) |
| | | 17.7 (3) | 33.1 (3) | | | 17.4 (4) |
| 78 | - | 12.9 (1) | 22.3 (3) | 14.3 (2) | 14.7 (1) | 61.8 (2) |
| | | | 16.2 (4) | | | |
| 79 | 20.3 (4) | 35.5 (2) | 14.3 (3) | - | 45.1 (4) | - |
| | | 89.7 (4) | 18.0 (4) | | | |
| 80 | 20.0 (3) | 82.0 (2) | 45.2 (2) | 11.8 (3) | 61.0 (2) | 17.0 (2) |
| | 16.2 (4) | 17.7 (3) | 15.9 (4) | | 50.9 (3) | 54.7 (3) |
| | | | | | 11.6 (4) | |
| 81 | - | - | - | - | - | - |
| 82 | 17.7 (3) | 60.7 (2) | 17.6 (1) | 35.9 (3) | 62.1 (2) | 22.8 (2) |
| | 25.9 (4) | 111.1 (3) | 49.4 (2) | | 122.0 (3) | 93.1 (3) |
| 83 | - | - | 16.6 (2) | - | - | - |
| 84 | 11.8 (3) | 66.1 (1) | 40.2 (3) | 13.6 (2) | 36.0 (1) | 23.4 (2) |
| | 11.6 (4) | 16.3 (3) | | | 14.7 (3) | |
| | | | | | 17.3 (4) | |
| 85 | - | 16.2 (4) | - | 12.7 (2) | 14.6 (1) | 11.1 (2) |
| | | | | | 15.3 (3) | 10.7 (3) |
| 86 | 99.0 (4) | 46.7 (1) | 34.6 (3) | 17.0 (2) | 50.5 (1) | 99.4 (4) |
| | | 37.7 (2) | 24.3 (4) | 48.1 (4) | 34.9 (2) | |
| 87 | 18.0 (2) | 78.3 (2) | 63.0 (4) | 19.3 (2) | 10.6 (1) | 86.9 (4) |
| | | 49.9 (3) | | 18.9 (3) | 72.8 (2) | |
| | | 14.4 (4) | | 37.3 (4) | 111.8 (3) | |
| 88 | 39.0 (2) | 262.0 (2) | 37.8 (2) | 13.7 (2) | 271.0 (2) | 69.6 (3) |
| | 12.9 (3) | | 65.9 (4) | 53.8 (3) | 10.0 (3) | 59.8 (4) |
| | 17.4 (4) | | | 24.9 (4) | | |
| 89 | - | 53.6 (2) | 53.5 (4) | 42.8 (4) | 44.1 (2) | 66.8 (4) |
| | | 62.5 (3) | | | 98.8 (3) | |

| Character no. | SAMPLE-I | | | SAMPLE-II | | |
|---|---|---|---|---|---|---|
| | A | B | C | A | B | C |
| 90 | 16.6 (3) | 92.0 (1) | 36.0 (3) | 19.6 (2) | 75.6 (1) | 50.6 (4) |
| | 43.0 (4) | 10.5 (3) | | 21.9 (4) | | |
| 91 | 26.4 (2) | 116.5 (2) | 43.7 (4) | 26.0 (2) | 16.2 (1) | 12.6 (3) |
| | | 31.1 (3) | | 19.6 (3) | 99.5 (2) | 85.0 (4) |
| | | 13.1 (4) | | 31.8 (4) | 79.6 (3) | |
| 92 | 52.2 (2) | 251.1 (2) | 61.7 (2) | 25.9 (2) | 15.1 (1) | 92.8 (3) |
| | 14.1 (3) | 15.5 (4) | 35.8 (4) | 52.4 (3) | 251.6 (2) | 50.5 (4) |
| | 21.2 (4) | | | 22.2 (4) | | |
| 93 | 12.7 (2) | 78.2 (2) | 46.7 (4) | 20.8 (2) | 15.9 (1) | 12.0 (3) |
| | | 28.6 (3) | | 16.5 (3) | 88.5 (2) | 91.4 (4) |
| | | | | 38.0 (4) | 44.3 (3) | |
| 94 | 15.7 (2) | 40.1 (1) | 67.9 (3) | 57.8 (2) | 77.6 (1) | 17.2 (2) |
| | 20.6 (3) | 46.7 (2) | | 23.0 (4) | 28.6 (2) | 95.7 (4) |
| | 23.9 (4) | 31.4 (3) | | | 29.3 (3) | |
| 95 | - | - | - | - | - | - |
| 96 | 15.7 (2) | 413.8 (1) | 172.2 (3) | 206.4 (2) | 277.6 (1) | 118.1 (2) |
| | 88.8 (3) | 10.4 (4) | | | | 20.9 (4) |
| | 29.9 (4) | | | | | |
| 97 | 34.3 (2) | 233.9 (1) | 12.5 (2) | 187.7 (2) | 210.4 (1) | 87.1 (2) |
| | 45.8 (3) | 11.0 (4) | 128.7 (3) | | 10.2 (2) | 10.7 (3) |
| | 32.4 (4) | | | | | 25.1 (4) |
| 98 | 13.4 (2) | 326.5 (1) | 81.2 (3) | 174.4 (2) | 222.1 (1) | 98.6 (2) |
| | 98.7 (3) | | | | | 21.0 (4) |
| | 28.6 (4) | | | | | |
| 99 | 37.6 (3) | 128.6 (1) | 56.0 (3) | 53.8 (2) | 141.5 (1) | 29.2 (2) |
| | 30.5 (4) | | | | | 31.6 (4) |

**APPENDIX XII** The first four vector scores of PCO analysis of the 327 diploid cultivars.

PRINCIPAL COORDINATE ANALYSIS

TRACE = 151.494

| | | | | | |
|---|---|---|---|---|---|
| LATENT ROOTS | | 5.464 | 4.853 | 4.121 | 3.671 |
| PERCENT OF TRACE | | 3.6 | 3.2 | 2.7 | 2.4 |
| C7c0304 | 1 | -0.224 | -0.117 | -0.117 | 0.013 |
| C7c0313 | 2 | 0.097 | 0.016 | 0.240 | 0.024 |
| C7c0329 | 3 | 0.286 | -0.042 | 0.102 | 0.210 |
| C7c0344 | 4 | 0.129 | 0.194 | 0.146 | -0.020 |
| C7c0348 | 5 | 0.215 | 0.008 | 0.005 | -0.089 |
| C7c0362 | 6 | 0.076 | -0.063 | 0.010 | 0.057 |
| C7c0390 | 7 | -0.090 | 0.009 | -0.240 | -0.036 |
| C7c0403 | 8 | 0.085 | -0.138 | -0.077 | -0.165 |
| C7c0427 | 9 | -0.000 | -0.228 | 0.000 | 0.096 |
| C7c0469 | 10 | 0.007 | 0.111 | 0.089 | 0.020 |
| C7c0640 | 11 | 0.261 | 0.004 | 0.008 | 0.135 |
| C7c0697 | 12 | 0.230 | -0.056 | 0.009 | 0.066 |
| C7c0791 | 13 | 0.091 | 0.122 | -0.085 | -0.044 |
| C7c0827 | 14 | 0.180 | 0.222 | -0.105 | 0.028 |
| C7c0894 | 15 | -0.078 | 0.131 | -0.073 | 0.061 |
| C7c0896 | 16 | 0.072 | 0.119 | 0.137 | 0.037 |
| C7c0936 | 17 | -0.068 | -0.092 | 0.082 | -0.256 |
| C7c0939 | 18 | -0.058 | -0.218 | -0.010 | -0.159 |
| C7c1052 | 19 | -0.122 | 0.055 | 0.118 | -0.068 |
| C7c1109 | 20 | -0.158 | -0.001 | -0.095 | -0.016 |
| C7c1119 | 21 | 0.035 | -0.139 | -0.074 | -0.177 |
| C7c1137 | 22 | -0.109 | -0.207 | -0.030 | -0.237 |
| C7c1153 | 23 | -0.043 | -0.008 | -0.166 | -0.078 |
| C7c1165 | 24 | -0.133 | -0.161 | -0.182 | -0.031 |
| C7c1205 | 25 | -0.079 | 0.027 | 0.078 | 0.099 |
| C7c1207 | 26 | 0.034 | 0.297 | -0.142 | -0.010 |
| C7c1266 | 27 | -0.285 | -0.066 | -0.129 | -0.114 |
| C7c1406 | 28 | 0.014 | -0.073 | 0.192 | -0.041 |
| C7c1518 | 29 | -0.097 | 0.176 | -0.047 | 0.057 |
| C7c1592 | 30 | -0.048 | -0.250 | -0.030 | 0.026 |
| C7c1633 | 31 | 0.006 | -0.012 | 0.142 | -0.063 |
| C7c1739 | 32 | -0.069 | -0.213 | -0.061 | 0.030 |
| C7c1840 | 33 | 0.010 | 0.120 | -0.141 | -0.113 |
| C7c1863 | 34 | -0.010 | -0.053 | 0.171 | -0.150 |
| C7c1864 | 35 | -0.182 | 0.065 | -0.147 | -0.054 |
| C7c1882 | 36 | -0.091 | 0.166 | 0.059 | -0.068 |
| C7c1886 | 37 | 0.139 | -0.133 | 0.119 | -0.153 |
| C7c1893 | 38 | -0.195 | 0.128 | 0.211 | 0.159 |
| C7c1905 | 39 | -0.174 | 0.033 | 0.147 | 0.006 |
| C7c1910 | 40 | -0.025 | -0.040 | 0.188 | -0.148 |
| C7c1913 | 41 | -0.022 | -0.049 | 0.145 | -0.061 |
| C7c1915 | 42 | -0.103 | -0.139 | 0.057 | 0.130 |
| C7c1937 | 43 | -0.203 | 0.263 | -0.061 | -0.014 |
| C7c1947 | 44 | -0.074 | 0.008 | -0.033 | -0.095 |
| C7c1948 | 45 | 0.161 | 0.171 | 0.030 | 0.001 |
| C7c1954 | 46 | -0.181 | 0.045 | -0.181 | -0.033 |
| C7c1966 | 47 | -0.164 | 0.292 | -0.088 | 0.019 |
| C7c1970 | 48 | -0.171 | 0.143 | -0.069 | 0.089 |
| C7c2151 | 49 | -0.071 | -0.151 | -0.074 | 0.202 |
| C7c2216 | 50 | 0.065 | 0.107 | -0.042 | 0.144 |
| C7c2219 | 51 | 0.039 | 0.031 | -0.080 | 0.139 |
| C7c2223 | 52 | -0.020 | 0.045 | -0.058 | 0.071 |
| C7c2234 | 53 | -0.048 | -0.011 | -0.058 | 0.015 |
| C7c2241 | 54 | -0.190 | 0.105 | 0.009 | 0.023 |
| C7c2287 | 55 | 0.272 | 0.154 | 0.007 | 0.016 |
| C7c2288 | 56 | 0.260 | 0.084 | 0.109 | -0.024 |
| C7c2319 | 57 | 0.193 | 0.065 | 0.049 | -0.103 |
| C7c2332 | 58 | 0.200 | -0.121 | -0.136 | -0.049 |
| C7c2353 | 59 | 0.272 | 0.007 | -0.022 | 0.085 |
| C7c2378 | 60 | -0.053 | 0.002 | -0.071 | -0.019 |
| C7c2418 | 61 | -0.000 | 0.072 | -0.182 | 0.129 |
| C7c2421 | 62 | 0.037 | -0.007 | 0.086 | 0.054 |
| C7c2450 | 63 | 0.235 | -0.066 | 0.065 | 0.130 |
| C7c2464 | 64 | -0.093 | -0.036 | 0.136 | 0.144 |
| C7c2472 | 65 | -0.257 | 0.056 | -0.012 | -0.027 |
| C7c2505 | 66 | -0.081 | -0.003 | 0.111 | 0.224 |
| C7c2547 | 67 | 0.113 | 0.067 | -0.018 | 0.059 |
| C7c2556 | 68 | -0.070 | 0.004 | 0.179 | 0.127 |
| C7c2586 | 69 | 0.229 | -0.005 | 0.088 | 0.047 |
| C7c2602 | 70 | 0.314 | 0.027 | -0.019 | -0.081 |
| C7c2624 | 71 | 0.146 | 0.007 | 0.087 | 0.039 |
| C7c2700 | 72 | 0.145 | 0.126 | -0.069 | 0.267 |
| C7c2742 | 73 | -0.042 | -0.102 | -0.145 | 0.115 |
| C7c2815 | 74 | -0.001 | 0.005 | 0.004 | 0.129 |
| C7c2834 | 75 | 0.285 | -0.110 | -0.179 | -0.097 |
| C7c2886 | 76 | 0.121 | -0.045 | 0.014 | 0.128 |
| C7c2941 | 77 | -0.167 | 0.101 | -0.112 | 0.085 |
| C7c2951 | 78 | -0.233 | 0.101 | 0.039 | 0.049 |
| C7c2966 | 79 | 0.036 | 0.201 | -0.061 | -0.108 |
| C7c2991 | 80 | -0.166 | -0.108 | -0.023 | 0.123 |
| C7c2995 | 81 | -0.030 | 0.138 | 0.018 | -0.015 |
| C7c3027 | 82 | -0.218 | -0.050 | 0.101 | -0.044 |
| C7c3042 | 83 | 0.105 | -0.082 | 0.127 | 0.044 |
| C7c3089 | 84 | 0.119 | -0.106 | -0.120 | 0.071 |
| C7c3096 | 85 | 0.044 | 0.022 | 0.175 | -0.054 |
| C7c3117 | 86 | -0.002 | -0.119 | -0.182 | -0.214 |
| C7c3125 | 87 | 0.048 | -0.272 | -0.010 | 0.038 |
| C7c3159 | 88 | 0.112 | -0.048 | -0.052 | -0.153 |
| C7c3161 | 89 | 0.088 | 0.215 | -0.173 | -0.097 |
| C7c3167 | 90 | -0.125 | 0.122 | 0.038 | -0.082 |
| CUP 13 | 91 | -0.137 | 0.021 | 0.057 | -0.165 |
| CUP 56 | 92 | 0.158 | 0.023 | -0.020 | 0.217 |
| CUP 61 | 93 | 0.207 | 0.052 | 0.181 | -0.098 |
| CUP 70 | 94 | 0.165 | 0.060 | -0.121 | 0.114 |
| CUS 117 | 95 | -0.127 | -0.070 | -0.014 | 0.027 |
| CUP 142 | 96 | -0.025 | -0.086 | 0.237 | 0.159 |
| CUP 149 | 97 | 0.206 | -0.067 | -0.106 | 0.021 |
| CUP 156 | 98 | 0.102 | 0.035 | 0.057 | -0.098 |
| CUP 173 | 99 | 0.041 | -0.009 | 0.114 | -0.009 |
| CUP 192 | 100 | 0.173 | 0.018 | 0.030 | 0.009 |
| CUP 194 | 101 | 0.014 | 0.058 | -0.016 | 0.201 |
| CUS 14 | 102 | 0.030 | 0.062 | 0.166 | 0.062 |
| CUS 100 | 103 | -0.158 | 0.062 | 0.052 | 0.006 |
| CUS 102 | 104 | 0.068 | -0.277 | -0.177 | -0.147 |
| CUS 103 | 105 | 0.174 | -0.031 | -0.041 | -0.003 |
| CUS 122 | 106 | 0.171 | 0.007 | -0.030 | 0.109 |
| CUS 172 | 107 | -0.020 | 0.131 | -0.152 | 0.103 |
| CUS 271 | 108 | -0.023 | 0.087 | 0.092 | -0.067 |
| CUS 277 | 109 | 0.154 | -0.093 | 0.100 | 0.104 |
| CUS 312 | 110 | 0.053 | 0.069 | 0.001 | -0.116 |
| CUS 484 | 111 | 0.160 | 0.137 | -0.045 | 0.155 |
| CUS 545 | 112 | 0.062 | 0.061 | -0.127 | -0.006 |
| CUS 549 | 113 | -0.045 | -0.024 | -0.167 | 0.146 |
| CUS 632 | 114 | 0.180 | -0.044 | -0.092 | -0.145 |
| CUS 656 | 115 | 0.086 | -0.060 | 0.090 | 0.115 |
| CUS 672 | 116 | 0.205 | 0.021 | 0.013 | 0.161 |
| HAW5520 | 117 | 0.131 | -0.070 | -0.022 | 0.094 |
| HAW5526 | 118 | 0.136 | 0.152 | 0.088 | 0.076 |
| HAW5529 | 119 | 0.342 | -0.071 | -0.038 | 0.096 |
| HAW5564 | 120 | -0.099 | -0.150 | -0.108 | 0.042 |
| HAW5593 | 121 | 0.094 | -0.253 | -0.115 | -0.029 |
| HAW5698 | 122 | 0.202 | 0.032 | -0.173 | -0.160 |
| HAW6165 | 123 | 0.222 | -0.034 | 0.023 | 0.095 |
| HJT5430 | 124 | 0.056 | -0.000 | 0.175 | -0.143 |
| HJT5442 | 125 | -0.041 | -0.168 | -0.010 | 0.191 |
| HJT5500 | 126 | 0.030 | -0.194 | -0.051 | 0.171 |
| HJT5515 | 127 | 0.123 | -0.262 | -0.071 | -0.029 |
| HJT5517 | 128 | 0.048 | 0.027 | 0.014 | -0.070 |
| HJT5623 | 129 | -0.000 | 0.054 | 0.056 | -0.067 |
| HJT5626 | 130 | -0.107 | -0.030 | 0.019 | -0.125 |
| HJT5643 | 131 | -0.032 | 0.071 | 0.056 | -0.012 |
| HJT5653 | 132 | -0.104 | -0.151 | -0.025 | -0.054 |
| HJT5661 | 133 | 0.045 | 0.194 | 0.042 | -0.076 |
| HJT5663 | 134 | 0.002 | 0.273 | 0.050 | -0.031 |
| HJT5666 | 135 | -0.138 | 0.191 | 0.147 | 0.002 |
| HJT5668 | 136 | 0.084 | -0.061 | 0.074 | -0.151 |
| HJT5711 | 137 | -0.201 | -0.140 | 0.060 | 0.156 |
| HJT5773 | 138 | -0.062 | -0.128 | 0.169 | 0.091 |
| HJT5777 | 139 | -0.001 | -0.240 | -0.071 | 0.178 |
| HJT5782 | 140 | 0.020 | 0.107 | 0.147 | -0.033 |
| HJT5783 | 141 | -0.038 | -0.051 | -0.215 | -0.062 |
| HJT5785 | 142 | -0.110 | 0.181 | 0.047 | 0.041 |
| HJT5787 | 143 | 0.029 | 0.163 | 0.036 | 0.074 |
| HJT5806 | 144 | 0.050 | 0.161 | -0.153 | -0.129 |
| HJT5816 | 145 | -0.219 | 0.047 | -0.247 | -0.082 |
| HJT5826 | 146 | -0.158 | -0.000 | 0.002 | 0.216 |
| HJT5835 | 147 | -0.076 | 0.178 | -0.032 | 0.003 |
| HJT5840 | 148 | -0.055 | 0.075 | 0.264 | -0.099 |
| HJT5848 | 149 | -0.008 | 0.161 | 0.230 | 0.043 |
| HJT5857 | 150 | 0.120 | 0.077 | -0.007 | 0.012 |
| HJT5859 | 151 | 0.010 | 0.087 | -0.027 | -0.187 |
| HJT5864 | 152 | -0.056 | -0.007 | 0.104 | 0.037 |
| HJT5865 | 153 | 0.111 | 0.155 | -0.139 | -0.146 |
| HJT5871 | 154 | 0.071 | -0.242 | 0.055 | -0.052 |
| HJT5873 | 155 | -0.038 | -0.111 | 0.038 | 0.049 |
| HJT5882 | 156 | -0.049 | -0.214 | -0.130 | 0.002 |
| HJT5883 | 157 | -0.142 | -0.115 | -0.175 | 0.047 |
| HJT5894 | 158 | 0.120 | -0.221 | 0.165 | -0.067 |
| HJT5919 | 159 | 0.100 | -0.139 | 0.143 | -0.125 |
| HJT5922 | 160 | -0.043 | 0.070 | 0.149 | 0.054 |
| HJT5937 | 161 | 0.042 | -0.004 | 0.149 | 0.047 |
| HJT5994 | 162 | -0.024 | -0.004 | 0.007 | -0.061 |
| HJT6005 | 163 | 0.092 | -0.129 | -0.151 | 0.000 |
| HJT6033 | 164 | -0.224 | 0.077 | -0.241 | -0.015 |
| HJT6053 | 165 | 0.085 | 0.247 | -0.120 | -0.097 |
| HJT6065 | 166 | -0.066 | 0.043 | 0.202 | 0.084 |
| HJT6085 | 167 | -0.076 | 0.107 | 0.174 | -0.084 |
| HJT6105 | 168 | 0.019 | -0.075 | 0.103 | 0.100 |
| HJT6142 | 169 | -0.154 | 0.120 | 0.122 | -0.004 |
| HJT6144 | 170 | 0.046 | 0.141 | 0.116 | -0.053 |
| HJT6147 | 171 | -0.124 | -0.185 | -0.096 | 0.081 |
| HJT6158 | 172 | 0.056 | -0.166 | -0.062 | -0.124 |
| HJT6164 | 173 | 0.084 | -0.075 | 0.200 | -0.007 |
| HJT6184 | 174 | 0.100 | 0.066 | -0.139 | 0.073 |
| HJT6189 | 175 | 0.093 | 0.015 | -0.148 | 0.012 |
| HUA 770 | 176 | 0.259 | 0.000 | -0.022 | 0.063 |
| HUA 822 | 177 | 0.183 | 0.104 | 0.024 | -0.133 |
| HUA 853 | 178 | 0.178 | 0.115 | 0.057 | 0.076 |
| HUA 847 | 179 | 0.073 | -0.127 | -0.068 | 0.062 |
| HUA 863 | 180 | 0.011 | -0.000 | -0.065 | 0.066 |

| | | | | | | |
|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

## APPENDIX XIII : The first ten vector scores of the chromatographic data.

PRINCIPAL COORDINATE ANALYSIS

TRACE = 29.249

| LATENT ROOTS | 3.303 | 2.584 | 2.130 | 1.233 | 1.553 | 1.461 | 1.346 | 1.250 | 1.131 | 1.029 |
|---|---|---|---|---|---|---|---|---|---|---|
| PERCENT OF TRACE | 11.3 | 20.1 | 27.4 | 34.0 | 39.3 | 44.3 | 48.8 | 53.2 | 57.1 | 60.6 |
| 1 | -.252 | .083 | .088 | -.035 | -.256 | -.166 | -.063 | -.043 | .146 | .009 |
| 2 | .587 | -.114 | .053 | -.246 | -.019 | -.222 | -.200 | -.017 | .071 | -.052 |
| 3 | .028 | .040 | .275 | -.153 | .134 | .122 | .005 | -.017 | .224 | -.040 |
| 4 | -.030 | -.020 | .224 | .027 | -.129 | -.068 | .020 | .080 | -.082 | .044 |
| 5 | .017 | -.307 | .065 | .059 | -.054 | .031 | .013 | .062 | .018 | .018 |
| 6 | .192 | .070 | -.284 | -.053 | -.013 | .131 | -.010 | .022 | -.211 | .120 |
| 7 | .208 | .048 | .007 | .014 | .040 | .023 | -.023 | .036 | -.022 | -.035 |
| 8 | .352 | .196 | .000 | -.083 | .196 | -.113 | -.020 | .170 | .160 | .022 |
| 9 | .030 | .150 | .029 | .179 | .031 | .014 | .011 | .065 | .170 | -.008 |
| 10 | -.014 | -.447 | .078 | .083 | .040 | -.073 | -.064 | -.034 | .051 | .140 |
| 11 | .027 | -.477 | .075 | .100 | -.056 | -.017 | -.063 | .012 | -.013 | -.022 |
| 12 | .332 | .107 | .129 | .088 | .103 | -.237 | -.055 | .209 | .139 | -.196 |
| 13 | -.334 | .076 | .051 | -.400 | -.015 | -.110 | -.256 | .021 | -.105 | -.031 |
| 14 | .246 | .056 | .053 | -.137 | .194 | -.127 | -.015 | -.252 | -.075 | -.025 |
| 15 | .160 | -.174 | -.127 | .087 | -.208 | -.081 | -.037 | .091 | .015 | .016 |
| 16 | .284 | -.308 | .040 | -.015 | .209 | .131 | .075 | -.008 | .127 | .235 |
| 17 | .146 | -.050 | .233 | -.047 | -.196 | .163 | .021 | -.065 | .124 | .134 |
| 18 | .017 | .028 | -.039 | .184 | -.042 | -.035 | -.014 | .217 | .092 | .000 |
| 19 | .136 | .177 | .078 | -.010 | .202 | -.245 | -.101 | .110 | -.006 | -.008 |
| 20 | .114 | .125 | .006 | .219 | .150 | -.149 | -.152 | .009 | -.236 | -.055 |
| 21 | .185 | .062 | -.212 | .046 | .127 | .040 | .008 | .020 | -.221 | -.005 |
| 22 | .056 | .017 | .083 | .048 | .184 | .161 | .091 | .180 | -.053 | .119 |
| 23 | .204 | .124 | -.222 | -.077 | -.022 | .038 | -.203 | .048 | -.053 | .009 |
| 24 | .164 | .066 | .149 | .222 | .118 | .183 | -.089 | -.055 | .119 | .113 |
| 25 | .115 | .115 | .120 | .060 | .057 | -.222 | .042 | .126 | -.207 | .131 |
| 26 | .131 | .127 | .144 | .077 | -.029 | -.016 | .153 | -.004 | -.129 | -.042 |
| 27 | .244 | .128 | -.060 | .060 | .141 | -.165 | .094 | -.258 | -.069 | -.014 |
| 28 | .070 | .152 | .341 | .022 | .180 | .059 | -.101 | -.065 | -.026 | -.190 |
| 29 | .328 | .108 | .015 | -.328 | .026 | -.120 | .038 | .093 | .007 | .000 |
| 30 | .279 | .087 | -.271 | .170 | .104 | .178 | .025 | .038 | -.047 | -.002 |
| 31 | .141 | -.074 | .060 | -.332 | .106 | -.069 | -.018 | .123 | -.067 | .028 |
| 32 | .195 | .028 | .163 | -.134 | .006 | .092 | -.193 | .078 | -.108 | .166 |
| 33 | .024 | .002 | .242 | .103 | -.132 | .059 | .088 | .012 | .053 | .146 |
| 34 | .103 | -.051 | .104 | -.067 | .042 | .045 | .016 | .127 | .157 | .076 |
| 35 | .157 | .217 | .148 | .083 | .116 | .150 | .019 | .178 | .114 | .046 |
| 36 | .120 | .002 | .087 | .106 | .085 | .055 | .049 | .194 | .076 | .067 |
| 37 | .170 | .044 | .257 | .009 | .014 | .141 | .043 | .078 | .043 | .091 |
| 38 | .127 | .003 | .150 | .055 | .088 | .015 | .153 | .121 | .188 | .176 |
| 39 | .270 | .082 | .041 | .041 | .107 | .063 | .067 | .067 | .047 | .007 |
| 40 | .232 | .018 | .132 | .003 | .124 | .080 | .062 | .002 | .097 | .037 |
| 41 | .256 | .015 | .132 | .003 | .124 | .080 | .062 | .002 | .097 | .037 |
| 42 | .131 | .007 | .255 | .078 | .085 | .017 | .159 | .057 | .013 | .110 |
| 43 | .131 | .007 | .255 | .078 | .085 | .017 | .159 | .057 | .013 | .110 |
| 44 | .165 | .032 | .094 | .187 | .065 | .189 | .089 | .071 | .012 | .123 |
| 45 | .109 | .033 | .141 | .023 | .041 | .217 | .152 | .093 | .263 | .008 |
| 46 | .084 | .204 | .102 | .052 | .149 | .248 | .104 | .025 | .063 | .332 |
| 47 | .084 | .441 | .014 | .022 | .075 | .038 | .099 | .043 | .027 | .212 |
| 48 | .019 | .033 | .132 | .052 | .157 | .029 | .015 | .131 | .207 | .063 |
| 49 | .093 | .016 | .144 | .065 | .144 | .166 | .165 | .023 | .019 | .142 |
| 50 | .022 | .076 | .206 | .162 | .025 | .005 | .057 | .159 | .087 | .001 |
| 51 | .051 | .087 | .180 | .106 | .059 | .150 | .044 | .155 | .037 | .250 |
| 52 | .042 | .142 | .127 | .120 | .156 | .231 | .089 | .067 | .033 | .077 |
| 53 | .176 | .149 | .055 | .166 | .043 | .071 | .081 | .126 | .045 | .104 |
| 54 | .270 | .063 | .092 | .032 | .221 | .061 | .066 | .032 | .029 | .014 |
| 55 | .008 | .135 | .073 | .012 | .038 | .098 | .072 | .138 | .054 | .199 |
| 56 | .154 | .193 | .152 | .242 | .197 | .127 | .115 | .006 | .088 | .033 |
| 57 | .043 | .155 | .024 | .085 | .053 | .101 | .188 | .164 | .032 | .068 |
| 58 | .087 | .282 | .137 | .255 | .092 | .112 | .044 | .090 | .042 | .086 |
| 59 | .144 | .076 | .196 | .238 | .074 | .112 | .177 | .031 | .098 | .074 |
| 60 | .053 | .055 | .206 | .030 | .103 | .146 | .084 | .094 | .190 | .095 |
| 61 | .152 | .064 | .027 | .051 | .071 | .019 | .061 | .161 | .092 | .005 |
| 62 | .013 | .203 | .096 | .006 | .054 | .070 | .039 | .067 | .022 | .021 |
| 63 | .003 | .512 | .105 | .156 | .016 | .204 | .105 | .188 | .009 | .057 |
| 64 | .121 | .054 | .054 | .151 | .080 | .198 | .073 | .037 | .033 | .147 |
| 65 | .151 | .110 | .108 | .233 | .060 | .196 | .031 | .286 | .065 | .074 |
| 66 | .073 | .084 | .128 | .061 | .011 | .055 | .069 | .041 | .265 | .079 |
| 67 | .059 | .494 | .107 | .124 | .003 | .032 | .057 | .006 | .005 | .037 |
| 68 | .159 | .016 | .224 | .127 | .054 | .130 | .196 | .170 | .109 | .048 |
| 69 | .423 | .147 | .155 | .015 | .180 | .120 | .168 | .048 | .009 | .009 |
| 70 | .264 | .023 | .101 | .292 | .184 | .095 | .107 | .064 | .018 | .018 |
| 71 | .256 | .121 | .040 | .118 | .010 | .220 | .154 | .045 | .189 | .048 |
| 72 | .037 | .017 | .092 | .013 | .269 | .039 | .230 | .082 | .047 | .021 |
| 73 | .181 | .006 | .145 | .024 | .224 | .028 | .187 | .188 | .211 | .065 |
| 74 | .289 | .026 | .140 | .184 | .022 | .043 | .109 | .106 | .092 | .042 |
| 75 | .210 | .003 | .137 | .212 | .175 | .091 | .001 | .091 | .077 | .003 |
| 76 | .343 | .172 | .052 | .066 | .150 | .051 | .331 | .032 | .045 | .035 |
| 77 | .120 | .065 | .265 | .610 | .293 | .039 | .233 | .053 | .052 | .060 |
| 78 | .337 | .062 | .293 | .184 | .010 | .054 | .203 | .018 | .018 | .160 |
| 79 | .118 | .201 | .226 | .167 | .107 | .163 | .047 | .045 | .063 | .093 |
| 80 | .231 | .074 | .205 | .115 | .248 | .056 | .053 | .009 | .031 | .019 |
| 81 | .134 | .070 | .113 | .055 | .121 | .004 | .156 | .119 | .120 | .040 |
| 82 | .023 | .272 | .145 | .271 | .180 | .046 | .326 | .107 | .183 | .070 |
| 83 | .232 | .018 | .182 | .005 | .124 | .080 | .062 | .002 | .097 | .037 |
| 84 | .019 | .060 | .150 | .034 | .047 | .011 | .089 | .079 | .038 | .154 |
| 85 | .378 | .288 | .046 | .013 | .028 | .024 | .057 | .079 | .043 | .070 |
| 86 | .251 | .103 | .104 | .195 | .107 | .053 | .156 | .099 | .125 | .042 |
| 87 | .119 | .152 | .061 | .195 | .144 | .128 | .118 | .100 | .013 | .036 |
| 88 | .107 | .275 | .013 | .164 | .055 | .120 | .040 | .228 | .014 | .039 |
| 89 | .062 | .143 | .016 | .292 | .196 | .015 | .110 | .036 | .107 | .138 |
| 90 | .246 | .042 | .201 | .033 | .129 | .078 | .034 | .033 | .054 | .027 |
| 91 | .187 | .033 | .558 | .033 | .038 | .140 | .029 | .078 | .058 | .056 |
| 92 | .243 | .052 | .324 | .175 | .101 | .018 | .066 | .023 | .063 | .090 |
| 93 | .186 | .066 | .088 | .271 | .060 | .071 | .027 | .112 | .176 | .127 |
| 94 | .305 | .135 | .121 | .192 | .204 | .124 | .125 | .037 | .125 | .041 |
| 95 | .214 | .035 | .121 | .192 | .240 | .167 | .028 | .037 | .008 | .248 |
| 96 | .098 | .070 | .001 | .251 | .037 | .087 | .117 | .020 | .123 | .088 |
| 97 | .232 | .018 | .132 | .003 | .124 | .080 | .062 | .002 | .097 | .037 |
| 98 | .161 | .216 | .116 | .006 | .195 | .132 | .087 | .004 | .134 | .129 |
| 99 | .113 | .104 | .113 | .016 | .193 | .017 | .290 | .113 | .103 | .070 |
| 100 | .205 | .165 | .104 | .148 | .006 | .078 | .060 | .068 | .025 | .048 |
| 101 | .185 | .037 | .161 | .051 | .049 | .215 | .116 | .040 | .046 | .177 |
| 102 | .152 | .004 | .027 | .051 | .071 | .019 | .061 | .161 | .092 | .005 |