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Research Article

Variability assessment and identification of early cassava (*Manihot esculenta* Crantz) genotypes

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Abstract
Thirteen early maturing cassava genotypes were evaluated along with M4, a high yielding variety at College of Horticulture, Kerala Agricultural University, Thrissur, India. All the fourteen genotypes differed with respect to quantitative and qualitative trait. Variability was more for aerial parts. Genotypes showed variable response to cassava mosaic disease (CMD) and cassava leaf spot. Three genotypes were resistant to CMD. Tuber yield had strong correlation with stem girth, tuber length, biomass and dry matter. Plant height, branch height and stem girth exhibited high heritability. Based on the biometric traits, genotypes could be grouped in to five clusters. High yielding varieties and local accessions fall in to the same cluster indicating the superiority of local accessions. Ranking of the accessions was done by construction of selection index indicated that CSV COH 1 a local accession collected from Malappuram district was the best followed by Sree Jaya a high yielding variety.

Key words:
Cassava, variability, correlation, heritability, Cassava mosaic disease, selection index

Introduction:

Tuber crops are the third most important food crops. Amongst them, cassava, globally known as a famine crop, serve as an important subsidiary or staple food of one fifth of world's population (FAOSTAT, 2008). It is estimated that around 700 million people obtain more than 500 calories per day from cassava consumption. Cassava is an introduced crop in India. Many of the cassava types under cultivation in Kerala and other States of India are either chance seedling or bud mutants selected for desirable characteristics and maintained through vegetative propagation. Cassava is a naturally out-crossing and clonally propagated crop. Genetic improvement of cassava is to a certain extent limited by poor knowledge of genetic diversity available within the species. Years of selection by farmers have resulted in diverse landraces. These landraces therefore serve as repository of favourable alleles for plant breeding because of their co-adapted gene complexes with adaptation to specific ecological conditions, tolerance to pests and diseases.

A majority of cultivated cassava cultivars are of long duration taking about ten months to mature, thus occupying land for a longer period. Developing early maturing cultivars will help in effectively utilizing this in crop rotation program (Nair and Unnikrishnan, 2007). According to Nair *et al.*, 1988, attention is to be given to develop early maturing good cooking quality varieties which can be harvested at six months so that they can effectively be utilised in cassava – rice double cropping systems practiced in Kerala. Considering the advantage of short duration genotypes, the present study attempts to identify extra early cassava genotypes with good yield potential.

Thirteen early maturing cassava genotypes of six months of duration, collected from various parts of Kerala (Table l), were evaluated along with M4, a high yielding long duration variety. The trial was conducted at College of Horticulture (COH), Kerala Agricultural University (KAU), Vellanikkara during June 2012 to December 2012. Recommended agronomic practices as per package of practices of KAU (2011) were followed during crop growth period. Experiment was laid out in randomised block design with three replications in plots of size 40 m^2 at a spacing of 90 cm x 90 cm.

Observations were recorded on 25 plants in each replication. Qualitative and quantitative characteristics of the shoots were observed at three months old plants and at harvest according to standard cassava descriptor (Fukuda *et al*., 2010). Characteristics of the roots were observed at harvest. Statistical analysis for quantitative traits was done by Analysis of variance (ANOVA).

Scoring of cassava mosaic disease (CMD) and *Cercospora* leaf spot (CLS) was also carried out according to standard procedures (Hahn *et al.*, 1989). The genotypes were classified in to resistant, moderately resistant and susceptible (Ogbe *et al.*, 2003). Statistical analysis (ANOVA) was done on arcsine transformed values of the disease scores. Correlations and the broad sense heritability for biometrical characters were calculated. Hierarchical clustering of the genotypes was done based on biometrical traits. Selection

index (SI) was calculated as enumerated below (Ojulong *et al.,* 2010).

SI = [FRY*10] + [DMC*8] + [HI*5] – [CMD*3] – [CLS*2] + [TG*2]

where FRY- fresh root yield, DMC - dry matter content, HI - harvest index ,CMD - cassava mosaic disease, CLS - *cercospora* leaf spot and TG - tuber girth.

The collected local genotypes were renamed as Cassava Variety College of Horticulture abbreviated as CSV COH and serially numbered from one to ten (Table 1).

Variability in qualitative traits **:** Qualitative traits which are not influenced by environment are important in identifying a genotype. Qualitative traits observed on the vegetative parts of cassava plants showed wide variation between the genotypes. The qualitative characteristics of cassava genotypes studied are detailed in Stipule colour was green purple or light green. The leaf central lobe shape was lanceolate, oblanceolate or elliptic. Different stem exterior colour observed in the accessions was light brown, golden, greenish yellow, grey and silver.

On examination of underground root tubers it was observed that the tuber external colour was predominantly dark brown among the evaluated genotypes. Three accessions had light brown and one accession possessed white coloured tubers. Similarly, majority of accessions possessed white root pulp. CSV COH 1 and Sree Prakash had cream root pulp while in CSV COH 10 it was yellow. The tuber cortex colour was pink for seven out of thirteen cassava genotypes studied. Accessions with yellow, purple and cream cortex colour were also observed.

The emerging leaf colour of most of the genotypes was purplish green and it was green in others. In comparison to emerging leaf colour, petiole colour exhibited wider variation. The colour of petiole was purple for seven genotypes tested. Green purple, red, reddish green, pink and greenish red petiole was also observed. Stipule colour was green purple or light green. The leaf central lobe shape was lanceolate, oblanceolate or elliptic. Different stem exterior colour observed in the accessions was light brown, golden, greenish yellow, grey and silver.

On examination of underground root tubers it was observed that the tuber external colour was predominantly dark brown among the evaluated genotypes. Three accessions had light brown and one accession possessed white coloured tubers. Similarly, majority of accessions possessed white root pulp. CSV COH 1 and Sree Prakash had cream root pulp while in CSV COH 10 it was yellow. The tuber cortex colour was pink for seven out of thirteen cassava genotypes studied. Accessions with yellow, purple and cream cortex colour were also observed.

From the present study on external morphology of vegetative parts (above ground) and storage tissue (underground tubers), it was observed that there was wide variability among the genotypes studied. The genotypes differed in few or more characters with respect to qualitative characteristics of stem or tuber. Variability of above ground portion was more compared to the tuber portion. This suggests that the farmers' selection for the variability of cassava genotypes were mostly based on qualitative traits of above ground portion. According to Raji *et al*, 2007, eventhough, only a few varieties were introduced in the beginning, many natural recombinants have evolved over the years and good variability is available in the field. There is high genetic diversity among crop populations maintained in farmers' fields. Human selection of many different varieties for diverse attributes such as farmer preferred agronomic and quality traits, resistance to pests and diseases, desirable plant architecture and other adaptation characteristics has been a key process in maintaining genetic diversity among cassava landraces.

Variability in quantitative traits **:**In the present study quantitative traits of both above ground and below ground portion showed high variability. This shows that the accession set contains enough phenotypic variation for traits of agronomic interest to be exploited in breeding programs of the crop (Table 3). Plant height varied from 181 cm (Hraswa) to 316 cm (M4). The varieties CSV COH 4 and M4 had highest branch height (205 cm and 185.33 cm). CSV COH 8 had the lowest branch height of 5 cm. The internodal length varied from 1.46 (Hraswa) to 3.10 cm of CSV COH 9. The M4 had thickest stem with 29.22 cm and the CSV COH 10 had the thinnest stem with 18.87cm. The number of scars taken along 30 cm distance at one meter of the stem was low in CSV COH 9 (9.8) and high in CSV COH 4, Sree Prakash and Hraswa. Less number of branches per plant was seen in CSV COH 4, Sree Prakash and CSV COH 8 while in all other accessions it was on par. Based on the biomass obtained, the accessions could be classified in to accessions with high biomass which included CSV COH 1, 2, 5, Sree Jaya and M4 and all other accessions fall in to low biomass group.

The tuber and yield characteristics of cassava genotypes are shown Table 4. Tuber numbers per plant varied from 3.28 in Sree Prakash to 6.60 of CSV COH 8. However, CSV COH 6, 7, Hraswa, Sree prakash, Sree Jaya and M4 were falling on to a class and all others fall in another group. CSV

COH 6, 7, 8, 9, 10, Hraswa and Sree Prakash had tuber yield which were on par, while , tuber yield per ha were high and on par in the CSV COH 1, 2, 5, and Sree Jaya with tuber yield of 32.65, 28.75, 27.04, and 34.78 tonnes per ha, respectively.

Longer tubers were observed in the CSV COH 1, while, shortest tubers were observed in Hraswa. CSV COH 2, 4, 5, 10, Sree Jaya and M4 also had longer tubers. The tuber neck varied from 22.75 mm of Hraswa to 62.30 mm of M4. Thick tubers were seen in CSV COH 1 and Hraswa and CSV COH 10 had thinnest tubers. The harvest index varied from 0.39 of Sree Prakash to 0.57 of CSV COH 8 and harvest index of CSV COH 1, 2, 3, 4, 5, 7, 9, 10, Hraswa and Sree Jaya were on par with CSV COH 8. According to the report of CIAT 1976, there is great germplasm variability in cassava for several agronomically important characters such as tuber yield, harvest index and root dry matter content.

Correlations between different biometrical traits of the cassava genotypes showed that tuber yield in the early cassava genotypes were found to have strong positive correlation with stem girth, tuber length, biomass and dry matter (Table 5). Moderate correlation was observed for tuber yield with plant height and branch height. Hence, by selecting plants with more plant height, branch height, stem girth, tuber length, biomass and dry matter can result in plants with high yield in cassava. However, according to Ntawuruhunga and Dixon, 2010, tuber numbers per plant, tuber length and girth were the main yield components, which can be used as selection criteria to identify the best genotypes for tuber yield potential. According to Mulualem and Dagne (2013), root fresh weight in cassava was strongly and positively correlated with number of vertical stem/plant, stem girth, root diameter root dry weight and weight of above ground plant parts.

Broad sense heritability (H^2) calculated for the quantitative traits are given in the Table 6. Bhateria *et al*. (2006) classified heritability estimates as high (> 0.50), medium (0.30 - 0.50) and low (< 0.30). In this study heritability estimates were high (> 0.50%) for almost all traits except tuber number, harvest index and tuber length. High H^2 could be attributed to higher proportion of genetic variability to phenotypic variability in the population. This supports similar observation by Ceccarelli *et al*. (1994) and Aduening *et al.* (2013). Plant height, branch height and stem girth showed very high broad sense heritability (>80%). For the characters number of scars, biomass, tuber yield, tuber girth, and dry matter content, heritability values were between 0.67 and 0.73. Considering the correlation and heritability values, plant height, branch height and stem girth can be used as the selection criteria to select high yielding genotypes in cassava.

Hierarchical clustering of the genotypes done using biometrical traits showed that the accessions fall in to five clusters (Figure 1) at a rescaled distance of 5. The first cluster included maximum number of accessions which included local collections as well as released varieties. This indicates the local genetic stock has many desirable traits which can be made use of in cassava improvement. In the second and third cluster there are only one accession each and they are CSV COH 3 and 7 respectively. CSV COH 9 and Sree Prakash fall into the fourth cluster. In the fifth cluster the CSV COH 10, M4 and CSV COH 2 were included. Based on the pattern of clustering it is clear that the released varieties do not form a separate cluster.

The concept of selection index (SI) can be used for identification of the best genotypes in breeding programmes. The values calculated for the genotypes based on fresh root yield, dry matter content, harvest index, cassava mosaic disease brown leaf spot and tuber girth are given in the Table 7. According to this index five genotypes are selected as the best out of the total of 14 evaluated, namely CSV COH 1, Sree Jaya, CSV COH 2, 3 and 5. Among the best genotypes CSV COH 1 had the thickest tuber, highest harvest index, highest tuber numbers and lowest CMD score, but its CLS score was one of the highest.

Based on the present study the CSV COH 1 which is a collection from Thavannur of Malappuram district was found to the best genotype with respect to yield and cassava mosaic disease resistance. This was found to be better than the released varieties. Short-duration (6-7 months) cassava provides opportunities to smallholder farmers for effective utilisation of resources such as land, moisture and nutrients as well as diversification of enterprise and income (Suja *et al.,* 2010). Hence, this accession can be used for direct cultivation after further evaluation or in breeding programmes.

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Table 1. Early cassava genotypes included in the study

Accession name	Name of collection	Source
CSV COH1	Thavannur	Thavannur, Malappuram
CSV COH 2	Parappalli	Parappalli , Quilon
CSV COH 3	Kottarakkara 1	Kottarakkara, Quilon
CSV COH 4	Kottarakkara 2	Kottarakkara, Quilon
CSV COH 5	Chavakkad 1	Chavakkad , Thrissur
CSV COH 6	Chavakkad 2	Chavakkad , Thrissur
CSV COH 7	Chittur	Chittur, Palakkad
CSV COH 8	Manjali	Manjali, Paraur, Ernakulam
CSV COH 9	Mannuthy	Mannuthy, Thrissur
CSV COH 10	Vellanikkara	Vellanikkara , Thrissur
Hraswa	Vellayani Hraswa	KAU, COA*, Vellayani
Sree Prakash	Sree Prakash	CTCRI**, Trivandrum
Sree Jaya	Sree Jaya	CTCRI, Trivandrum
M4	M4	CTCRI, Trivandrum

*COA – College of Agriculture
**CTCRI : Central Tuber Crops Research Institute

Table 2. Qualitative characteristics of early maturing cassava genotypes

Genotype	Emerging Leaf colour	Petiole colour	Stem Exterior colour	Stipule colour	Central lobe shape	Root external colour	Root pulp colour	Root cortex colour
CSV COH1	Purplish green	Pink	Golden	Light green	Lanceolate	Light Brown	Cream	Pink
CSV COH 2	Purplish green	Reddish green	Golden	Light green	Oblanceolate	Dark Brown	White	Pink
CSV COH 3	Purplish green	Greenish red	Golden	Green purple	Elliptic	Dark Brown	White	Pink
CSV COH 4	Green	Purple	Light brown	Light green	Elliptic	Dark Brown	White	Yellow
CSV COH 5	Green	Red	Golden	Green purple	Oblanceolate	Dark Brown	White	Yellow
CSV COH 6	Green	Green purple	Grey	Light green	Linear	White	White	Yellow
CSV COH 7	Purplish green	Purple	Light brown	Green purple	Lanceolate	Dark Brown	White	Pink
CSV COH 8	Purplish green	Green purple	Greenish yellow	Green purple	Oblanceolate	Dark Brown	White	Pink
CSV COH 9	Purplish green	Purple	Light brown	Green purple	Lanceolate	Dark Brown	White	Pink
CSV COH 10	Purplish green	Purple	Light brown	Green purple	Lanceolate	Light Brown	Yellow	Yellow
Hraswa	Green	Purple	Light brown	Green purple	Lanceolate	Dark Brown	White	Pink
Sree Prakash	Purplish green	Red	Greenish yellow	Light green	Linear	Light Brown	Cream	Cream
Sree Jaya	Purplish green	Purple	Light brown	Light green	Lanceolate	Dark Brown	White	Purple
M4	Purplish green	Purple	Silver	Green purple	Lanceolate	Dark Brown	White	Purple

Table 3. Quantitative traits of vegetative parts in cassava genotypes

Accession no	Plant height (cm)	Branch height (cm)	Inter nodal length	Stem girth (mm)	Scar no. in 30cm @1m	Branch no.s	Biomass (kg)
CSV COH1	231.17^{cd}	151.58^{de}	1.68^{a}	25.56^{ef}	18.18^{cde}	3.25^{d}	3.14^{d}
CSV COH 2	253.33^{e}	123.67^{cde}	1.89^{ab}	23.24^{bcd}	15.93^{abc}	3.00^{cd}	2.90^{bcd}
CSV COH 3	245.33^{de}	119.67^{cd}	1.90^{ab}	21.98^{de}	16.07^{bcd}	3.27^{d}	2.05^{a}
CSV COH 4	257.33^{e}	205.00^{bc}	1.64^{a}	24.00^{g}	18.27^{bcd}	0.40^{a}	2.36^{abc}
CSV COH 5	256.44^{e}	145.11^{dc}	2.40^{bcd}	28.45^{ab}	12.60^{ab}	3.18^{cd}	3.04^{cd}
CSV COH 6	211.33^{ab}	28.33^{a}	2.11^{abc}	19.56^{ab}	14.27^{abc}	1.87^{bcd}	1.97^{a}
CSV COH 7	250.67^{de}	136.33^{de}	2.93^{de}	22.15^{cd}	10.27^{ab}	2.93^{cd}	2.19^{ab}
CSV COH 8	223.33^{c}	5.00^{a}	2.59^{cde}	20.00^{abc}	11.73^{ab}	1.67^{abc}	1.63^{a}
CSV COH 9	245.33d^{c}	138.33^{de}	3.10^{e}	20.52^{abc}	9.80^{a}	3.00^{cd}	1.94^{a}
CSV COH 10	198.00^{a}	95.67^{bc}	2.52^{bcde}	18.87^{a}	12.07^{ab}	3.13^{cd}	1.63^{a}
Hraswa	181.00^{a}	83.00^{b}	1.46^{a}	19.52^{cd}	21.07^{e}	3.27^{d}	1.60^{a}
Sree Prakash	212.00^{bc}	67.22^{b}	1.63^{a}	20.56^{abc}	20.33^{de}	0.92^{ab}	2.31^{ab}
Sree Jaya	280.28^{f}	156.73^{ef}	2.71^{cde}	26.57^{ghde}	11.33^{ab}	2.25^{bcd}	3.34^{d}
M4	316.22^{g}	185.33^{fg}	2.57^{cde}	29.22^{g}	13.00^{ab}	2.82^{cd}	3.18^{d}

Table 4. Tuber and yield characteristics of cassava genotypes

Accession no	Tuber no.	Tuber yield tones/ha	Tuber length. (cm)	Tuber neck (mm)	Tuber girth (mm)	Harvest Index	Dry matter (kg)
CSV COH1	4.98^{bcde}	32.65^{ef}	46.97^{e}	45.34^{c}	52.50^{f}	0.51^{de}	1.12^{def}
CSV COH 2	5.93^{de}	28.75^{def}	43.79^{de}	30.86^{abc}	44.73^{de}	0.50^{de}	1.06^{ef}
CSV COH 3	5.53^{de}	22.05^{abcd}	35.65^{abcd}	33.87^{abc}	42.57^{cd}	0.51^{de}	0.85^{bcde}
CSV COH 4	5.33^{cde}	24.97^{cde}	41.95^{bcde}	31.10^{abc}	44.78^{de}	0.51^{de}	0.95^{de}
CSV COH 5	6.16^{e}	27.04^{def}	40.29^{bcde}	35.47^{abc}	39.90^{abcd}	0.47^{bcde}	0.91^{cde}
CSV COH 6	4.33^{abcd}	13.93^{a}	35.17^{ab}	26.93^{ab}	40.36^{bcd}	0.42^{ab}	0.52^{a}
CSV COH 7	4.93^{abcde}	17.91^{abc}	39.73^{bcde}	45.77^{c}	38.37^{abc}	0.44^{bcde}	0.67^{abc}
CSV COH 8	6.60^{e}	22.01^{abcd}	39.15^{abcd}	34.27^{abc}	38.02^{abc}	0.57^{e}	0.80^{bcd}
CSV COH 9	5.53^{de}	18.21^{abc}	38.42^{abcd}	40.99^{bc}	36.19^{ab}	0.48^{bcde}	0.71^{abcd}
CSV COH 10	5.40^{de}	18.76^{abc}	41.57^{abcde}	38.93^{bc}	35.16^{a}	0.53^{de}	0.72^{abcd}
Hraswa	3.67^{abc}	15.33^{ab}	31.32^{a}	22.75^{a}	48.39ef	0.48^{bcde}	0.63^{ab}
Sree Prakash	3.28^{a}	14.82^{a}	35.26^{abc}	41.11^{bc}	44.27^{de}	0.39^{a}	0.50^{a}
Sree Jaya	4.39^{abcd}	34.78^{f}	43.43^{cde}	40.96^{bc}	43.54^{de}	0.52^{de}	1.25^{ef}
M4	3.37^{ab}	23.34^{bcd}	42.88^{bcde}	62.30^{d}	40.82^{bcd}	0.42^{abc}	0.70^{abcd}

Table 5. Correlation between yield and yield contributing characteristics of extra early cassava genotypes

Traits	Plant height (cm)	Branch height (cm)	Inter nodal length (cm)	Stem girth (mm)	Scar no.s/pl.	Branch no.s/pl.	Biomass (kg)/pl.	Tuber no.s/pl.	Tuber Yield (tones/ha)	Tuber length. (cm)	Tuber neck (mm)	Tuber girth (mm)	Harvest Index	Dry matter (kg)/pl.	CMD	CLS
Plant height (cm)	1.00															
Branch height (cm)	0.69*	1.00														
Inter nodal length (cm)	0.40	0.06	1.00													
Stem girth (mm)	0.83*	0.72*	0.11	1.00												
Scar no.s/pl.	-0.41	-0.05	*-0.97*	-0.13	1.00											
Branch no.s/pl.	0.01	0.12	0.24	0.13	-0.26	1.00										
Biomass (Kg)/pl.	0.74*	0.64*	0.01	0.91*	-0.04	0.09	1.00									
Tuber no.s/pl.	-0.01	-0.07	0.27	-0.06	-0.42	0.15	-0.13	1.00								
Tuber fresh wt (kg)/pl.	0.56*	0.55*	0.02	0.71*	-0.11	0.14	0.79*	0.31								
Tuber Yield (tones/ha)	0.56*	0.55*	0.02	0.72*	-0.11	0.14	0.79*	0.31	1.00							
Tuber length. (cm)	0.57*	0.57*	0.22	0.61*	-0.30	0.09	0.69*	0.29	0.81*	1.00						
Tuber neck (mm)	0.66*	0.46	0.47	0.55*	-0.37	0.15	0.50*	-0.29	0.23	0.52*	1.00					
Tuber girth (mm)	-0.08	0.22	*-0.78*	0.25	0.79*	-0.03	0.39	-0.33	0.39	0.13	-0.15	1.00				
Harvest Index	-0.10	-0.03	0.08	-0.10	-0.18	0.13	-0.15	0.70*	0.48	0.33	-0.28	-0.01	1.00			
Dry matter (kg)/pl.	0.44	0.51*	-0.01	0.56*	-0.09	0.14	0.65*	0.40	0.97*	0.73*	0.05	0.39	0.61*	1.00		
Cassava mosaic disease	-0.54	*-0.51*	-0.25	*-0.59*	0.36	-0.09	*-0.55*	*-0.57*	*-0.85**	-0.87	-0.27	-0.09	*-0.60**	*-0.83**	1.00	
Cercospora leaf disease	0.44	0.66*	0.13	0.50*	-0.19	0.20	0.52*	-0.01	-0.63*	0.72*	0.32	0.12	0.31	0.61	*-0.63**	1.00

Table 6. Broad sense heritability of biometrical traits in early maturing cassava

Sl no	Character	Broad sense heritability (H^2)
1	Plant height	0.89
2	Branch height	0.90
3	Internodal length	0.67
4	Stem girth	0.86
5	Scar no. in 30cm @1m	0.65
6	Branch number	0.53
7	Biomass	0.69
8	Tuber number	0.50
9	Tuber yield	0.67
10	Tuber length	0.40
11	Tuber neck	0.54
12	Tuber girth	0.73
13	Harvest index	0.50
14	Dry matter	0.71

Table 7. Selection index calculated for extra early cassava genotypes

Accession no	Selection index	Rank
CSV COH1	143.08	1
CSV COH 2	120.52	3
CSV COH 3	117.09	4
CSV COH 4	105.85	6
CSV COH 5	108.38	5
CSV COH 6	88.16	12
CSV COH 7	92.46	11
CSV COH 8	99.82	9
CSV COH 9	87.91	13
CSV COH 10	86.71	14
Hraswa	104.99	7
Sree Prakash	94.29	10
Sree Jaya	126.58	2
M4	102.68	8

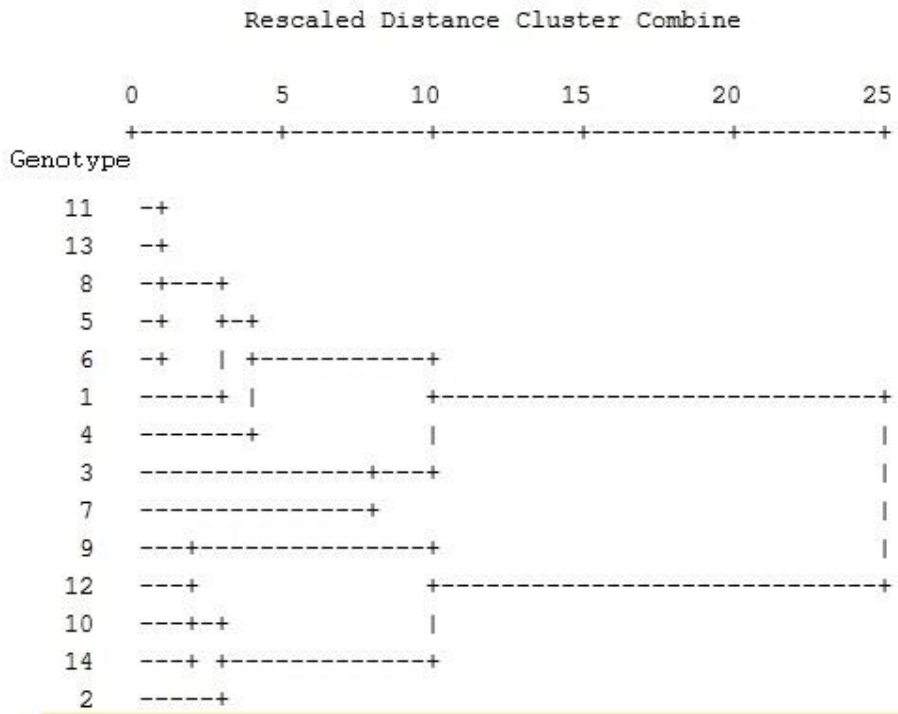

Fig 1. Dendrogram using Average Linkage (Between Groups)