Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(6): 2334-2338
Received: 11-09-2018
Accepted: 15-10-2018

Lal Vijay Singh
Department of Horticulture, Udai Pratap Autonomous College, Varanasi, Uttar Pradesh, India

Diwaker Singh
Department of Horticulture, Udai Pratap Autonomous College, Varanasi, Uttar Pradesh, India

Amit Kumar Singh
Department of Horticulture, Udai Pratap Autonomous College, Varanasi, Uttar Pradesh, India

Dharmender Singh
Department of Horticulture, Udai Pratap Autonomous College, Varanasi, Uttar Pradesh, India

NK Tiwari
Faculty of Agricultural Sciences SGT University, Gurgaon, Haryana, India

Correspondence
Lal Vijay Singh
Department of Horticulture, Udai Pratap Autonomous College, Varanasi, Uttar Pradesh, India

Genetic divergence of parental lines and their F_1 progeny in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

Lal Vijay Singh, Diwaker Singh, Amit Kumar Singh, Dharmender Singh and NK Tiwari

Abstract
The experiment was conducted in Randomized Complete Block Design with three replications. In present investigation 54 genotypes (10 lines + 4 testers + 40 F_1's) of bottle gourd were grouped into 8 distinct non over lapping clusters. This indicated presence of considerable diversity in the genotypes. The clusters contained genotypes of hetero genous origin. The genotypes of same geographic region were also found to be grouped together in the same clusters. Thus, there was no consistent relationship between genetic divergence and geographical distribution. Cluster I had maximum number of genotypes (23) followed by clusters VI (12), cluster III (10) and cluster VIII (5) while, rest of the four clusters contains mono genotypes. The intra cluster D^2 values ranged from 0.00 (cluster II, IV, V and VII) to 1088.31 (cluster VIII) while, the inter cluster diversity ranged from 142.37 (cluster IV and cluster IV) to 2849.61 (cluster IV and cluster VIII). The inter cluster distances between cluster IV to cluster VII (2849.61) and cluster V to cluster VIII (2838.87) were also very high. The higher inter cluster distance indicated greater genetic divergences between the genotypes of those clusters, while lower inter cluster values between the clusters suggested that the genotype of the cluster were not much genetically diverse from each other. Cluster III showed the maximum means values for vine length at last picking stage, number of primary branches per plant, fruit circumference, fruit weight, reducing sugar total sugars whereas, Cluster V showed high mean values for days to first fruit harvest, fruit circumference, fruit weight, fruit yield per plant. The results suggested that crosses between selected lines/F_1's from widely separated clusters are most likely to give desirable recombinants/hybrids.

Keywords: genetic divergence, bottle gourd, D^2 analysis, cluster analysis

Introduction
Among the cultivated vegetables, cucurbits are associated with the origin of agriculture and dawn of civilization. Among food crops, cucurbits are largest producer of biological water, easily digestible and recommended even to sick and frail patients. Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] is also known as white-flowered gourd and most important vegetables of ancient China. Because of hard mature rind of mature fruits, it is known as gourd. It is also commonly grown in Ethiopia, Africa, Central America and other warmer regions of the world. It is one of the important cucurbits in India, both as rainy and summer season vegetable. Out of the all cultivated cucurbits, bottle gourd with its high yield potential and adaptability to diverse climatic conditions holds a great promise to cope up with the per capita per day requirement of vegetables in the balanced diet (Singh, 1998) [11] of the fast growing population pressure and greater dietary awareness, particularly among the literate masses of a country like India. Bottle gourd was one of the first plant species to be domesticated for human use, providing food, medicine and a wide variety of utensils and musical instruments made from the large hard shelled mature fruits. A total of six species have been recognized belonging to the genus *Lagenaria*. Out of six species of *Lagenaria* only *Lagenaria siceraria* is the domesticated annual and monoecious in nature while the other five are wild congeners, perennial and dioecious (Bisognin, 2002) [2].

The tender fruits of bottle gourd can be used as a vegetable or for making sweets (*e.g.*, *Halva*, *kheer*, *petha* and *burfi*), kofta and pickles. The fruit is rich in pectin also, which showed good prospects for jelly preparation. A decoction made from the leaf is a very good medicine for jaundice. The fruit has cooling effect, it is a cardiotonic and diuretic, good for people suffering from biliousness, indigestion and convalescences *i.e.*, regain health after illness. The pulp is good for overcoming constipation, cough, night blindness and as an antidote against certain poisons. The plant extract is used as a cathartic and seeds are used in dropsy. In addition, the seeds and seed oil are edible.

The fruits contain 96.3 per cent moisture, 2.9 per cent carbohydrate, 0.2 per cent protein, 0.1 per cent fat, 0.5 per cent mineral matter and 11 mg of vitamin C (Ascorbic acid) per 100 g fresh weight (Thamburaj and Singh, 2005) [14].

To develop a new variety there is need of high magnitude of genetic variability in the base material and the vast of variability for desired characters. A good knowledge on genetic diversity or genetic similarity could be helpful in long term selection gain in plants (Kumar *et al*., 2012) [6]. Hence, genetic variability and diversity is of prime interest to the plant breeder as it plays a key role in framing and successful breeding programme. The genetically diverse parents are always able to produce high heterotic effects and great frequency of desirable segregants in further generation as already reported by Kumar *et al*. (1994) [5]. D^2 statistic is a useful tool to measure genetic divergence among genotypes in any crop as developed by Mahalanobis (1936) [7]. However, in the present study, an attempt has been made to identify genetically divergent promising lines and their F_1 progenies, so as to select the potential parents for breeding programme to attain the anticipated improvement in fruit yield per plant of bottle gourd either by crossing two dissimilar parents to get heterotic F_1 or by making single cross, three way cross, double cross and selfing of crosses obtained by the divergent parents of bottle gourd.

Materials and Methods

The experimental materials consisted of 14 promising parental lines of bottle gourd and their F_1 progenies. Out of these advanced breeding parental lines 10 parents were choosen as lines and four as testers and crossed as per L × T design to get 40 F_1 at U P A C Varanasi, (U.P.). These experimental materials were grown under Randomized Block Design (RBD) with three replications at the Main Experiment Station (MES) of the Department of Horticulture, Udai Pratap Autonomous College Varanasi (U.P.) India. The treatments were sown in rows spaced 3.0 meters apart with a plant to plant spacing of 0.5 meter. The experiment was sown on 7th March, 2017. All the recommended agronomic package of practices and protection measures were followed to raise a good crop. Fertilizers and manures were applied as per recommended dose. Observations were recorded on all the six plants maintained carefully in each plot for eighteen quantitative characters *viz*., days to first staminate flower anthesis, days to first pistillate flower anthesis, node number to first staminate flower, node number to first pistillate flower, days to first fruit harvest, vine length at last picking stage (m), number of primary branches per plant, fruit length (cm), fruit circumference (cm), fruit weight (kg), number of fruits per plant, fruit yield per plant (kg), total soluble solids (°B), ascorbic acid (mg/100 g fresh fruit), reducing sugar (%), non-reducing sugar (%), total sugars (%) and dry matter content in fruit (%). Analysis of variance was carried out as suggested by Panse and Sukhatme (1967) [9]. Genetic divergence was estimated by using D^2 statistics of Mahalanobis (1936) [7] and clustering of genotypes was done according to Tocher's method as described by Rao (1952) [10]. The per cent contribution of characters towards genetic divergence was calculated according to Singh and Chaudhary (1985) [13].

Results and Discussion

The analysis of variance revealed that the significant differences were present for all the characters studied and the experimental materials were genetically divergent from each other (Table-1). This indicates that there is ample scope for selection of promising lines and their F_1 progenies from the present gene pool aimed at enhancing genetic yield potential of bottle gourd. All the fifty four genotypes were grouped into 8 different non over lapping clusters following Mahalanobis's methods (Table-2). Cluster I had highest number of genotypes (23) followed by cluster VI (12), III (10), VIII (5) and cluster II, IV, V, VII were found as monogenotypic clusters. The estimates of intra and inter-cluster distance represented by D^2 values are given in table-3. The intra-cluster D^2 value ranged from 0.00 (cluster II, IV, V and VII) to 1088.31 (cluster VIII) while the inter-cluster value ranged from 142.37 (cluster IV and cluster IV) to 2849.61 (cluster IV and cluster VIII) indicated that the selected breeding lines as well as F_1's were highly divergent (Table-4.11). The highest intra-cluster distance was shown by cluster VIII (573.59), whereas minimum was zero for monogenotypic clusters (clusters II, IV, V and VII). The maximum inter-cluster distance was observed between cluster IV and cluster VIII (2849.61), followed by cluster V and cluster VIII (2838.87), cluster VI and cluster VIII (2727.10) suggesting that the genotypes/F_1's belonging to these clusters may be used as parents for hybridization programme to develop desirable type because crosses between genetically divergent lines/F_1's will generate heterotic segregants (Varalakshmi *et al.*, 1994 and Mathew *et al.*, 2001) [15, 8]. As heterosis can be best exploited and chances of getting transgressive segregants are maximum when genetically diverse lines are crossed (Karuppaiah *et al.*, 2005; Singh *et al.*, 2007 and Islam *et al.*, 2010) [4, 12, 13]. The present finding of diverse crosses (particularly clusters IV and V) involving parents with different clusters not only revalidates the findings of previous workers but also reflects the chances of getting tansgrassive segregates either by making the three way crosses between clusters IV, V and VI with cluster VIII or double crosses between clusters II, IV, V and VI with cluster VIII.

The comparison of cluster means revealed considerable differences among the clusters of different quantitative and quality characters (Table-4). Cluster III showed high mean value for maximum six characters *viz*., vine length at last picking stage (6.04 m), number of primary branches per plant (18.12), fruit circumference (29.40 cm), fruit weight (1.42 kg), reducing sugar (2.08%), total sugars (2.73%) followed by cluster V which for four characters *viz*., days to first fruit harvest (62.57 days), fruit weight (1.42 kg), number of fruits per plant (6.10), fruit yield per plant (8.66 kg) and cluster II which showed high mean value for two characters *viz.*, node number to first staminate flower (11.10) and non-reducing sugar (0.88%). Cluster IV, VII and VIII showed high mean value for 2 characters. Cluster IV showed high mean value for fruit length (47.87 cm) and ascorbic acid (9.95 mg). Cluster VII showed high mean value for node number to first pistillate flower (11.17) and dry matter content in fruit (3.62%) while cluster VIII showed high mean value for days to first pistillate flower anthesis (50.49 days) and total soluble solids (3.46° B). Cluster VI showed high mean value for days to first staminate flower anthesis (49.68 days).

Highest per cent contribution towards total genetic divergence (Table-4) was exhibited by total soluble solids (48.43%) followed by fruit length (13.28%), reducing sugar (13.00%), days to first fruit harvest (11.60%) and dry matter content in fruit (8.39%) therefore necessary attention is required to be focused on these characters (Badade *et al.*, 2001 and Mathew *et al.*, 2001) [1, 8].

Intra and inter-cluster distance diagram for different quantitative characters in bottle gourd is given in Fig.-1. Clustering by Tocher method shows that the lines/F_1's fall into same cluster having lowest degree of divergence from each other (Fig.-2) and crosses among these lines/F_1's of the same cluster will be unable to produce any transgressive segregants. While, the lines/F_1's belonging to different clusters having maximum divergence can be successfully utilize in hybridization programmes to get desirable heterotic F_1's/transgressive segregants.

Table 1: Analysis of variance (mean square) for randomized block design for 18 characters in bottle gourd

S. No.	Characters	Treatments (*df*=53)	CV (%)
1.	Days to first staminate flower anthesis	13.078**	1.07
2.	Days to first pistillate flower anthesis	8.869**	0.99
3.	Node number to first staminate flower	3.676**	3.25
4.	Node number to first pistillate flower	3.528**	2.98
5.	Days to first fruit harvest	12.424**	0.80
6.	Vine length at last picking stage (m)	2.613**	7.35
7.	Number of primary branches per plant	25.665**	2.28
8.	Fruit length (cm)	82.910**	0.90
9.	Fruit circumference (cm)	12.660**	1.32
10.	Fruit weight (kg)	0.185**	4.44
11.	Number of fruits per plant	4.684**	7.59
12.	Fruit yield per plant (kg)	6.608**	5.72
13.	Total soluble solids (°B)	0.464**	0.57
14.	Ascorbic acid (mg/100 g fresh fruit)	1.307**	1.69
15.	Reducing sugar (%)	0.145**	0.93
16.	Non-reducing sugar (%)	0.045**	2.01
17.	Total sugars (%)	0.038**	0.90
18.	Dry matter content in fruit (%)	1.668**	2.47

Table 2: Clustering pattern of fifty four genotypes of bottle gourd on the basis of Mahalnobis 'D^2' statistics

Cluster number	No. of genotypes	Genotypes
I	23	NDBG-504 × NDBG-104, NDBG-10 × NDBG-104, NDBG-11, NDBG-10, NDBG-504 × Pusa Naveen, NDBG-603, NDBG-749-2 × NDBG-104, NDBG-S-5, NDBG-517 × NDBG-104, NDBG-11 ×NDBG-104, NDBG-522 × NDBG-S-5, NDBG-603 × NDBG-624, NDBG-517, NDBG-522, NDBG-522 × NDBG-624, NDBG-517 × NDBG-624, NDBG-509 × NDBG-624, NDBG-509 × NDBG-S-5, NDBG-603 × NDBG-104, NDBG-509 ×NDBG-104, NDBG-10 × NDBG-624, NDBG-504, NDBG-517 × Pusa Naveen
II	1	NDBG-504 × NDBG-S-5
III	10	Narendra Rashmi × NDBG-624, Narendra Rashmi × NDBG-S-5, Pusa Naveen, Narendra Rashmi, NDBG-601 × NDBG-S-5, NDBG-603 × Pusa Naveen, NDBG-11 × NDBG-S-5, NDBG-517 × NDBG-S-5, NDBG-624, NDBG-749-2*NDBG-624
IV	1	NDBG-522 × Pusa Naveen
V	1	NDBG-10 × Pusa Naveen
VI	12	NDBG-603 × NDBG-S-5, NDBG-104, NDBG-601 × NDBG-624, NDBG-504 × NDBG-624, NDBG-522 × NDBG-104, NDBG-601 × Naveen, NDBG-11 × Pusa Naveen, NDBG-749-2 × NDBG-S-5, NDBG-601*NDBG-104, NDBG-749-2 × Pusa Naveen, NDBG-509 × Pusa Naveen, NDBG-11 × NDBG-624
VII	1	NDBG-601
VIII	5	Narendra Rashmi × Pusa Naveen, Narendra Rashmi × NDBG-104, NDBG-10 × NDBG-S-5, NDBG-509, NDBG-749-2

Table 3: Intra and inter clusters D^2 values for eight clusters in bottle gourd

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII
Cluster I	521.62	730.18	981.17	1008.54	1123.95	1118.35	979.55	1394.74
Cluster II		0.00	1470.76	142.37	395.80	654.13	1947.47	2477.33
Cluster III			715.36	1626.59	1499.91	1630.95	1155.62	1378.58
Cluster IV				0.00	209.44	685.54	2241.86	2849.61
Cluster V					0.00	680.45	2188.02	2838.87
Cluster VI						613.87	1908.49	2727.10
Cluster VII							0.00	1163.97
Cluster VIII								1088.31

Table 4: Clusters mean values and per cent contribution of eighteen characters in bottle gourd

S. No.	Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Contribution (%)
1.	Days to first staminate flower anthesis	49.61	49.40	48.15	44.30*	47.80	49.68**	49.23	47.89	0.14
2.	Days to first pistillate flower anthesis	49.69	47.80	49.04	46.73	48.87	49.57	46.07*	50.49**	0.00
3.	Node number to first staminate flower	8.81	11.10**	8.44	9.33	7.63*	8.44	10.50	9.45	0.00
4.	Node number to first pistillate flower	9.96	10.87	10.22	10.20	8.60*	9.59	11.17**	10.76	0.00

5.	Days to first fruit harvest	60.71	58.80	62.39	58.63*	62.57**	61.91	59.37	62.15	11.60
6.	Vine length at last picking stage (m)	5.70	4.86	6.04**	4.78	3.85*	5.19	5.09	5.32	0.00
7.	Number of primary branches per plant	15.68	16.63	18.12**	14.43	11.93	14.41	10.13*	15.28	2.17
8.	Fruit length (cm)	42.73	47.73	38.86	47.87**	45.87	42.55	33.93*	39.23	13.28
9.	Fruit circumference (cm)	25.67	25.03	29.40**	24.67	27.87	25.82	21.80*	25.41	1.68
10.	Fruit weight (kg)	1.34	1.33	1.42**	1.17	1.42**	1.29	0.99*	1.36	0.07
11.	Number of fruits per plant	4.20	5.17	4.79	4.45	6.10**	4.38	3.66*	4.70	0.07
12.	Fruit yield per plant (kg)	5.54	6.87	6.41	6.36	8.66**	5.57	3.60*	6.13	0.49
13.	Total soluble solids (°B)	2.94	2.46	3.07	2.31*	2.31*	2.42	3.10	3.46**	48.43
14.	Ascorbic acid (mg/100 g fresh fruit)	9.54	9.30	8.50*	9.95**	9.13	9.27	8.95	9.07	0.07
15.	Reducing sugar (%)	1.72	1.70	2.08**	1.86	1.93	1.76	1.65*	1.91	13.00
16.	Non-reducing sugar (%)	0.85	0.88**	0.65*	0.82	0.73	0.83	0.80	0.75	0.63
17.	Total sugars (%)	2.57	2.58	2.73**	2.69	2.66	2.59	2.45*	2.66	0.00
18.	Dry matter content in fruit (%)	3.19	2.94	2.88*	3.23	3.33	3.35	3.62**	3.32	8.39

*Lowest mean value among different clusters, ** Highest mean value among different clusters

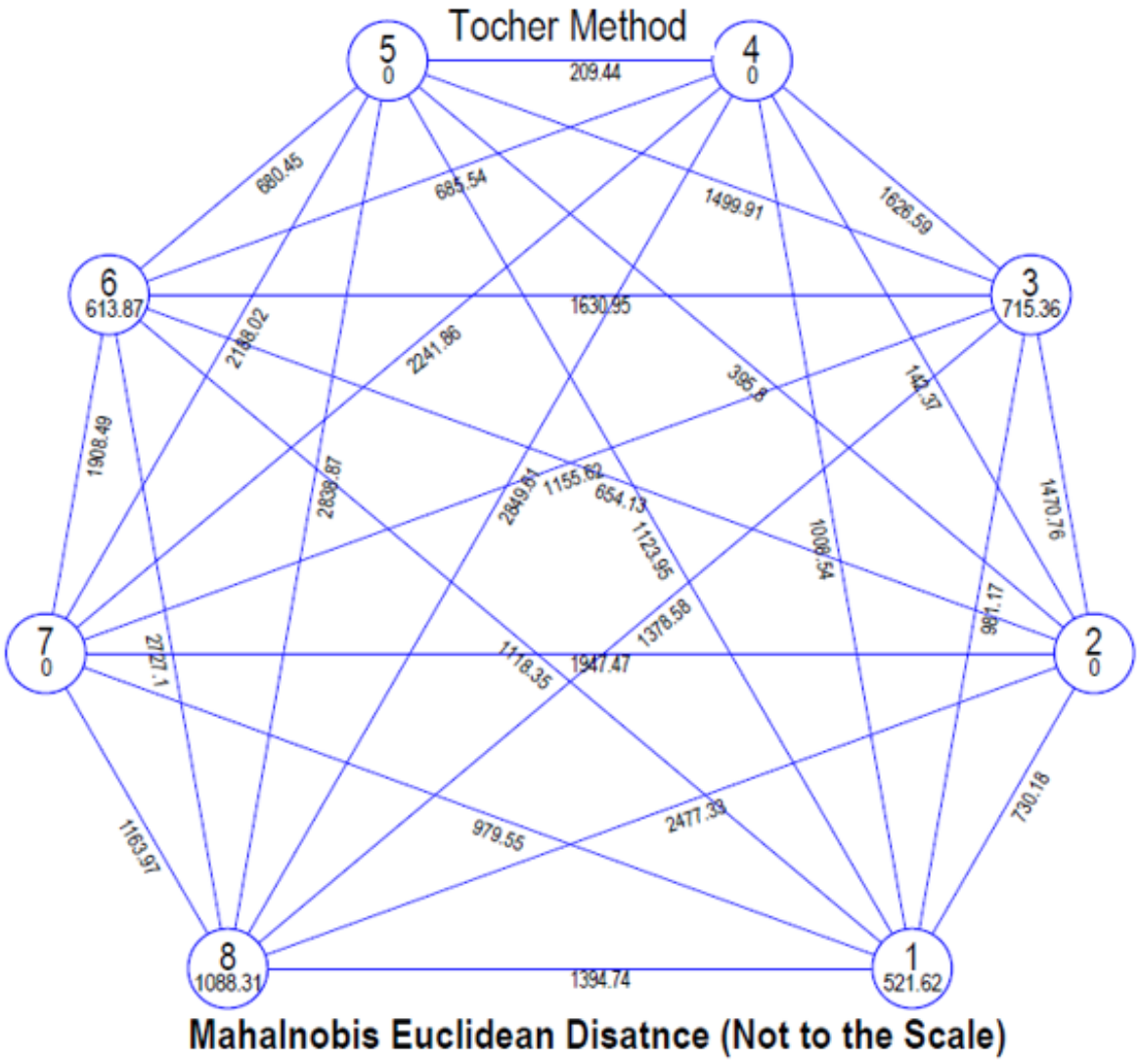

Fig 1: Intra and inter-cluster distance diagram for different quantitative characters in bottle gourd

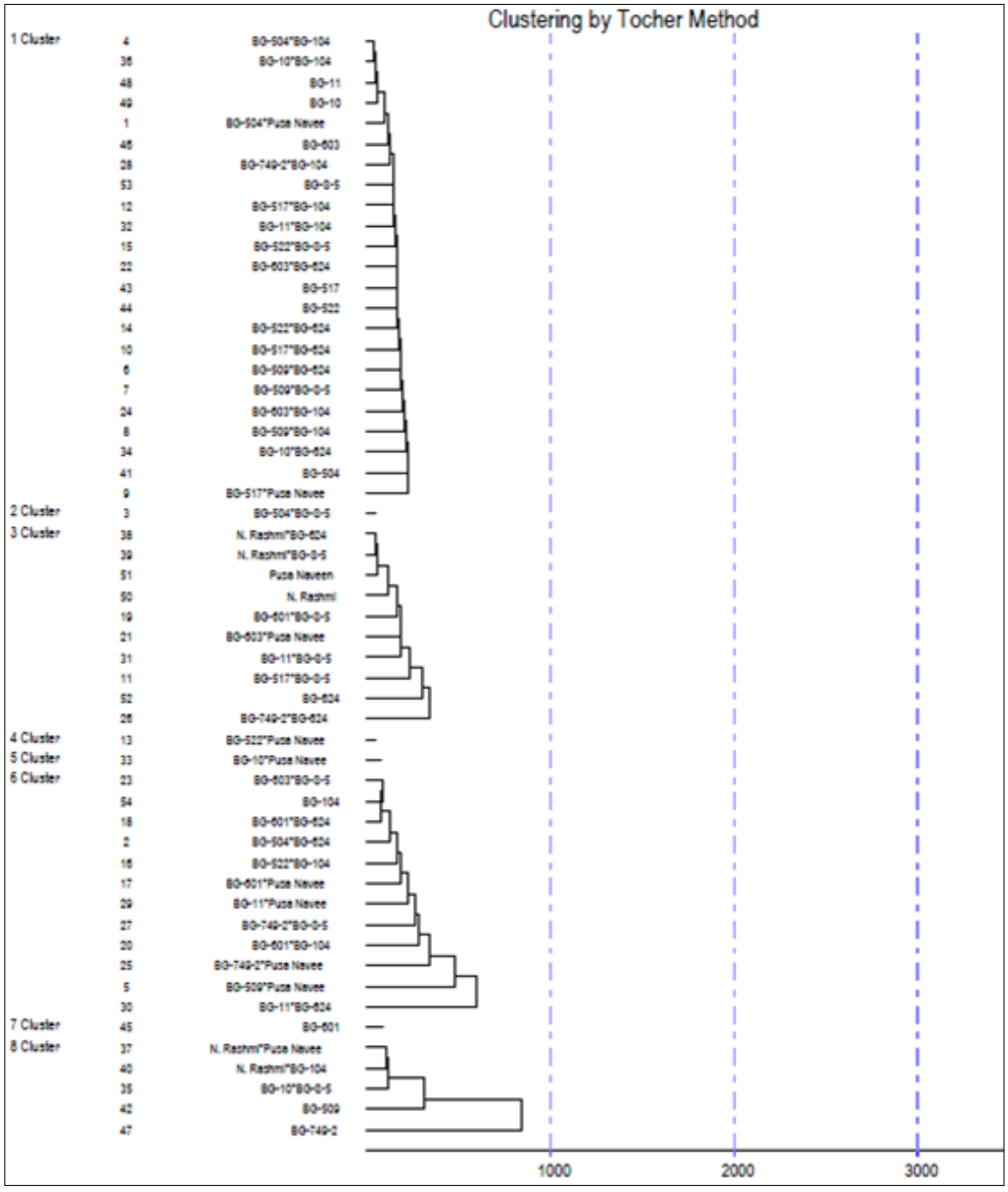

Fig 2: Clustering by Tocher method in bottle gourd

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