RESEARCH PAPER | Asian Journal of Bio Science, Volume **8** | Issue 1 | April, 2013 | 39-42
Received : 04.12.2012; **Revised :** 27.01.2013; **Accepted :** 28.02.2013

Multivariate analysis and choice of parent for hybridization in apple (*Malus* x *domestica* Borkh.)

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Medium quantum of genetic divergence was observed among sixteen apple genotypes under the present study. All the genotypes, on the basis of total variability were grouped into four distinct clusters. Maximum number of cultivars were accommodated in cluster IV (Fuji, Gala, Jonadel, Jonagold, Red Fuji, Royal Gala and Spijon) followed by cluster I (Arlet, Ruspippin, Sinta and Summerred), Cluster III (Crimson Gold, Elstar and Neomi) and cluster II ('Spartan' and 'Quinte'). Cluster IV had highest intra cluster value (9.32) so was most divergent and cluster I having least intra cluster value (8.20) was least divergent. Highest value (30.331) for inter cluster distance was recorded between cluster I and II while it was lowest (9.994) between cluster III and IV. Cluster means were maximum in cluster II followed by cluster I, cluster III and cluster IV. Neomi was best cultivars for fruit yield/plant, fruit length, fruit diameter, fruit weight, total sugars and non-reducing sugars, however, Jonagold was best for TSS. Cultivars Spartan, Elstar, Royal Gala, Jonagold and Summerred would prove best for different vegetative characters.

Key words : Apple, Cluster analysis, D^2 statistics, Genetic divergence

How to cite this paper : Sharma, Girish, Bashir, Rubiqua, Sharma, Nirmal and Jamwal, Mahital (2013). Multivariate analysis and choice of parent for hybridization in apple (*Malus* x *domestica* Borkh.). *Asian J. Bio. Sci.*, **8** (1) : 39-42.

INTRODUCTION

The cultivated apple (*Malus* x *domestica* Borkh.) is a member of family Rosaceae and sub family Pomoideae, have originated in south western Asia, Asia Minor, the Caucasus central Asia and the Himalayan region of India and Pakistan (Juniper *et al.*, 1999). It is an important temperate fruit crop of India with respect to acreage, production, economic value and above all popularity among the consumers. In India, it is a prime commercial fruit crop of Himachal Pradesh, Jammu and Kashmir and Uttranchal and some parts of north eastern states including Arunachal Pradesh, Sikkim, Nagaland, Meghalaya and Nilgiri hills of Tamil Nadu (Awasthi and Chauhan, 2001). Apple productivity has gradually declined since 1975 till date and on the basis of low production and productivity, India is now ranked 10th in the world apple cultivation scenario. The important factors which are responsible for low productivity are age old varieties, inappropriate sites, irregular bearing, poor soil conditions, lack of suitable adaptable cultivars and poor selection of pollinizers and their inadequate proportion. Therefore, urgent need is felt for development/introduction of new improved varieties which could help in elevating the apple productivity in India. For the success of any breeding programme the basic requirement is the variability found within the members of the population. It is this variation which if heritable could be used for cultivar improvement, as improved cultivars are the backbone of any orchard system. Therefore, prior to initiation of any breeding programme they should be tested and extent of variability present must be adequately assessed so that the breeding programme could yield the desired results. To use or exploit the available variability present in the genetic material in the form of some specific groups or classes, the divergence studies based upon some desirable/suitable parameters is of very essential and of utmost significance. Keeping in view, the above the genetic divergence and cluster analysis using D^2 statistics was undertaken with the objectives to assess the variability present among the sixteen apple genotypes and potential use of this variability for hybridization programmes. Use of Mahalanobis D^2 statistics to estimate or evaluate the net/total divergence in

breeding for crop improvement has been indicated by number of workers in different fruit crops (George, 1976; Singh and Chaudhary, 1992). Sharma (1998) pointed out that the use of genetically divergent parents in hybridization under transgressive breeding programme is dependent upon categorization of breeding material on the basis of appropriate criteria. George (1976) while estimating the genetic variability among arecanut genotypes highlighted the significance of presence of variation or diversity among the parent population, so as to have high heterotic response and to have more number of desirable segregants. Apart from providing requisite assistance or help in selection of divergent parents in hybridization, D^2 statistics also adequately assists in the measurement of diversification and the contribution of the relative proportion of each component trait towards the total genetic divergence or variation.

RESEARCH METHODOLOGY

The present investigations were carried out in the Department of Fruit Breeding and Genetic Resources, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India on sixteen apple genotypes *viz.*, Arlet, Crimson Gold, Elstar, Fuji, Gala, Jonadel, Jonagold, Neomi, Quinte, Red Fuji, Royal Gala, Ruspippin, Sinta, Spartan, Spijon and Summered. The genetic divergence was estimated by Mahalanobis D^2 statistics, as suggested by Rao (1952). A set of uncorrelated linear combinations (y's) was obtained by the pivotal condensation of the common dispersion matrix (Rao, 1952) of a set of correlated variables (x's). Using the relationship between y's and x's the mean values of different genotypes for different characters (x_1 to x_{10}) were transformed into the mean values of a uncorrelated linear combinations (y_1 to y_{10}). The D^2 value between ith and jth genotype for K characters was calculated as:

$$D^2_{ij} = \sum_{t=1}^{K} \left(y_{it} - y_{jt}\right)^2$$

Treating D^2 as the generalized statistical distance between a pair of population (genotypes), all populations were grouped into number of clusters according to method described by Rao (1952). The criterion used in clustering by this method was that any two genotypes belonging to the same cluster, atleast on an average, show a small D^2 value than those belonging to two different clusters.

RESEARCH FINDINGS AND ANALYSIS

The clustering pattern of sixteen cultivars of apple on tree, shoot, flowering and fruit characters are presented in Table 1. The genetic divergence in the present study observed among the sixteen cultivars is of medium quantum. The sixteen cultivars on the basis of net variability were grouped into four distinct clusters. Maximum number of cultivars (7) were accommodated into cluster IV (Fuji, Gala, Jonadel, Jonagold, Red Fuji, Royal Gala and Spijon) while the minimum number (2) were in cluster II which included Spartan and Quinte. Inter and intra cluster divergence values (D^2) between and within four clusters are presented in the Table 2. The intra cluster distance was maximum (9.32) for cluster IV and minimum (8.20) for cluster I. Highest value (30.331) for inter cluster distance was recorded between cluster I and II while it was lowest (9.994) between cluster III and IV. On the basis of results it is inferred that subsequent hybridization between the genotypes having broad genetic base should result in maximum heterotic performance and eventually the desirable transgressive recombinants, as broad genetic base is a fundamental requirement for any crop improvement programme. The cluster IV accommodating cultivars Fuji, Gala, Jonadel, Jonagold, Red Fuji, Royal Gala and Spijon were more divergent, followed by cluster III having three cultivars namely Crimson Gold, Elstar and Neomi. Wide diversity in the progeny is expected when hybridization is attempted within cultivars which are more divergent. Since inter cluster distance is maximum (30.331) between cluster I and II so maximum variability will be achieved when hybridization between the cultivars accommodating these clusters is attempted. The cluster means of the various tree, shoot, flowering and fruiting characters are presented in Table 3. The average cluster means revealed highest values for the characters like fruit weight (8.81g), fruit set after 50 days (64.46) fruit retention (49.88%), TSS (11.79^{0}B) in cluster I. The cluster II had better mean performance for the traits like fruit yield per plant (39.08 kg), duration of flowering (19.25 days), flesh firmness (12.34), fruit diameter (6.59 cm), fruit length (5.74 cm) and plant spread (4.92 m). In similar way, cluster III revealed superior mean performance for the characters like trunk girth (46.76 cm), followed by spur frequency (12.66%), total sugars (7.62%), reducing sugars

Table 1: Clustering pattern of sixteen cultivars of apple on the basis of genetic divergence

Cluster number	Number of cultivars	Cultivars included
I	4	Arlet, Ruspippin, Sinta, and Summered
II	2	Spartan and Quinte
III	3	Crimson Gold, Elstar and Neomi
IV	7	Fuji, Gala, Jonadel, Jonagold, Red Fuji, Royal Gala and Spijon

Table 2: Intra and inter cluster distance (D^2)

Clusters	I	II	III	IV
I	8.201	30.331	16.428	14.598
II		8.410	24.595	21.102
III			9.156	9.994
IV				9.321

Table 3: Cluster means for the twenty characters among sixteen apple cultivars

Characters	Clusters			
	I	II	II	IV
Shoot length (cm)	17.71	16.22	17.08	19.47
Fruit set after 50 days	64.46	44.50	60.00	59.33
Fruit retention	49.88	32.25	46.94	46.52
Fruit yield per plant	29.47	39.08	28.13	36.59
Fruit length (cm)	5.73	5.74	5.38	5.68
Fruit diameter (cm)	6.36	6.59	6.17	6.28
Fruit weight (g)	8.81	8.46	8.48	8.68
Acidity (%)	0.69	0.72	0.60	0.64
Total sugar (%)	7.20	7.59	7.62	7.48
Reducing sugar (%)	6.40	6.50	6.78	6.43
TSS (^{o}B)	11.79	11.34	11.40	11.57
Number of seeds	6.96	7.00	5.55	5.83
Flesh firmness (kg/cm^2)	11.56	12.34	11.16	11.61
Plant spread (NS)	2.96	3.76	3.76	3.89
Plant spread (EW)	4.06	4.92	4.26	4.67
Duration of flowering (days)	17.54	19.25	18.56	17.83
Trunk girth	31.46	41.96	46.76	42.33
Plant height (cm)	4.06	4.76	4.61	4.95
Internodal length (cm)	2.88	3.06	2.82	2.94
Spur frequency (%)	12.04	12.25	12.66	11.66

Table 4: Promising cultivars of apple for different characters

Characters	Highest cultivars	Lowest cultivars	Promising cultivar at par with highest
Plant height	Spartan	Fuji	Royal Gala, Jonadel, Neomi
Trunk girth	Elstar	Summered	Fuji, Royal Gala
Plant spread (NS)	Royal Gala	Neomi	Spartan
Plant spread (EW)	Jonadel	Summered	Royal Gala, Elstar
Shoot length	Jonagold	Quinte	Arlet, Gala
Internodal length	Summered	Elstar	Crimson Gold
Spur frequency	Fuji	Jonagold	-
Duration of flowering	Neomi, Ruspippin	Crimson Gold	-
Fruit retention (O.P.)	Ruspippin	Spartan	Gala and Summered
Date of harvest			
Fruit yield/plant			
Fruit length	Neomi	Crimson Gold	-
Fruit diameter	Neomi	Crimson Gold	-
Fruit weight	Neomi	Crimson Gold	-
Flesh firmness	Red Fuji	Fuji	Arlet, Elstar
Number of seeds/plant	Ruspippin	Sinte	Fuji, Spartan, Spijon and Summered
Total soluble solid	Jonadel	Quinte	
Fruit acidity	Spijon	Neomi	Crimson Gold
Total sugar	Neomi	Crimson Gold	
Reducing sugar	Neomi	Spijon	
Non-reducing sugar	Spartan	Jonagold	Jonadel

(6.78%). The characters like shoot length (19.47cm), plant height (4.95 m), plant spread (3.89 m) had higher values in cluster IV. The character fruit set after 50 days (64.46) in cluster I, yield per plant (39.08 kg) in cluster II, trunk girth (46.76 cm) in cluster III and shoot length (19.47cm) in cluster IV showed the highest values. A number of workers have indicated the significance of genetic divergence in apple (Xin and Shen, 1992; Barua and Sharma, 2002; Pereira *et al.,* 2003). Xin and Shen (1992) clustered 46 apple genotypes into five groups on the basis of traits like internodal length, spur frequency, spur co-efficient, number of long shoot. In the present study the above said characters revealed variation but in a narrow sense, probably the cultivars in the present study were not much divergent in respect of these traits. Mercy and George (1987) grouped 30 culinary banana varieties into 12 clusters using D^2 statistics. The trait bunch weight and hand weight contributed significantly towards divergence. Linoaiah *et al.* (1998) after canonical variate analysis found that plant height, stem girth, flowering shoot per square meter and percentage flowering per square meter contributed much towards the genetic diversity. These characters though not very significant in our study still they could be effectively exploited in future crop improvement. Singh and Chaudhary (1992) in wild apricot and Dwivedi and Mitra (1995) in litchi also reported substantial variation after applying D^2 statistics. Hence, it is concluded that genotypes of cultivars with wide genetic variation accompanied with useful characteristics could be effectively employed in intra specific crosses with the hope that this would lead to the transmission of higher genetic gain for different putative traits major being yield from practical utility point of view. On the basis of the performance of different cultivars and the cluster analysis, the sixteen apple cultivars have been identified for different characters (Table 4), which are potential parents for hybridization programmes. Neomi is best cultivars for fruit yield/plant, fruit length, fruit diameter, fruit weight, total sugars and non-reducing sugars. However, Jonagold is best for TSS. Cultivars Spartan, Elstar, Royal Gala, Jonagold and Summerred would prove best for different vegetative characters.

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