

Utilization of Genetic Diversity and its Association with Heterosis for Progeny Selection in Potato Breeding Programs

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Abstract: Genetic diversity and heterosis was estimated for six important yield contributing quantitative traits in thirteen parents and their thirty hybrids. Hybrids were derived from line-tester mating design. According to diversity analysis thirteen parents were grouped in six clusters and superior male and female parents were distributed in relatively distance cluster. Among the thirteen parents TPS-13, TPS-67, lalpakri, patnai and ausha were selected to produce hybrids with considerable hybrid vigor. In the present investigation degree of heterosis varied from trait to trait. Highest average mid-, better- and standard- parent heterosis was recorded in the tuber number, yield and average tuber weight traits, respectively. Correlation coefficient of genetic distance with F₁ performance, mid-, better- and standard- parent heterosis for six studied traits were statistically non significant and most of the cases were negative.

Key words: *Solanum tuberosum* % Genetic diversity % Heterosis % Correlation coefficient % True potato seeds (TPS)

INTRODUCTION

Potato is a part of the diet of half a billion consumers in the developing countries [1]. Usually in potato cultivation seed tubers are used as planting material. Vegetatively propagated potato once systemically infected with a viral disease and it passes from one vegetative generation to the next. So that, potato production is dramatically reduce in subsequent colonial generation. In addition, the new cultivars needed for sustainable increase in potato production during a period of environmental change and human population growth [2]. Hybridization offers a greater possibility in crop improvement than any other breeding methods and it is the only effective means of combining together the desirable characters of two more varieties.

The success of breeding programs depends upon selection of proper parents. It has been found that the progenies derived from crossing divergent parents gave divergent and useful progenies. It has been often postulated by the breeders that geographical distribution reflects genetic diversity. The importance of genetic diversity in selecting parents for hybridization is well

known. It also known that degree of heterosis is related to the magnitude of genetic divergence between the parental lines. A limited study has been made on genetic divergence in potato [3-6]. The knowledge of genetic divergence and its nature and degree serves a useful purpose to identifying desirable parents for breeding program. The selection of parents or line based on individual attributes may not be as advantageous as that based on a number of important components, collectively, especially if the aim is to seek improvement in complex quantitative traits such as yield. Mahalonobis [7].

Heterosis is considered to be an outcome of genetic complementation between divergent parents. Quantitative genetic explanation for this phenomenon depends directly on existence of dominance effect at different loci in hybrids. Assuming heterosis as a function of heterozygosity, it can be considered as a function of parental diversity. Several works have emphasized the importance of genetic divergence for the selection of desirable parents in many crops [8-14] Heterosis is a major breeding tool for improving productivity potential of crop plants and genetic diversity of parental lines is usually considered to be an important factor to maximize the chances of heterotic combination [15].

The objectives of this study were to measure genetic diversity among the thirteen parents and assess the relationship between genetic distance and the performance of hybrids derived from them.

MATERIALS AND METHODS

Thirteen potato genotypes comprising three from Tuber Crops Research Center of Bangladesh Agricultural Research Institute and ten from different parts of Bangladesh were collected. All the 13 parents were evaluated in the experimental field of plant breeding and gene Engineering Lab, Department of Botany, University of Rajshahi, Bangladesh (GSP 24°17'-24°31' N latitude and 88°28'-88°43' E longitude) to assess the genetic distance among the parents. Each parent consists of three rows of five meter long, whereas distance between two tubers was 1×0.25 meter. Plant height, branch number, tuber number, yield, average tuber weight and dry matter content % were estimated and genetic divergence among the genotypes was studied using Mahalanobis D^2 [7] statistics and its auxiliary analysis. The D^2 values between all varieties were arranged in orders of relative distances from each other and were used for clusters formation as suggested by Rao [16]. Among the thirteen genotypes, ten were used as female and three as male. Hybridization was performed and 43 F_1 progenies were obtained and 30 of them from line-tester matching and 13 (parents) from self hybridization. For hybridization, pollens were collected from selected male parents separately. Emasculation following bagging of the female flowers done on the day before pollination. After pollination bagging and labeling of the flowers were done properly. To produce larger berries, a maximum of six flowers were kept/inflorescence. Each of the female flowers was pollinated 2-3 times after emasculation. Berries were harvested 50 days after pollination and kept at room temperature for another 15 days for softening the berries. Seed were then extracted from the berries, dried and stored in a dessicator with proper labeling for using in the next cropping season. TPS (True potato seeds) of this 43 (30 hybrids and 13 parents) progenies were sown in plastic tray containing 1:1 (v/v) mixture of compost and sand. After six weeks the seedlings were transplanted in to field. At a distance of 30 cm within and 60 cm between rows. Data were recorded for all 43 progenies in the seedling generation after 120 days of plantation. Plant height, branch number, tuber number, yield, average tuber weight and dry matter content % were recorded to assess the heterosis in seedling generation. All the experiments were carried out in a completely randomized block design with

three replications. Ausha was used as a standard parent to estimate heterosis. Heterosis was estimated by using following formula.

MPH (Mid Parents Heterosis) % = $(F_1 - MP) \div MP \times 100$

BPH (Better Parent Heterosis) % = $(F_1 - BP) \div BP \times 100$

SPH (Standard parent Heterosis) % = $(F_1 - SP) \div SP \times 100$

All the statistical analysis was performed by using GENSTAT 9.2 software.

RESULTS AND DISCUSSION

Mean data for six morphological traits of the parents was subjected to diversity analysis which partitioned evaluates 13 genotypes in to six major groups (Table 1). The results revealed that group I, II and VI comprised three genotypes in each group. On the other hand group IV and V comprised one genotype in each group and group III comprised two genotypes.

Canonical variety analysis was done to compute the intra-cluster Mahalanobis's values. Cluster wise intra and inter-cluster distance (D^2) values were present in Table (2). The maximum and minimum intra cluster value was recorded in group VI and II respectively. The highest inter cluster distance was found between group I and VI and lowest was in between group III and V. Low inter-cluster distance value and high inter-cluster distance value between the groups suggested close relationship and wide diversity between the two cluster, respectively.

The cluster mean for the characters studies are represented in Table (3). The highest plant height, branch number, tuber number, yield, average tuber weight and dry matter content % were recorded from the group II, II, I, III, V and IV, respectively. The maximum divergence was observed in cluster VI. It revealed that genotypes within the cluster with high degree of divergence would produce more desirable breeding materials for achieving maximum genetic advance. So that, more emphasis should be given on the member of cluster VI during parent selection for hybridization program. On the other hand, cluster II and I also had high intra cluster value and the nil intra cluster values were exhibited by cluster IV and V, this indicated negligible genetic diversity among the genotypes for each cluster.

The maximum intra-cluster distance was observed between cluster I-VI was followed by IV -VI and III-IV. High divergence genotypes would produce a broad spectrum of variability in the subsequent generation enabling further selection and improvement [17].

Table 1: Germplasm grouping based on morphological traits

Group	Cultivars	Main characters
I	Lalpakri (Lp) ¹ 2n=36*	Plant short spreading; stem few, hairy, pinkish in colour, leaf structure open and dark green; tuber medium, round pinkish with white patches, eyes few not uniformity distributed; flowers light pink.
	Patnai (Pt) 2n=24	Plant tall and erect, stem many and very hairy, leaf structure open and green in colour, tuber oval with smooth radish skin; eye deep, prominent and distally distributed, flower pink
	Lalshill (Ls) 2n=36	Plant tall, erect; stem few, hairy, pinkish green; leaf structure open and green in color; tuber oval, round, medium with smooth red skin; eye deep and prominent, moderate in number, concentrated towards the distal end of the tuber; flower pink.
II	Challisha (Cl) 2n=24	Plant short and spreading, stem few, very much hairy with light pinkish green in colour, leaf structure semi open and dark green, tuber round, medium, creamy white, smooth skin, eye very few in number, shallow, distributed unevenly, flower light pink
	Sadagoti (Sag) 2n=24	Plant tall and erect, stem moderately hairy, leaf structure open and green in colour, tuber round, irregular, creamy white eye deep, moderate in number more at the distal end; flower pinkish white.
	Silbility (Sib) 2n=36	Plant tall and spreading; stem few, moderately hairy and light pinkish green in colour; leaf structure open and green in colour; elongated tuber with smooth shiny, slightly reddish skin, deep eyes uniformly distributed on the tuber; flower pink.
III	Hera (Hr) 2n=36	Plant tall and Spreading, stem few, hairy green in colour, leaf structure open and light green in colour, tuber oval, large, light yellow skin, eye depth Shallow, flower White
	Chamak (Ch) 2n=36	Plant tall and erect, stem few hairy and green, leaf structure open and green in colour, tuber white, oval round, shallow eye uniformly distributed on the tuber
IV	Ausha (Ah) 2n=36	Plant short and spreading; stem few, hairy and green; leaf structure closed, dark green in colour; tuber round, rough, slightly pinkish skin with creamy patches, eye shallow, few in number; distributed on tuber surface; flower pink.
V	MFII (MII) 2n=36	Plant tall and spreading, stem few, hairy deep green in colour, leaf structure open and dark green in colour, tuber oblong, white crime in colour, eye few, deep moderate, uniformly distributed on the tuber, flower white
VI	Tps-13 (13) 2n=48	Plant tall, prostrate, stem few in number, leaf structure slightly close, light green in colour, tuber oval, whitish skin, eye few in number, deep prominent, distributed unevenly on the tuber, flower pinkish white.
	Tps-67 (67) 2n=48	Plant tall stem few in number and green in colour, leaf structure open, green; tuber oval, whitish skin, eye few in number, deep, prominent and distally distributed; flower pink
	Tps-364 (364) 2n=48	Plant short, erect, stems many, green in colour, leaf structure open and green; tuber round white shiny whitish skin eye many, shallow distributed unevenly flower pink.

¹= code name for cultivars * chromosome number, Source: Mondal 2003

Table 2: Average Intra (bold value) and inter cluster distance

	I	II	III	IV	V	VI
I	1.82	6.93	9.16	5.08	10.17	15.08
II		2.05	8.13	9.35	5.83	8.43
III			0.89	10.40	4.30	4.53
IV				0.00	9.70	14.28
V					0.00	6.31
VI						2.39

Table 3: Cluster mean for 13 potato genotypes

Group	Plant height (Cm)	Branch number	Tuber number	Yield (g)	Average tuber weight (g)	Dry matter content (%)
I	47.59	2.88	23.18	104.18	4.88	22.64
II	58.22	5.25	20.77	254.29	14.61	22.29
III	31.22	3.33	9.77	386.55	41.80	19.31
IV	28.22	2.66	11.77	85.11	7.26	23.20
V	50.74	3.88	6.88	347.55	52.35	22.51
VI	28.07	3.48	11.37	265.03	30.41	21.85

Table 4: Mean and range of performance and heterosis in the 30 F1 hybrids

Traits	Performance		Mid parentheterosis		Better parentheterosis		Standard parentheterosis	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Plant height (Cm)	43.52	19.0-65.0	19.90	-39.6-76.4	-1.19	-50.3-75.4	26.34	-26.8-74.8
Branch number	3.27	1.0-8.0	-9.38	-66.7-78.6	-19.12	-68.6-72.7	-5.01	-64.5-93.5
Tuber number	15.37	2.0-48.0	28.92	-75.4-261.0	10.26	-82.4-202.2	33.02	-59.6-167.3
Yield (g)	188.21	63.2-480.4	-11.63	-65.0-64.4	28.73	-68.0-61.2	-38.59	-75.5-75.4
Average tuber weight (g)	15.15	6.9-65.6	-21.58	-82.1-234.9	-46.29	-86.6-134.8	-54.64	-79.3-96.4
Dry matter content%	20.97	17.8-25.20	-5.162	-16.0-13.9	-8.58	-19.7-12.7	13.37	-4.2-39.9

Table 5: Correlation coefficient of genetic distance with performance and heterosis in the 30 F₁ hybrids

Traits	Correlation coefficient			
	Performance	Mid parent heterosis	Better parent heterosis	Standard parent heterosis
Plant height (Cm)	0.131	0.210	0.289	0.158
Branch number	-0.204	-0.264	-0.289	-0.175
Tuber number	0.173	0.117	0.104	0.182
Yield (g)	-0.254	-0.189	-0.253	-0.256
Average tuber weight (g)	-0.320	-0.218	-0.251	-0.330
Dry matter content%	-0.059	-0.015	0.003	-0.051

Table 6: Cluster wise mid parent heterosis pattern in 30 F₁ hybrids of potato

Group	<10%	>10%-50%>	50%<
Plant height			
I×VI	Ls/67, Lp/364, Pt/364	Ls/13, Lp/67, Pt/67, Ls/364	Lp/13, Pt/13
II×VI	Sag/13, Sag/67, Sib/67, Sib/364, Sag/364	Cl/13, Sib/13, Cl/67, Cl/364,	
III×VI	Cm/13, Hr/67, Cm/364,	Hr/13, Cm/67, Hr/364	
IV×VI	Ah/364	Ah/13	Ah/67
V×VI	MII/364	MII/67, MII/13	
Branch number			
I×VI	Lp/13, Ls/13, Pt/13, Lp/67, Ls/67, Pt/67, Lp/364, Ls/364 Pt/364		
II×VI	Cl/13, Sib/13, Cl/67, Sag/67, Sib/67, Cl/364, Sib/364, Sag/364	Sag/13	
III×VI	Cm/13, Hr/67, Cm/364, Hr/364	Hr/13	Cm/67
IV×VI	Ah/364		Ah/13, Ah/67
V×VI	MII/364	MII/13,	MII/67
Tuber number			
I×VI	Lp/13, Ls/13, Ls/67, Pt/67, Pt/364		Pt/13, Lp/67, Lp/364,
Ls/364			
II×VI	Cl/13, Sib/13, Sag/13, Sib/67, Cl/364, Sag/364		Cl/67, Sag/67, Sib/364
III×VI	Hr/13, Cm/67, Hr/67,	Cm/13, Cm/364, Hr/364	
IV×VI	Ah/67	Ah/13,	Ah/364
V×VI	MII/13, MII/364	MII/67	
Yield			
I×VI	Ls/13, Ls/67, Pt/67, Lp/364, Ls/364,	Pt/364	Lp/13, Pt/13, Lp/67
II×VI	Cl/13, Sib/13, Sag/13, Cl/67, Sag/67, Sib/67, Cl/364, Sib/364 Sag/364,		
III×VI	Cm/13, Hr/13, Hr/67, Cm/364, Hr/364		Cm/67,
IV×VI	Ah/13, Ah/67	Ah/364	
V×VI	MII/67, MII/364	MII/13	
Average tuber weight			
I×VI	Lp/13, Ls/13, Pt/13, Lp/67, Ls/67, Lp/364, Ls/364, Pt/364	Pt/67	Pt/67
II×VI	Cl/13, Sib/13, Sag/13, Cl/67, Sag/67, Sib/67, Cl/364, Sib/364, Sag/364		
III×VI	Cm/13, Hr/13, Cm/364, Hr/364		Cm/67, Hr/67
IV×VI	Ah/13, Ah/67, Ah/364		
V×VI	MII/67, MII/364		MII/13
Dry matter %			
I×VI	Lp/13, Ls/13, Pt/13, Lp/67, Ls/67, Pt/67, Lp/364, Ls/364, Pt/364		
II×VI	Cl/13, Sib/13, Sag/13, Cl/67, Sag/67, Sib/67, Cl/364, Sib/364, Sag/364		
III×VI	Cm/13, Hr/13, Cm/67, Hr/67, Cm/364, Hr/364		
IV×VI	Ah/13, Ah/364	Ah/67	
V×VI	MII/13, MII/67	MII/364	

The observation from cluster mean suggested that none of the cluster contained genotypes with all the desirable traits, which could be directly selected and utilize. Interestingly, most of the maximum and minimum cluster means were distributed in relatively distance

cluster. Thus, hybrids development from the cross of cluster I with VI and IV with VI may produce high magnitude of heterosis or desirable transgressive segregants, which would facilitate successful breeding of potato.

Based on genetic diversity, line tester mating design was used to produce hybrids. Members of group VI was used as line (male parents) and members of the rest of the groups were used as line (female parents). Resultant hybrids evaluated for better mid parents, better parents and standard parent heterosis. Heterosis was calculated as percent increase or decrease over mid parent, corresponding better parent and standard parent. The mean and ranges of performance and heterosis of the 30 F₁ hybrids are presented in Table (4). The degree of heterosis showed variation from trait to trait. Highest average mid parent heterosis (28.9%), better parent heterosis (28.7%) and standard parent heterosis (34.6%) was recorded in the traits tuber number, yield and average tuber weight, respectively.

Mid parent heterosis in plant height was ranged from -39.6 to 76.4 and over 50% heterosis value was found in crosses Lp/13, Pt/13 and Au/67. For traits branch number mid parent heterosis was ranged from -66.7 to 78.6 and over 50% heterosis was recorded in crosses Cm/67, Ah/13, Ah/67 and MII/67. Mid parent heterosis for tuber number was from -75.4 to 216.0 and over 50% heterosis was found in crosses Pt/13, Lp/67, Lp/364, Ls/364, Cl/67, Sag/67, Slb/364 and Ah/364. For yield over 50% mid parent heterosis was recorded in crosses Lp/13, Pt/13, Lp/67, Cm/67 and it was ranged from -65.0 to 64.4. Mid parent heterosis in trait average tuber weight was ranged from -82.1 to 234.9 and over 50% heterosis was found in crosses Pt/67, Cm/67, Hr/67 and MII/13. Mid parent heterosis of dry matter content % was ranged from -16.0 to 13.9 and no crosses was found over 50% heterosis most of them was bellow 10% except Ah/67 and MII/364.

Correlation coefficient of genetic distance with the F₁ performance mid parent heterosis, better parent heterosis and standard parent heterosis was calculated and presented in Table (5). The result revealed that all the correlation values was statistically non significant. Among the six traits, only two traits plant height and tuber number had positive correlation value of genetic distance with F₁ performance, mid parent heterosis, better parent heterosis and standard parent heterosis, rest of the traits had negative correlation values.

Cluster wise mid parent heterosis are presented in Table (6). The result reveal that group IV showed high heterosis crossers with group I in the important agronomic traits such as, tuber number, yield and average tuber weight.

In this study, hybrids obtained from very closely or distantly related parents showed low heterosis but crosses produced from parents of intermediate divergence

classes tended to show higher heterosis for tuber number, tuber weight and average tuber weight. This suggests that intermediate divergence of parental lines could give higher heterosis for these traits. Liu *et al.* [18] reported similar results in wheat, Geleta *et al.* [19] in pepper and also support by Moll *et al.* [20] who reported that heterosis decreases beyond a certain level of genetic diversity because of incompatible gene combinations when two highly divergent parental populations are crossed. Busch *et al.* [21] also indicated that the probability of recovering a superior progeny genotype is greater if both parents are similar in performance as opposed to one parent being inferior for one or more traits. On the contrary, for characters such as tuber number, tuber weight and average tuber weight it is advisable to select distantly related parents in order to achieve higher heterosis.

The results of this study showed that genetic distance correlated inefficiently with heterosis and hybrid performance. Many reports in various crop species such as maize [9, 10], rice [11], wheat [12], alfalfa [13] and chickpea [14] also showed low correlations of genetic distance with heterosis.

Although reduced correlations between genetic distances with the heterosis of most of the measured characters were observed, the majority of the progeny expressed appreciable levels of heterosis in the desired directions for these characters. Thus, heterosis probably also exists due to different allelic combinations at particular loci in each parent which when brought together in hybrid combination, complement each other, resulting in heterosis expression [22]. Riday *et al.* [13] indicated that such loci may not be directly related to observable morphological differences but could have an effect on the physiology of the plant.

From overall observation, TPS-13, TPS-67, lalpakri, patnai and ausha were found best parents for producing superior hybrids with high yielding attributes, as well as high yield. Most of these parents were more diverse from each other and distributed in relatively distance cluster. Hybrids obtained from those parents exhibit considerable heterosis for yield contributing traits, which was expected. Genetic distance among the parents is important and it is accelerate hybrid vigor in potato breeding.

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