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Repeatability of Progeny Mean, Combining Ability, Heterosis and Heterobeltiosis in Early Generations of a Potato Breeding Programme

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Abstract Thirty-three populations of Andigena potatoes developed by 11×3 (line × tester) mating were studied from seedling to third clonal generations for number of tubers, average tuber weight, tuber yield, plant vigour, predominant tuber shape, predominant tuber size and uniformity in tuber shape, uniformity in tuber size and uniformity in tuber colour. Inter-generation correlation coefficients for progeny means, general combining ability, specific combining ability, heterosis and heterobeltiosis were computed for various characters. Magnitude of inter-generation correlation coefficients showed that various parameters for uniformity in tuber shape, uniformity in tuber size, uniformity in tuber colour, predominant tuber shape and predominant tuber size could be reliably estimated in early generations starting from the seedling generation. The parameters for tuber yield, average tuber weight and tuber number could only be reliably estimated from second clonal generation onward. Repeatability of progeny means showed that negative selection for tuber yield and average tuber weight could be initiated from first clonal generation and for tuber number from second clonal generation. Plant vigour was found to be a highly inconsistent character.

Keywords clonal generations · correlations · seedling generation · size and colour · *Solanum tuberosum* L. · tuber shape · yield

Abbreviations

ATW average tuber weight
BP value for better parent of the cross
FCG first clonal generation

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GCA general combining ability
MP mean value of two parental clones
PSH predominant tuber shape
PSI predominant tuber size
PV plant vigour
SCA specific combining ability
SCG second clonal generation
SG seedling generation
TCG third clonal generation
TN tuber number per plot
TPS true potato seed
TY total yield per plot
UCO uniformity in tuber colour
USH uniformity in tuber shape
USI uniformity in tuber size

Introduction

Progeny mean, combining ability effects, heterosis and heterobeltiosis help a breeder to identify promising parents and crosses for a potato breeding programme (Gopal 1997, 1998; Gopal et al. 2000). However, due to variable performance of clones and progenies in early generations (Anderson and Howard 1981; Brown et al. 1987a, b; Maris 1988; Gopal et al. 1992; Gopal 1997) estimates of general combining ability (GCA), specific combining ability (SCA), heterosis and heterobeltiosis also vary from generation to generation (Gopal 1998; Gopal et al. 2000). Maris (1988), Neele et al. (1991), Gopal (1997) and Gopal et al. (2000) studied the repeatability of performance of various characters in Tuberosum × Tuberosum and Tuberosum × Andigena families. These studies did not report repeatability for uniformity in various tuber characters which are important for raising a commercial crop from true potato seed (Golmirzaie and Mendoza 1988). In the present investigation repeatability of progeny mean, GCA, SCA, heterosis and heterobeltiosis for all important agronomic traits from seedling to third clonal generation were studied to identify the earliest generation for estimating these parameters reliably in a breeding programme aimed at improving *Solanum tuberosum* ssp. *andigena*.

Materials and Methods

Fourteen *Solanum tuberosum* ssp. *andigena* genotypes were grown and crossed in a line × tester (11×3) pattern (Kempthorne 1957) during summer crop (April–September) of 1998 at Central Potato Research Station, Kufri (31°08′N, 77°18′E, 2,530 masl). The genotypes were selected based on their good tuber bulking, tuber yield and other acceptable characters, like tuber color and shape, from evaluation on 1,073 Andigena accessions (Kumar and Kang 1998). Moreover, these genotypes were quite diverse as they were grouped into six morphological clusters based on a genetic divergence analysis. In India, different genotypes/clones of Andigena are maintained in tuber form with their identity as JEX/A- and JEX/B-numbers (Birhman et al. 1998). The true seeds of these Andigena genotypes had been received long ago from American countries. Among these, genotypes JEX/A 30, JEX/A 44, JEX/A 459, JEX/A 715, JEX/A 798, JEX/A 805, JEX/A 855, JEX/A

1048, JEX/A 1102, JEX/A 1205 and JEX/B 998 were used as females and JEX/A 318, EX/A 680-16 and JEX/A 764 as males. Seedlings and subsequent clonal generations were raised at Central Potato Research Station Jalandhar (31°02′N, 75°02′E, 237 masl) under sub-tropical short-day conditions of autumn seasons (October–December) of 1998–2001. Fresh true potato seeds (TPS) of 33 families extracted from berries harvested in August 1998 were treated with 2,000 ppm gibberellic acid (GA_3) for 24 h for dormancy breaking. After drying in shade, TPS were sown in seedling trays filled with 1:1 mixture of sand and farmyard manure in the last week of September 1998. After 20 days, when seedlings were of three to four-leaf stage, these were transferred individually to small polythene bags. At six to seven-leaf stage they were transplanted to the field. At harvest three tubers per seedling for each of 48 randomly selected genotypes per family were retained from seedling generation (SG) to form three replications of first clonal generation (FCG). The same procedure was applied to form the material for second clonal generation (SCG) and third clonal generation (TCG). All trials were laid in a Randomized Complete Block Design with a plot size of 5.76 m^2 comprising four rows of 12 hills per row planted at intra- and inter-row spacing of 20 and 60 cm, respectively. The recommended agronomic practices were followed. Every year the crop was harvested 90 days after planting. Observations were recorded on number of tubers per plot, average tuber weight (g) and tuber yield per plot (kg), plant vigour (Score: 1=very low, to 5=very high), predominant tuber shape (Score: 1=round, 2=oval and 3=oblong), predominant tuber size (Score: 1=very small, to 5=very large) and uniformity in tuber shape (Score: 1=low, to 3=high), uniformity in tuber size (Score: 1=low, to 3=high), uniformity in tuber colour (Score: 1=low, to 3=high). Data recorded in scores were transformed using square root transformation before analyses. Combining ability analysis was done according to Kempthorne (1957). A fixed effect model was used to test the significance of combining ability effects. Heterosis and heterobeltiosis were calculated as per the following formulae:

$$\text{Heterosis}(\%) = \left(\overline{X} - \text{MP}\right)/\text{MP} \times 100$$
$$\text{Heterobeltiosis}(\%) = \left(\overline{X} - \text{BP}\right)/\text{BP} \times 100$$

$\overline{X}$ is the mean of hybrid family. MP is the mean value of two parental clones. BP is the value for the better parent of the cross. Phenotypic correlation coefficients between generations were computed using the computer software MSTAT (Michigan State University, USA).

Results

Analysis of variance of progeny means showed significant differences between families for various characters. Differences in combining ability effects due to females, males and female × male were significant for most of the characters except due to males for tuber number in SG, uniformity in tuber shape in FCG and SCG, uniformity in tuber size in SG and FCG and predominant tuber shape in SG, FCG and SCG. Mean squares due to parents vs. crosses were also significant, indicating the presence of heterosis in the families studied.

Repeatability of progeny means All inter-generation correlation coefficients were high ($r > 0.70$) for predominant tuber shape, predominant tuber size, uniformity in tuber shape, uniformity in tuber size and uniformity in tuber colour. Whereas, most of the inter-generation correlation coefficients for plant vigour, tuber yield, tuber number and average

Table 1 Phenotypic correlation coefficients between generations for different genetic parameters

	Correlation coefficients between					
	SG vs. FCG	SG vs. SCG	SG vs. TCG	FCG vs. SCG	FCG vs. TCG	SCG vs. TCG
(a) Progeny mean						
(1) TN	0.247	−0.016	−0.061	0.479**	0.425*	0.835**
(2) ATW	0.629**	0.433*	0.398*	0.764**	0.799**	0.919**
(3) TY	0.815**	0.576**	0.509**	0.658**	0.588**	0.882**
(4) PV	0.886**	0.109	0.367*	0.136	0.383*	0.391*
(5) USH	0.852**	0.903**	0.907**	0.929**	0.852**	0.906**
(6) USI	0.851**	0.723**	0.833**	0.821**	0.825**	0.864**
(7) UCO	0.976**	0.983**	0.984**	0.979**	0.965**	0.973**
(8) PSH	0.892**	0.951**	0.938**	0.926**	0.877**	0.950**
(9) PSI	0.892**	0.897**	0.915**	0.900**	0.890**	0.891**
(b) GCA						
(1) TN	0.569*	−0.457	−0.173	0.061	0.105	0.782**
(2) ATW	0.852**	0.286	0.453	0.438	0.649*	0.855**
(3) TY	0.756**	0.552*	0.425	0.708**	0.626*	0.881**
(4) PV	0.937**	−0.137	0.590*	−0.030	0.604*	−0.003
(5) USH	0.821**	0.843**	0.790**	0.963**	0.779**	0.829**
(6) USI	0.852**	0.812**	0.938**	0.833**	0.860**	0.841**
(7) UCO	0.982**	0.981**	0.990**	0.991**	0.965**	0.972**
(8) PSH	0.915**	0.976**	0.941**	0.953**	0.897**	0.930**
(9) PSI	0.908**	0.931**	0.908**	0.899**	0.937**	0.950**
(c) SCA						
(1) TN	0.066	0.064	0.037	0.652**	0.586**	0.831**
(2) ATW	0.474**	0.492**	0.339	0.927**	0.874**	0.936**
(3) TY	0.864**	0.586**	0.546**	0.635**	0.571**	0.879**
(4) PV	0.847**	0.248	0.139	0.243	0.090	0.670**
(5) USH	0.858**	0.927**	0.927**	0.932**	0.890**	0.926**
(6) USI	0.855**	0.705**	0.800**	0.806**	0.804**	0.869**
(7) UCO	0.974**	0.987**	0.979**	0.969**	0.967**	0.977**
(8) PSH	0.878**	0.940**	0.938**	0.918**	0.888**	0.957**
(9) PSI	0.884**	0.878**	0.940**	0.998**	0.878**	0.878**
(d) Heterosis (%)						
(1) TN	0.407*	0.139	0.042	0.450**	0.408*	0.760**
(2) ATW	0.629**	0.439*	0.422*	0.714**	0.826**	0.847**
(3) TY	0.814**	0.510**	0.539**	0.644**	0.639**	0.898**
(4) PV	0.822**	0.171	0.100	0.255	0.028	0.426*
(5) USH	0.807**	0.900**	0.905**	0.920**	0.835**	0.904**
(6) USI	0.873**	0.777**	0.832**	0.785**	0.817**	0.886**
(7) UCO	0.972**	0.982**	0.983**	0.976**	0.958**	0.969**
(8) PSH	0.881**	0.957**	0.925**	0.913**	0.858**	0.935**
(9) PSI	0.947**	0.870**	0.906**	0.871**	0.894**	0.893**

Table 1 (continued)

	Correlation coefficients between					
	SG vs. FCG	SG vs. SCG	SG vs. TCG	FCG vs. SCG	FCG vs. TCG	SCG vs. TCG
(e) Heterobeltiosis (%)						
(1) TN	0.438*	0.156	0.097	0.439*	0.342	0.684**
(2) ATW	0.723**	0.371*	0.400*	0.572**	0.665**	0.780**
(3) TY	0.800**	0.483**	0.571**	0.725**	0.697**	0.883**
(4) PV	0.747**	0.294	0.194	0.282	0.210	0.527**
(5) USH	0.855**	0.901**	0.905**	0.929**	0.855**	0.904**
(6) USI	0.868**	0.654**	0.691**	0.707**	0.763**	0.824**
(7) UCO	0.975**	0.984**	0.984**	0.978**	0.964**	0.974**
(8) PSH	0.890**	0.974**	0.915**	0.912**	0.853**	0.924**
(9) PSI	0.943**	0.889**	0.832**	0.909**	0.842**	0.891**

r simple correlation coefficient; *GCA* general combining ability; *SCA* specific general combining ability; *TN* tuber numbers per plot; *ATW* average tuber weight; *TY* tuber yield per plot: *PV* plant vigour; *USH* uniformity in tuber shape; *USI* uniformity in tuber size; *UCO* uniformity in tuber colour; *PSH* predominant tuber shape and *PSI* predominant tuber size

*significant at $0.01 \leq P < 0.05$; **significant at $P < 0.01$

tuber weight were of low magnitude except between SCG and TCG where these were high for tuber yield and its components. The highest correlation coefficient ($r = 0.984$) was obtained for uniformity in tuber colour between SG and TCG and while the lowest was −0.016 for tuber number between SG and SCG (Table 1).

Repeatability of general combining ability effects Trends of inter-generation correlations for GCA effects of various characters were similar to that observed for progeny mean. Highest correlation coefficient was 0.991 for uniformity in tuber colour between FCG and SCG and lowest was −0.457 between SG and SCG for tuber number (Table 1).

Repeatability of specific combining ability effect All inter-generation correlation coefficients for uniformity in various tuber characters, predominant tuber shape and predominant tuber size were high ($r > 0.70$). For tuber yield and its components highest correlations were between SCG and TCG. For plant vigour, highest correlation was between SG and FCG ($r = 0.847$) followed by SCG and TCG ($r = 0.670$). All other inter-generation correlations for this character were non-significant. The highest correlation coefficient was 0.998 for predominant tuber size between FCG and SCG and the lowest was 0.037 between SG and TCG for tuber number.

Repeatability of heterosis Uniformity in various tubers characters, predominant tuber shape and predominant tuber size had high repeatability over generations for heterosis too. For tuber number, high correlation coefficient was observed only between SCG and TCG; others were low and mostly non-significant. For tuber yield and average tuber weight highest correlations were between SCG and TCG, though many other correlation coefficients for these characters were also significant. For plant vigour inter-generation correlations were non-significant, except SG vs. FCG where it was high ($r = 0.822$). The

Table 2 Genotypes with consistently good or poor general combining ability (GCA)

Characters	Genotypes with consistent GCA					
	Over seedling and clonal generations		In seedling generation		In second and third clonal generations	
	Good[a]	Poor[b]	Good	Poor	Good	Poor
(1) TY	JEX/B 998	JEX/A 798, JEX/A 1102, JEX/A 764	JEX/A 30, JEX/A 44, JEX/A 459, JEX/A 715, JEX/B 998, EX/A 680-16	JEX/A 798, JEX/A 805, JEX/A 855, JEX/A 1102, JEX/A 1205, JEX/A 764	JEX/A 459, JEX/A 715, JEX/B 998, JEX/A 318, EX/A 680-16	JEX/A 798, JEX/A 1048, JEX/A 1102, JEX/A 764
(2) TN	–	JEX/A 805	JEX/A 44, JEX/A 715, JEX/A 798, JEX/A 855, JEX/A 1102, JEX/B 998, JEX/A 764	JEX/A 459, JEX/A 805, JEX/A 1048, EX/A 680-16	JEX/A 798, JEX/A 1102, JEX/B 998, JEX/A 764	JEX/A 459, JEX/A 805, JEX/A 1048, EX/A 680-16
(3) ATW	EX/A 680-16	JEX/A 1102, JEX/A 1048	JEX/A 44, JEX/A 855, JEX/B 998, EX/A 680-16	JEX/A 715, JEX/A 1048, JEX/A 805, JEX/A 764, JEX/A 1102, JEX/A 1205	JEX/A 459, JEX/A 715, JEX/A 805 EX/A 680-16	JEX/A 798, JEX/A 1048, JEX/A 1102, JEX/A 764
(4) PV	–	–	JEX/A 44, JEX/B 998, JEX/A 318	JEX/A 459, JEX/A 855, JEX/A 764	JEX/A 715	–
(5) USH	JEX/A 1205	JEX/A 855,	JEX/A 1205, JEX/A 1102	JEX/A 805, JEX/A 318	JEX/A 1205 JEX/A 855, JEX/A 1102, JEX/A 764	JEX/A 855, JEX/A 1102
(6) USI	–	JEX/A 1048, JEX/A 1102	JEX/A 30, JEX/A 715,	JEX/A 1048, JEX/A 1102, JEX/A 764	JEX/A 30, EX/A 680-16	JEX/A 459, JEX/A 1048, JEX/A 1102
(7) UCO	JEX/A 798, JEX/A 805, JEX/A 1205	JEX/A 1102, JEX/B 998, JEX/A 1048, JEX/A 764	JEX/A 44, JEX/A 715, JEX/A 798, JEX/A 805, JEX/A 855, JEX/A1205, EX/A 680-16	JEX/A 30, JEX/A 459, JEX/A 1048, JEX/A 1102, JEX/B 998, JEX/A 764	JEX/A 44, JEX/A 715, JEX/A 798, JEX/A 805, JEX/A 855, JEX/A 1205, EX/A 680-16	JEX/A 1048, JEX/A 1102, JEX/B 998, JEX/A 764
(8) PSH	JEX/A 855, JEX/A 805, JEX/A 459	JEX/A 1048, JEX/B 998	JEX/A 459, JEX/A 715, JEX/A 798, JEX/A 805, JEX/A 855, JEX/A 764	JEX/A 30, JEX/A 44, JEX/A 1048, JEX/A 1102, JEX/A 1205, JEX/B 998, JEX/A 318	JEX/A 459, JEX/A 798, JEX/A 805, JEX/A 855, JEX/A 764	JEX/A 30, JEX/A 44, JEX/A 1048, JEX/B 998

Table 2 (continued)

Characters	Genotypes with consistent GCA					
	Over seedling and clonal generations		In seedling generation		In second and third clonal generations	
	Good[a]	Poor[b]	Good	Poor	Good	Poor
(9) PSI	JEX/A 459	JEX/A 1102	JEX/A 459, JEX/B 998,	JEX/A 44, JEX/A 1048, JEX/A 1102	JEX/A 30, JEX/A 459, JEX/B 998	JEX/A 1102

GCA General combining ability; *TN* tuber numbers per plot; *ATW* average tuber weight; *TY* tuber yield per plot: *PV* plant vigour; *USH* uniformity in tuber shape; *USI* uniformity in tuber size; *UCO* uniformity in tuber colour; *PSH* predominant tuber shape and *PSI* predominant tuber size

[a] Genotypes with significant ($P < 0.05$) GCA in desired direction.

[b] Genotypes with significant ($P < 0.05$) GCA in undesired direction.

highest correlation coefficient for heterosis was 0.983 for uniformity in tuber colour between SG and TCG and lowest was 0.028 between FCG and TCG for plant vigour.

Repeatability of heterobeltiosis Trends of various inter-generation correlation coefficients were similar to that observed for heterosis, except that here correlation between SCG and TCG for plant vigour was also significant. The highest correlation coefficient for heterobeltiosis was 0.984 for uniformity in tuber colour between SG and SCG and the lowest was 0.097 between SG and TCG for tuber number.

Genotypes with consistent GCA effects over generations Genotypes with consistently good or poor GCA over all generations for various characters are listed in Table 2. EX/A 680-16 was a good general combiner for average tuber weight in all generations. JEX/B 998 was a good general combiner for tuber yield in all generations. Other genotypes with consistently good GCA over generations were: JEX/A 798 and JEX/A 805 for uniformity in tuber colour; JEX/A 1205 for uniformity in tuber shape; JEX/A 805, JEX/A 855 and JEX/A 459 for predominant tuber shape and JEX/A 459 for predominant tuber size. Genotypes with consistently poor combining ability over generations are also listed (Table 2) so that their use is discouraged by the potato breeders. Some genotypes had high GCA only in seedling or clonal generations. Genotypes with good GCA only in seedling generation may be of value for TPS crop only and those with good GCA only in clonal generations can be useful parents for developing varieties for clonally propagated crop. Such genotypes with high GCA for yield in seedling generation were JEX/A 30, JEX/A 44 and EX/A 680-16. For other characters these had average or good combining ability e.g. JEX/A44 also possessed good general combining ability for tuber number, average tuber weight, plant vigour and uniformity of tuber colour besides tuber yield. Similarly JEX/A 30 was a good general combiner for uniformity of tuber size and predominant tuber shape; and EX/A 680-16 for uniformity of tuber colour.

Genotypes with consistent good GCA effects for tuber yield over second and third clonal generations were JEX/B 998, JEX/A 715, JEX/A 459, JEX/A 318 and EX/A 680-16.

Table 3 Families with consistently high progeny mean, specific combining ability, heterosis and heterobeltiosis over generations

Character	Families with good performance over seedling and clonal generations	Best performing families in	
		Seedling generation	Both second and third clonal generations
(1) TY	JEX/A 805×JEX/A 764	JEX/ A 44×EX/A 680-16	JEX/ A 459×EX/A 680-16
	JEX/B 998×JEX/A 318	JEX/ A 30×EX/A 680-16	JEX/ A 805×JEX/A 764
	JEX/A 44×EX/A 680-16	JEX/ A 715×JEX/A 318	JEX/ A 715×JEX/A 318
		JEX/ A 805×JEX/A 764	JEX/ B 998×JEX/A 318
(2) TN	–	JEX/ A 1048×JEX/A318	JEX/ A 798×EX/A 680-16
		JEX/ A 44×EX/A 680-16	JEX/ B 998×JEX/A 318
		JEX/ A 459×EX/A 680-16	JEX/ A 1205×JEX/A 318
		JEX/ A 1102×JEX/A 764	JEX/ A 1102×JEX/A 764
(3) ATW	JEX/A 855×JEX/A 318	JEX/ A 30×EX/A 680-16	JEX/ A 459×EX/A 680-16
	JEX/A 30×EX/A 680-16	JEX/ A 44×JEX/A 764	JEX/ A 855×JEX/A 318
	JEX/A 805×JEX/A 764	JEX/ A 798×JEX/A 318	JEX/ A 805×JEX/A 764
		JEX/ A 805×JEX/A 764	JEX/ A 715×JEX/A 318
(4) PV	JEX/A 44×EX/A 680-16	JEX/ A 44×JEX/A 764	JEX/ A 44×EX/A 680-16
	JEX/A 715×EX/A 680-16	JEX/ A 44×EX/A 680-16	JEX/ A 715×EX/A 680-16
(5) USH	JEX/A 798×JEX/A 764	JEX/ A 855×JEX/A 318	JEX/ A 855×JEX/A 318
	JEX/A 715×JEX/A 318	JEX/ A 1102×EX/A 680-16	JEX/ A 1102×EX/A 680-16
	JEX/A 855×JEX/A 318	JEX/ A 459×JEX/A 764	JEX/ A 459×JEX/A 764
	JEX/A 30×EX/A 680-16	JEX/A 805×JEX/A 764	JEX/ A 805×JEX/A 764
	JEX/A 44×EX/A 680-16		
	JEX/B 998×EX/A 680-16		
	JEX/A 805×JEX/A 764		
(6) USI	JEX/A 805×JEX/A 318	JEX/ A 805×JEX/A 318	JEX/ A 805×JEX/A 318
	JEX/A 855×JEX/A 318	JEX/ A 459×EX/A 680-16	JEX/ A 459×EX/A 680-16
	JEX/A 44×EX/A 680-16	JEX/ A 1205×JEX/A 764	JEX/ A 1205×JEX/A 764
	JEX/A 715×EX/A 680-16	JEX/ A 44×EX/A 680-16	JEX/ A 44×EX/A 680-16
	JEX/B 998×EX/A 680-16		
(7) UCO	JEX/A 44×JEX/A 318	JEX/ A 459×JEX/A 318	JEX/ A 459×JEX/A 318
	JEX/A 459×JEX/A 318	JEX/ A 30×EX/A 680-16	JEX/ A 30×EX/A 680-16
	JEX/A 798×JEX/A 318	JEX/ A 1048×EX/A 680-16	JEX/ A 1048×EX/A 680-16
	JEX/A 805×JEX/A 318	JEX/ A 715×EX/A 680-16	JEX/ A 715×EX/A 680-16
	JEX/A 715×EX/A 680-16		
	JEX/A 855×EX/A 680-16		
	JEX/A 1048×EX/A 680-16		
	JEX/A 1205×EX/A 680-16		
(8) PSH	JEX/A 1102×JEX/A 318	JEX/ A 805×JEX/A 318	JEX/ A 805×JEX/A 318
	JEX/A 855×JEX/A 764	JEX/ A 459×JEX/A 318	JEX/ A 459×JEX/A 318
	JEX/A 715×JEX/A 764	JEX/ A 715×JEX/A 764	JEX/ A 715×JEX/A 764
	JEX/A 805×JEX/A 318	JEX/ A 459×EX/A 680-16	JEX/ A 459×EX/A 680-16
	JEX/A 855×JEX/A 318		
	JEX/A 44×EX/A 680-16		
	JEX/A 798×EX/A 680-16		
	JEX/A 855×EX/A 680-16		
	JEX/A 459×JEX/A 764		
	JEX/A 715×JEX/A 764		

Table 3 (continued)

Character	Families with good performance over seedling and clonal generations	Best performing families in	
		Seedling generation	Both second and third clonal generations
(9) PSI	JEX/A 30×EX/A 680-16 JEX/A 459×EX/A 680-16 JEX/B 998×EX/A 680-16 JEX/A 459×JEX/A 764 JEX/A 805×JEX/A 764 JEX/A 855×JEX/A 318	JEX/ A 459×EX/A 680-16 JEX/ B 998×EX/A 680-16 JEX/ A 805×JEX/A 764 JEX/ A 459×JEX/A 764	JEX/ A 459×EX/A 680-16 JEX/ B 998×EX/A 680-16 JEX/ A 805×JEX/A 764 JEX/ A 459×JEX/A 764

TN tuber numbers per plot; *ATW* average tuber weight; *TY* tuber yield per plot: *PV* plant vigour; *USH* uniformity in tuber shape; *USI* uniformity in tuber size; *UCO* uniformity in tuber colour; *PSH* predominant tuber shape and *PSI* predominant tuber size

Families with consistently high progeny mean, SCA, heterosis and heterobeltiosis over generations Families with consistently good performance over all generations are listed in Table 3. Among these, JEX/A 805×JEX/A 764, JEX/B 998×JEX/A 318 and JEX/A 44×EX/A 680-16 families had high performance for tuber yield. Families with desired predominant shape, predominant size and high uniformity for tuber characters are required for a TPS crop (Golmirzaie and Mendoza 1988). Family JEX/A 855×JEX/A 318 had all these desired characters except uniformity in tuber colour which was average only. Family JEX/A 44×EX/A 680-16 was promising in seedling generation for yield and tuber uniformity characters. Families with promising performance in SCG and TCG for tuber yield and its components were JEX/A 459×EX/A 680-16, JEX/A 805×JEX/A 764, JEX/A 715×JEX/A 318 and JEX/B 998×JEX/A 318.

Discussion

Solanum tuberosum ssp. *andigena* being adapted to short days, is a suitable cultivated species for use in potato breeding programmes for sub-tropics (Gopal et al. 2000). Andigena genotypes, however, have poor yields and have more tubers of smaller size than produced by Tuberosum cultivars (Tai and Tarn 1980). Andigena thus needs to be improved for this and a number of other tuber characters. The present investigation was based on Andigena×Andigena families generated to improve various tuber characters including tuber yield and its components.

Inter-generation correlation coefficients presented in Table 1 showed that those between two immediate generations especially between SG and FCG, were higher than those between distant generations for various parameters of tuber yield and its components. This reflects “carry over effects” for these characters from a generation to its immediate next generation. Such “carry over effects” have also been reported by Blonquist (1963), Brown et al. (1987b), Gopal et al. (1992) and Gopal (1997).

The most advanced generation in the present study was TCG. So evaluation based on this generation could be considered more reliable than in earlier generations. Thus, correlation coefficient of earlier generation with TCG was considered a good indicator for identifying the earliest generation in which a particular character could be assessed reliably.

All inter-generation correlation coefficients for uniformity in tuber shape, uniformity in tuber size, uniformity in tuber colour, predominant tuber shape and predominant tuber size for progeny mean, GCA effects, SCA effects, heterosis and heterobeltiosis were quite high. This indicates that genetic parameters for these characters could be reliably assessed in all generations starting from the seedling generation itself. Conversely, for tuber yield and its components, reasonably high correlations for various parameters were only between SCG and TCG, indicating that these characters could be evaluated reliably only in SCG onwards. The magnitude of correlation coefficients of SG vs. TCG and FCG vs. TCG for tuber yield and its components for progeny mean, GCA, heterosis and heterobeltiosis indicated that compared to tuber yield and average tuber weight, it would be more difficult to assess tuber number reliably in early generations. Similar results were also obtained for clonal selection by Gopal et al. (1992) who suggested that negative selection for tuber yield and average tuber weight can be initiated from FCG and for tuber number from SCG. Plant vigour appeared to be the most inconsistent character in the present study, as inter-generation correlations for various parameters of this trait were non-significant and low even between SCG and TCG (Table 1). Thus it would be difficult to practice selection and estimate various parameters for this trait in the early generations.

Magnitudes of inter-generation correlation coefficient for progeny mean in present study were higher than those reported by Maris (1988) and Neele et al. (1991). This may be because seedlings in the present study were raised in the field and not in pots as done by Maris (1988) and Neele et al. (1991). Gopal (1997) evaluated the repeatability of progeny performance over SG, FCG and SCG under short day subtropical conditions by raising seedlings in the field. Most of the inter-generation correlation coefficients for progeny means in the present study were even higher than those reported by Gopal (1997) except for tuber number and plant vigour where reverse was true. Raising of seedlings in field results in better expression of characters. Hence for progeny selection it would be advisable to raise seedlings in the field rather than in pots (Gopal 1997).

The inter-generation correlations for GCA of uniformity of tuber shape, uniformity of tuber size, uniformity of tuber colour, predominant tuber shape and predominant tuber size in the present study were in general higher than those obtained by Gopal (1998). However, among the various characters, Gopal (1998) too had observed highest repeatability for GCA of uniformity in tuber colour. In contrast to our results, Gopal (1998) had obtained very high inter-generation correlations for GCA of plant vigour also.

In conclusion, reliable estimates of breeding value of parents (GCA) and families (progeny mean, SCA, heterosis) for uniformity in various tuber characters, predominant tuber size and predominant tuber shape could be established in all generations starting from the seedling generation. However, breeding value of parents and families for tuber yield and its components could only be reliably estimated from SCG onwards. The study also confirmed the earlier findings (Gopal 1997) that progeny selection should be effective in early generations but to a limited extent for tuber yield and its components. Inter-generation correlation coefficients for progeny means of these characters (Table 1) suggest that, as in clonal selection (Gopal et al. 1992), only negative selection for tuber yield and average tuber weight could be initiated from first clonal generation and for tuber number from second clonal generation. Parents and families with consistently high general combining abilities (Table 2) and high progeny means (Table 3), particularly in SCG and TCG, may prove useful in improving the Andigena potatoes. Among these EX/A 680-16 had been reported to be a good general combiner for most of the agronomic traits in previous studies (Gaur et al. 1985; Gopal 1998).

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