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Genetic analysis of within family variation in true seed crop of potato (*Solanum tuberosum* L.)

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Abstract

A study was conducted on 72 families from 18 × 4 factorial mating design to evaluate them for within family variation for tuber yield, its components and general impression in seedling (transplanted) and seedling-tuber potato crops. Plant (genotype) to plant (genotype) variation within a family for tuber yield was affected by the choice of males, females and their specific combinations, whereas no such effect was observed for general impression. For within family variation of tuber number and average tuber weight, choice of parents and crosses was more important in the seedling than in the seedling-tuber crop. Nature of gene action was predominantly non-additive for within family variation of various characters. A comparison of combining ability effects for progeny means and within family variations showed the possibility of having parents and crosses which may result in progenies with high tuber yield and an acceptable level of uniformity for various tuber characters as determined by general impression. For identifying such TPS populations, good general combiners for progeny mean of tuber yield should be intercrossed and families subjected to progeny selection for tuber yield, general impression and within family variation for general impression. 'PJ376 × EX/A680-16' was identified as a promising cross which may result in a true potato seed population suitable both for seedling and seedling-tuber crops.

Key words : *Solanum tuberosum*, combining ability, within family variation, seedling crop, seedling-tuber crop, TPS crop

Introduction

Use of true (botanical) seed for commercial cultivation of potato has advantages in terms of disease free and low cost planting material, storage, transport etc. The true potato seed (TPS) crops can be raised using transplanted seedlings and seedling- tubers (i.e. produce of seedling crop) as planting material [1]. Due to autotetraploid and highly heterozygous nature of potato, a TPS family produced by selfing or hybridization of parental lines is a collection of single plants that differ in their genetic constitution (genotype). This result in non-uniformity within in a TPS population. The main objective of breeding for true potato seed crop thus is to obtain progenies with high yield and low within family plant to plant variation for various tuber characters [2, 3]. Identification of parents and crosses which could result in such families is crucial for the success of TPS technology. Gopal [4] reported combining ability for progeny means of tuber yield, its components and other agronomic characters in seedling (transplanted) and seedling-tuber crops in potato. The present study reports combining ability for within family variation of tuber yield, its components and general impression with the objective to suggest an optimum breeding procedure for identifying promising TPS families.

Materials and methods

A random sample of 22 potato genotypes (Table 2) generally used as parents, was drawn from the National Potato Breeding Programme at the Central Potato Research Institute, Shimla. These were grown and crossed during summer (May-August) 1992 at the Central Potato Research Station, Kufri (32^{o}N, 77^{o}E, 2500 m above mean sea level) in an 18 × 4 (females × males) factorial mating design (line × tester pattern) [5], using CP1710, CP2132, EX/A680-16 and EX/A723, as males because of their high pollen fertility and broad genetic base. The 72 progenies thus generated were evaluated at the Punjab Agricultural University, Ludhiana (31^{o}N, 75^{o}E, 230 m above mean sea level) during autumn (October-January) 1993-94 and 1994-95. True seeds were sown in seedling trays filled with 1:1 (v:v) mixture of sand and farmyard manure on 20 September 1993. When seedlings were of 3-4 leaf stage (about 30 days after sowing) these were transplanted in a field and replicated twice with each progeny represented by 60 randomly selected seedlings. At harvest, 3 tubers/seedling for each of the 50 randomly selected genotypes per progeny were retained and used to form 3 replications (1 tuber/genotype/replication) of the seedling-tuber crop. The experiments were laid out in a completely randomised block design in short rows of 5 tubers each at recommended intra-and inter-row distances of 20 cm and 60 cm, respectively. Normal manurial and cultural schedules were followed.

Data were recorded on plot basis in all replications on all the 72 progenies for four characters namely tuber yield (g/plant), tuber number (per plant), average tuber weight (g) and general impression (score: 1 = very good, to 5 = very poor). General impression was based on all the characters at harvest including tuber yield, its components, tuber colour, tuber shape, eye depth, uniformity in tuber colour, shape, size etc. Within family variation was computed for all the families. As within family variation is not expected to be normally distributed, it was transformed using square root transformation and standard deviation so obtained was subjected to combining ability analysis. General combining ability (GCA) and specific combining ability (SCA) effects were estimated. Computer software BMM (PAU, Ludhiana) was used for the purpose. The fixed effect model was used considering the set of genotypes as a complete population.

Results and discussion

Mean squares of combining ability due to females, males and their interactions for within family standard deviation of tuber yield were significant in both seedling and seedling-tuber crops, whereas these were non-significant for general impression. This showed that plant (genotype) to plant (genotype) variation for tuber yield will be affected by the choice of males, females and their specific combinations, whereas no such effect will be observed for general impression in both the crops. Thompson *et al.* [6] reported that TPS families did not differ substantially for uniformity in tuber size and shape, the components of general impression of the present study. Mean squares of combining ability due to all sources for within family standard deviation of tuber number were significant in seedling crop and non-significant in seedling-tuber crop. For within family standard deviation of average tuber weight mean squares due to females were significant in both the crops and those due to females × males interaction were significant only in the seedling crop. Thus, choice of parents and crosses for having low plant to plant variation for tuber number and average tuber weight is more important in the seedling than in the seedling-tuber crop. Higher family variation in seedling than in seedling- tuber generation showed that predictability and repeat ability of performance of hybrid TPS population can't be obtained. Due to heterozygous nature of potato there would not be uniformity in the hybrid TPS populations. This is a fundamental genetic handicap in the breeding of TPS potato and hence the lack of widespread adoption of TPS system.

The ratio of variance components due to combining ability versus total genetic variance (Table 1) showed a preponderance of non- additive gene action for within family variation of various characters. Progeny means of these characters based on the present material were also found to have predominantly non-additive genetic control [4]. This may be due to narrow genetic base of the tested genotypes resulting from the informal previous selection [7].

Table 1. The predictivity ratio (variance due to gca/total genetic variance) for within family standard deviation in potato

Character		
	Seedling crop	Seedling-tuber crop
Tuber yield	0.27	0.19
Tuber number	0.43	-
Average tuber weight	0.04	0.34

Mean squares of combining ability due to all sources for tuber number were non-significant in the seedling-tuber crop.

General combining ability estimates (Table 2) showed that in the seedling crop, among females the best combiners (i.e. one with the lowest within family variation) for tuber yield and both of its components (i.e. tuber number and average tuber weight) were 'JE 812' followed by 'MS81-152'. 'F1277' followed by 'MS78-46' were good combiners for tuber yield and tuber number, but average combiners for average tuber weight. 'AB455' was the worst combiner (i.e. with the highest within family variation) for tuber yield and both of its components, and 'JR465' was a poor combiner for tuber yield and tuber number. Among males, 'CP1710' was a good combiner for tuber yield and 'EX/A680-16' was a poor combiner for tuber yield and tuber number. In the seedling-tuber crop, among females 'F1277' followed by 'PJ376' were the best combiners for tuber yield and average tuber weight, whereas 'MS84-1169' followed by 'MS78-56' were the worst combiners for these characters. 'RG1197' was a poor combiner for tuber yield and a good combiner for average tuber weight. Among males, 'CP1710' and 'CP2132' were good combiners and 'EX/A680-16' was a poor combiner for within family variation of tuber yield. Some other genotypes were also good or poor combiners for within family variation of one or the other character in the two crops (Table 2).

A comparison of seedling and seedling-tuber crops for general combining ability estimates of parents showed that there was very little similarity in this regard. This suggests that combining ability analysis needs to be done separately for the seedling and seedling-tuber crops. A comparison of general combining ability for progeny mean of these parents [4] with their general combining ability for within family variation (of the present study), showed that a good combiner for progeny

Table 2. Estimates of general combining ability effects for within family standard deviation in seedling and seedling-tuber crop for various characters[2]

Parents	Seedling crop			Seedling-tuber crop	
	Tuber yield	Tuber number	Av. tuber weight	Tuber yield	Av. tuber weight
Females					
AB455	37.29**	2.81**	3.15**	–5.54	–2.27
E4451	0.70	0.02	0.26	7.63	–0.99
F1277	–36.25**	–2.11**	–0.64	–26.98**	–3.48**
JE812	–36.78**	–2.24**	–2.26**	–7.86	–0.28
JH222	14.88	2.67**	0.09	8.81	3.31**
JN1501	–12.24	0.76	–0.69	–9.66	–1.07
JR465	31.07**	2.02**	0.56	3.43	1.45
JTH/C107	–10.29	–0.27	–0.37	5.92	0.62
MS78-46	–18.64*	–1.84**	0.83	–12.52*	–1.35
MS78-56	18.53*	–0.16	0.52	13.41*	4.02**
MS79-34	11.55	–1.17*	0.25	–1.26	1.12
MS80-758	–6.14	1.12*	–0.91	–1.23	0.06
MS81-152	–24.06**	–1.18*	–1.75**	12.43*	0.51
MS82-638	20.30*	0.42	0.65	–0.38	0.70
MS84-1169	5.77	0.03	0.23	14.12*	5.74**
PJ376	6.62	0.25	0.26	–17.94**	–3.18**
RG1197	–2.55	–0.91	0.10	14.04*	–3.46**
SLB/K23	0.26	–0.20	–0.30	3.57	–1.44
SE	8.81	0.53	0.48	6.34	1.21
Males					
CP1710	–20.53**	–0.82	–0.30	–12.09**	–0.42
CP2132	–2.92	–0.12	0.16	–9.83**	–0.64
EX/A680-16	24.00**	2.07**	0.22	21.59**	1.39
EX/A723	–0.56	–1.13*	–0.08	0.33	–0.33
SE	3.70	0.22	NS	2.66	NS

[2]Mean squares of combining ability due to all sources for general impression were non-significant in both the crops.
Mean squares of combining ability due to all sources for tuber number were non-significant in the seedling-tuber crop.
*, **Significant at $P < 0.05$, 0.01, respectively.

mean of a character was, in general, a poor combiner for within family variation of that character, and vice-versa. For example, 'EX/A680-16', a good combiner for progeny mean of tuber yield [4] was a poor combiner for within family variation for this character. Similarly, 'CP1710', 'CP2132' and 'JE812' which were poor combiners for progeny means of most of the characters were, in general, good or average combiners for within family variation for the corresponding characters. This suggests that a family with high progeny mean of a character is expected to have high plant to plant variation for that character and it may be difficult to combine high progeny mean with low within family variation. However, non-significant mean squares of combining ability for within family standard deviation of general impression indicate that it should be possible to identify parents and crosses which may result in high tuber yield and an acceptable level of uniformity for various tuber characters like tuber colour, tuber shape, tuber size, eye depth, uniformity in tuber colour, shape, size etc. which were part of the general impression. Further, from practical point of view low plant to plant variation for these characters is more important than that of tuber yield and its components as long as total yield of a family is high.

As variation due to females × males interaction were significant, many crosses had significant sca for various characters in seedling as well as seedling-tuber crops. In the seedling crop, top five crosses with lowest sca (i.e. the desired direction) for within family standard deviation for tuber yield were : 'MS82-638 × EX/A680-16', 'PJ376 × EX/A723', 'JR465 × CP1710', 'AB455 × EX/A723' and 'AB455 × CP1710'. Among these the last two crosses also had low sca for within family standard deviation of tuber number and average tuber weight. In the seedling-tuber crop the five top crosses with low sca for within family standard deviation for tuber yield were: 'RG1197 × CP2132', 'JE812 × EX/A723', 'F1277 × CP1710', 'JN1501 × CP2132' and 'SLB/K23 × EX/A680-16'.

There was no association between gca of parents and sca of crosses in both the crops indicating that selection of parents on the basis of general combining ability will not limit the exploitation of sca effects. Parentage of different crosses showed that all types of epistatic interactions i.e. additive × additive, additive × dominance and dominance × dominance were important for desired sca values for various characters.

Based on the above findings, it is suggested that for getting a family with high tuber yield and low (acceptable level) within family variation for general impression, good general combiners for progeny mean of tuber yield should be crossed in all possible combinations and families so obtained should be subjected to progeny selection [8] for these parameters. Such families in the present study were 'JH222 × CP1710' and 'PJ376 × EX/A680-16' in the seedling crop (yield > 130g/plant and within family standard deviation for general impression < 1.00), and 'JTH/C107 × EX/A680-16', 'RG1197 × EX/A680-16' and 'PJ376 × EX/A680-16' in the seedling-tuber crop (yield > 180 g/plant and within family standard deviation for general impression < 0.85). Incidently, 'JTH/C107 × EX/A680-16' has been already recommended by the Central Potato Research Institute, Shimla for commercial cultivation under the name TPS-C3. The cross 'PJ376 × EX/A680-16' which had high yield and low within family variation for general impression in both seedling and seedling-tuber crops should be tested on a large scale for commercial TPS crop.

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