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Early generation selection for agronomic characters in a potato breeding programme

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Summary. A random sample of seedlings representing high, medium and poor vigour was studied for tuber colour, tuber shape, eye depth, tuber cracking, tuber yield per plant, average tuber weight and number of tubers per plant in four successive generations (F_1, F_1C_1, F_1C_2, and F_1C_3). Based on the performance of vigour groups in various generations and inter-generation correlation coefficients, we propose a procedure for the elimination of unproductive genotypes early in the breeding programme. The data indicates that seedlings of poor vigour can be discarded at the seedling stage prior to transplantation in the field. The rejection of clones on the basis of tuber colour, tuber shape, eye depth and tuber cracking can also be initiated at the seedling stage. For tuber yield and average tuber weight a negative selection (rejection of poor phenotypes) is suggested from the first clonal generation and for number of tubers, from second clonal generation, until statistically sound replicated trials can be conducted for carrying out positive selection.

Key words: Potato breeding – Early generation selection – Selection procedure – *Solanum tuberosum*

Introduction

In early generations of selection in a potato breeding programme, the major limitation in effective testing is number of tubers per clone. Clones in these generations are therefore generally assessed in unreplicated plots consisting of just one or a few hills. The tubers used for planting various clones also often vary in size. These factors (Blomquist and Lauer 1962; Harris et al. 1967; Davies and Johnston 1974) in addition to normal year and location effects make the identification of potentially desirable genotypes in early generations difficult.

Selection in early generations is generally based on visual assessment of individual genotypes for their commercial worth. There are, however, reports (Davies and Johnston 1965; Tai 1975; Anderson and Howard 1981; Brown et al. 1984; Brown et al. 1987b; Maris 1988) that repeatability of the performance of clones selected in early generations is low to very low in subsequent generations and that selection of individual clones on the basis of general impression results at best in a random reduction in number of genotypes. Tai (1975), Brown (1987) and Brown et al. (1987a) suggested that instead of individual clonal selection, progeny selection should be carried out since the mean performance of a cross was found to have good repeatability in early generations. The selected progenies could then be multiplied to a level that would allow a more reliable assessment of individual genotypes. This method, however, is laborious and cumbersome. Hence it is necessary to resort to individual clonal selection from early stages of breeding.

Individual clonal selection may be more efficient if unlike general impression, the selection is based on specific characters. Howard (1963), Maris (1966, 1988) and Kichefski et al. (1976) studied the efficiency of selection for individual characters in early generations. Their results were, however, conflicting. The study presented here was therefore undertaken to determine the efficiency of selection for individual characters. The seedlings were raised in the field to allow full expression of yield and tuber characters in contrast to most of the previous studies wherein the seedlings were raised in glasshouses. With a view to improving the efficiency of selection, we also studied seedling vigour.

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Materials and methods

The study was conducted at the Central Potato Research Station, Jalandhar (Punjab), India (31°N, 75°E, 230 m above sea level) for four cropping seasons during 1982–1983 to 1985–1986. Out of the large number of crosses that have been made for making selections in various potato breeding programmes, the cross 'Kufri Jyoti' × composite pollen was selected for this study. The composite pollen consisted of equal quantities of pollen from the parents 'Kufri Sheetman', 'G 2524', 'EX/A 680-16' and 'JEX/B 723'. The female parent 'Kufri Jyoti'; is resistant to late blight and is the main variety under cultivation in both the hills and plains of India. Male parents were selected on the basis of their diversity and capacity to produce abundant fertile pollen. A total of 2,500 seeds of this cross were sown in wooden trays containing a 1:1 (v:v) mixture of compost and sand. Twenty days after sowing the seedlings were visually scored and classified into high, medium and poor vigour on the basis of plant size and foliage cover. From each vigour group 100 randomly selected seedlings were transplanted to polythene bags (5 × 10 cm) containing a 1:1 (v:v) mixture of compost and sand. After another 20 days the seedlings along with the soil balls were transplanted into the field at a distance of 30 cm within and 60 cm between rows. The data were recorded on 45 randomly selected seedlings of each vigour group. These seedlings (F_1) were also studied in the next three successive clonal generations (i.e. F_1C_1, F_1C_2 and F_1C_3, respectively).

Each clone was represented by a single row of 4 hills in F_1C_1, 12 hills in F_1C_2 and 15 hills replicated 4 times in F_1C_3. The spacing within and between rows was kept as per normal cultivation practice, i.e. at 20 and 60 cm, respectively. As much as possible, within the limitation of number of tubers per clone, tubers of uniform size were used to raise the clonal generations. Normal manurial and cultural schedules were followed during the seasons.

Observations on tuber colour, tuber shape, eye depth, tuber cracking, tuber yield per plant, number of tubers per plant and average tuber weight were recorded on individual clones in all of the generations studied. The first four characters were recorded visually. Tuber colour was recorded as white, red, splashed or white with picked eyes; tuber shape as round, oval, oblong or irregular; eye depth as shallow, medium or deep; and tuber cracking as present or absent. Tuber yield per plant, number of tubers per plant and average tuber weight were measured quantitatively, and the data used for calculating range, means, frequency distribution, coefficients of variation and inter-generation correlations within characters (Gomez and Gomez 1984).

Results and discussion

Tuber colour, tuber shape and eye depth

These characters remained unchanged over all the generations (F_1 to F_1C_3) in all of the clones studied, indicating that selection for these characters could be initiated in the seedling generation. Our results thus differ from those of Howard (1963), who reported that selection for tuber shape in the seedling generation is not effective, and agree with those of Swiezynski (1978), who reported that selection for tuber shape and deep eyes is effective in the seedling generation. The difference between our results and those of Howard (1963) could be due to the fact that he raised the seedlings in a glasshouse in pots, whereas in our study as well as in that of Swiezynski (1978) the seedlings were raised in the field where these characters have the potential to be fully expressed.

Tuber growth cracking

Out of 135 clones studied 11 showed tuber growth crack in the F_1 and another 8 in the F_1C_1. These 19 clones were almost equally distributed among the three vigour groups, i.e. 8 were in the high vigour group, 5 in the medium vigour group and 6 in the poor vigour group. No new clone showed tuber crack in subsequent generations, indicating thereby that association for this character between any two generations from F_1C_1 onwards was perfect ($r = 1.0$). The clones showing growth cracks in the F_1 and/or F_1C_1 invariably showed cracking in subsequent generations also. Hence, the clones showing growth cracks could be eliminated from the F_1 generation onwards. This confirmed the findings of Kichefski et al. (1976).

Seedling vigour, tuber yield, average tuber weight and number of tubers

The range and coefficients of variation (CV) of tuber yield per plant, average tuber weight and number of tubers per plant for the three vigour groups in various

Table 1. Range and coefficients of variation in different vigour groups in different generations

Character	F_1 vigour group	Generation							
		F_1		F_1C_1		F_1C_2		F_1C_3	
		Range	CV (%)	Range	CV (%)	Range	CV (%)	Range	CV (%)
Average tuber yield/ plant (g)	High	175–1,015	40.9	176–535	24.8	193 –620	22.8	246 –600	18.3
	Medium	13–500	66.9	140–488	34.7	223 –569	17.3	208 –650	22.9
	Poor	2–240	95.5	48–500	58.5	87 –560	41.2	92 –537	33.9
Average tuber weight (g)	High	6.9–35.3	37.5	7.2–34.3	33.1	9.0–47.8	36.5	19.9–63.6	24.6
	Medium	0.6–47.5	80.7	7.6–34.6	43.4	13.9–46.4	31.8	19.3–56.3	23.5
	Poor	0.6–15.2	85.9	6.3–35.2	44.8	4.9–34.5	37.3	14.0–49.4	36.7
Number of tubers/ plant	High	10–78	47.6	8–36	32.8	9–31	27.2	6–19	26.9
	Medium	3–74	65.5	10–32	34.4	8–24	24.1	5–19	27.5
	Poor	2–33	67.2	7–40	47.2	8–72	52.7	8–31	32.6

Table 2. Analysis of variance of different F_1 vigour groups in F_1C_3 generation

Character	ANOVA				
	Source	*df*	M.S.S.		
			High vigour	Medium vigour	Poor vigour
Average tuber yield/plant (g)	Replication	3	17,379.17	51,051.02**	68,994.99**
	Genotype	44	28,992.09**	33,629.32**	59,514.05**
	Error	132	20,916.29	12,399.52	11,053.49
Average tuber weight (g)	Replication	3	25.47	133.16	0.98
	Genotype	44	337.11*	333.57**	341.12**
	Error	132	159.55	87.31	88.09
Number of tubers/plant	Replication	3	12.46	15.11	69.28**
	Genotype	44	26.40**	34.16**	35.87**
	Error	132	12.27	11.23	11.64

*, ** Significant at $P < 0.05$ and $P < 0.01$, respectively

Table 3. Mean performance of different F_1 vigour groups in different generations

Character	F_1 vigour group	Generation							
		F_1		F_1C_1		F_1C_2		F_1C_3	
		$\bar{X}$	±SE	$\bar{X}$	±SE	$\bar{X}$	±SE	$\bar{X}$	±SE
Average tuber yield/plant (g)	High	497.0	29.0	301.4	10.7	388.6	12.6	448.4	11.7
	Medium	191.0	19.7	282.7	15.3	384.3	10.0	421.4	15.1
	Poor	81.2	12.3	257.9	23.8	332.7	21.2	360.4	19.3
Average tuber weight (g)	High	15.0	0.8	18.5	0.9	25.2	1.3	41.7	1.5
	Medium	11.7	1.5	16.7	1.1	26.4	1.3	38.3	1.4
	Poor	6.4	0.6	15.0	1.0	20.4	1.2	29.8	1.7
Number of tubers/plant	High	36.2	2.5	17.9	0.8	16.6	0.6	11.2	0.4
	Medium	21.5	2.9	20.4	2.3	15.2	0.6	11.4	0.5
	Poor	11.9	1.3	19.1	1.4	18.4	1.5	13.1	0.7

$\bar{X}$, Mean; SE, standard error

generations are given in Table 1. The data shows a large variability for all these three characters in F_1 seedlings. However, as the number of plants of each genotype increased in subsequent generations, the variability decreased, indicating that the high variability of these characters that was observed in the F_1 generation was due to smaller plot size leading to high environmental effects. The clones of the poor vigour group showed the highest character variation in all generations for all three characters. An analysis of variance (Table 2) conducted with F_1C_3 material showed that there was significant genetic variability for all three characters in all three vigour groups.

The average performance of different vigour groups in four generations is presented in Table 3. The average F_1 yield of three vigour groups differed significantly from each other ($P<0.05$). The high vigour group produced high average yield, and the poor vigour group, poor average yield. In subsequent generations the differences between vigour groups lessened. In the F_1C_1 generation the differences were not significant; in the F_1C_2 and F_1C_3 generations the high and medium vigour groups were at par and superior to the poor vigour group. The performance of the F_1C_3 generation is based on a large number of plants and replications and is therefore more reliable than the performance of any of the previous generations. The non-significant difference ($P<0.05$) in tuber yield that was observed between high and medium vigour groups in th F_1C_3 showed that the difference in yield between these groups in the F_1 was mainly due to environmental factors. Significant but lessened differences for tuber yield between these two groups and the poor vigour group in the F_1C_3 suggests that yield differences between them in the F_1 were due to both genetic and environmental factors. A similar trend was observed for average tuber weight and number of tubers. Thus, the seedlings in the poor vigour group were inferior to those in high and medium vigour groups.

To know how many good clones would be lost if seedlings of poor vigour were discarded, we worked out the distribution of F_1C_3 tuber yield in the three vigour groups (Table 4). The data shows that out of the 17.0% of the genotypes that were observed in the highest yielding class (yield/plant > 500 g), 9.6% were from the high vigour group, 5.9% from the medium vigour group and only 1.5% (viz. 8.8% of the total high-yielding seedlings) from the poor vigour group. Thus only 8.8% of the high-yielding clones would be lost if the entire poor vigour class was eliminated in the F_1 generation. Considering the extent of resources involved in carrying all of the seedlings to subsequent generations, it would be desirable to discard the poor vigour seedlings at the time of transplanting in the field as there would be no significant loss of high-yielding seedlings.

In Europe and North America where the crop is grown under long photoperiods, high vigour of the seedlings is associated with late maturity. Hence, very vigorous clones are rejected in early testing stages in potato breeding programmes. In contrast, the crop in India is grown largely under short-day conditions that restrict foliage growth and induce early tuberization and early maturity (Pushkarnath 1976). This makes even the very vigorous genotypes desirable for use under Indian conditions.

The inter-generation correlation coefficients (Table 5) were calculated to examine the relationship of performance in different generations. All of the correlation coefficients were positive and significant except for number of tubers for which the r values between the F_1 and F_1C_2,

Table 4. Percentage distribution of genotypes in yield and vigour groups

F_1 vigour group	Yield (g/plant) of F_1C_3					
	<100	100–200	201–300	301–400	401–500	>500
High	0.0	0.0	0.7	7.4	15.6	9.6
Medium	0.0	0.0	3.0	9.6	14.8	5.9
Poor	3.0	5.2	8.9	8.9	5.9	1.5
Total	3.0	5.2	12.6	25.9	36.3	17.0

and between the F_1 and F_1C_3 were non-significant. The values of the correlation coefficients for various characters and generations were low to moderate and ranged from 0.02 to 0.65. The correlation coefficients between the seedling and the clonal generations were weaker than those between the clonal generations. Further, the correlation coefficients F_1 versus $F_1C_3 < F_1C_1$ versus $F_1C_3 <$ F_1C_2 versus F_1C_3 indicated that the later the generation, the better its relationship wth the F_1C_3 and hence the better the evaluation of clones for these characters.

The correlation coefficient between tuber yields of the F_1 and F_1C_3 was low ($r = 0.29$), indicating that no selection for yield may be made in the F_1 generation. These findings differ from those of Howard (1963) and Verma (1972), who suggested that low yielders could be rejected at the seedling stage, but agree with those of Maris (1988), who suggested that rejections for tuber yield should not be done in the F_1 generation, particularly in early maturing types. The correlation coefficients between tuber yields of the F_1C_1 and F_1C_3 ($r = 0.48$) and between the F_1C_2 and F_1C_3 ($r = 0.60$) were not high enough to suggest a positive selection for good yielders in these generations. However, they did suggest that negative selection (rejection of poor yielders only) could be carried out in these generations.

The correlation coefficients between average tuber weights of different generations ($r = 0.22$–0.65) were almost of the same magnitude as those for tuber yield. The estimates of r (Table 5) between the F_1 and F_1C_3 were low and, therefore, no selection at this stage can be recommended. Kichefski et al. (1976) also reported that selection for average tuber size was ineffective in F_1 generation. The r values were, however, moderately high for the F_1C_1 versus F_1C_3 and F_1C_2 versus F_1C_3, suggesting that negative selection for this character could be done from the F_1C_1 generation onwards.

Inter-generation correlation coefficients ($r = 0.02$–0.45) for number of tubers were lower than those for tuber yield and tuber weight. The r values (Table 5) between the F_1 and F_1C_3 were non-significant, indicating that selection for this character was not possible in the F_1 generation. This confirmed the findings of Howard (1963). The r value between the F_1C_1 and F_1C_3 was low, whereas that

Table 5. Correlation coefficients (r) for tuber yield, average tuber weight and number of tubers in different generations

Generation	Tuber yield			Average tuber weight			Number of tubers		
	F_1C_1	F_1C_2	F_1C_3	F_1C_1	F_1C_2	F_1C_3	F_1C_1	F_1C_2	F_1C_3
F_1	0.24*	0.19*	0.29**	0.38**	0.22**	0.38**	0.21*	0.11	0.02
F_1C_1	–	0.52**	0.48**	–	0.52**	0.55**	–	0.45**	0.29**
F_1C_2	–	–	0.60**	–	–	0.65**	–	–	0.40**

*, ** Significant at $P < 0.05$ and $P < 0.01$, respectively

between the F_1C_2 and F_1C_3 was moderately high, suggesting that a negative selection for tuber number could be started in F_1C_2 generation onwards.

Conclusions

Based on the above results the following selection procedure is suggested:

1) Seedlings of poor vigour may be rejected prior to transplanting in the field as they represent inferior genotypes.

2) Those clones with undesirable tuber colour, tuber shape, eye depth and tuber cracking may be rejected from the seedling stage onwards as these characters have a high repeatability.

3) No rejection should be done on the basis of tuber yield, average tuber weight or number of tubers in the seedling generation.

4) Negative selection for tuber yield and tuber weight can be initiated from the F_1C_1 generation onwards, whereas number of tubers can be considered for the rejection of undesirable types from the F_1C_2 generation onwards.

This procedure of individual clonal selection would help in an early and safe elimination of unproductive genotypes. Progeny selection as suggested by Brown et al. (1987 a) in combination with individual clonal selection as shown above can reduce the population to a manageable size before it is multiplied and tested on large scale.

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