EARLY GENERATION SELECTION METHODS USED IN POLISH POTATO BREEDING[1]

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Abstract

Polish potato breeding involves two stages: development of parental lines and their use in the development of new cultivars. In the breeding of new cultivars, early generation selection is based mainly on visual discrimination of superior genotypes. Careful evaluation of clones is done in later generations. In parental line breeding the whole selection procedure is completed in early generations. Experience gained in early generation selection for virus resistance, yield, and dry matter content has been summarized. Evidence has also been presented that evaluation of individual tubers makes possible an inexpensive selection of numerous genotypes for several important characters.

Resumen

El mejoramiento de papas en Polonia incluye dos etapas: el desarrollo de líneas parentales y su uso en la selección de cultivares nuevos. En el desarrollo de cultivares nuevos, la selección temprana se basa mayormente en la discriminación visual de genotipos superiores. Luego se hace la evaluación rígida de los clones engeneraciones posteriores. En el mejoramiento de líneas parentales, todo el proceso de selección es completado en generaciones tempranas.

Experiencia ganada en la selección en generaciones tempranas para resistencia a virus, rendimiento y contenido de materia seca ha sido sumarizada. Se ha presentado también evidencias de que la evaluación individual de tubérculos hace posible la reducción del costo del proceso de selección de numerosos genotipos para varios caracteres importantes.

Introduction

As potato breeders apply early generation selection to increase the frequency of favorable genotypes, they encounter the following difficulties in identifying advantageous recombinants: 1) characters are subject to chance variation and it is difficult to recognize the best genotypes (6, 13); 2) breeders need to select for many independent characteristics and it is impos-

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sible to simultaneously apply strong selection pressure for each attribute (14); 3) for some important characters, like yielding ability or tuber size, the mean of progenies is inferior to mid parent values (11); 4) potatoes have large plants that take much space; and 5) selection is difficult because tubers are under ground.

Methods of selection depend on breeding objectives and the breeding system. Therefore, before describing early generation selection methods used in Polish potato breeding it is important to know about the breeding work being conducted there.

Potato Breeding in Poland

The three main breeding objectives in Poland are: 1) tuber yield, 2) resistance to viruses and 3) table quality or high dry matter content. Breeding work is realized in 2 stages: 1) parental line breeding and 2) development of new cultivars. Parental line breeding attempts to produce clones outstanding in selected characters which can be utilized by breeders developing new cultivars. Each year about 100 thousand seedlings are grown in Poland to obtain parental lines and about 700 thousand to obtain new cultivars.

The breeding cycle for development of new cultivars takes about 12 years from original cross to final product. In parental line breeding this takes only 4 years (Table 1). Both involve early generation selection, but in parental line breeding early generation selection is practiced more extensively. Most of our experience in such selection comes from this work. This paper will discuss: 1) selection for tuber yield, 2) selection for virus resistance, 3) selection for dry matter content and 4) selection based on evaluation of individual tubers.

Selection for Yield

Yield is the most important goal in Polish potato breeding. In the development of new cultivars there is a gradual reduction in the number of clones and each year selection pressure is applied for yield. Clones are evaluated first in multiplication plots and then for nine years in breeder's, preliminary and final trials. Clones which pass all this testing and become new cultivars have produced, on the average, 1.4 t/ha more than standard cultivars (24).

In parental line breeding high yielding clones are selected in a much shorter period of time. Field-grown, first year seedlings are selected for yield. Then first-year tuber progeny, grown in 30-hill plots are further selected for yield. The next year promising clones are evaluated in 8-hill plots $\times$ 4 replications $\times$ 2 harvest dates $\times$ 2 locations; a total of 128 hills of each

clone. The best clones are evaluated again the following year in similar 2nd trials.

TABLE 1. — *Breeding cycles used in Polish potato breeding for cultivar and parental line development.*

Year	Type of material used for breeding new cultivars	Selection for		
1	1st year seedlings (pots)			Q[1]
2	1st tuber progeny	Y[2]		Q
3	2nd tuber progeny	Y		Q
4	3rd tuber progeny	Y		(Q)[3]
5	1st own trials	Y	V[4]	(Q)
6	2nd own trials	Y	V	(Q)
7	1st preliminary trials	Y	V	(Q)
8	2nd preliminary trials	Y	V	(Q)
9	3rd preliminary trials	Y	V	(Q)
10	1st final trials	Y	V	(Q)
11	2nd final trials	Y	V	(Q)
12	3rd final trials	Y	V	(Q)
	Type of material used for breeding new parental lines			
1	1st year seedlings (field)	Y	V	Q
2	1st tuber progeny	Y	V	Q
3	1st trials (8-hill plots)	Y	(V)	Q
4	2nd trials (8-hill plots)	Y	(V)	Q

[1]Q = tuber quality
[2]Y = tuber yield
[3]( ) = weak selection pressure
[4]V = virus resistance

Mean starch yields of clones tested in 2nd trials were compared with starch yield of a standard cultivar, Lenino. Starch yields are an indirect measure of tuber yields, which were not recorded. In most years selected clones yielded as much or more than the standard cultivar (Table 2).

Basing on accumulated experience (20, 21, 25), we have drawn the following conclusions: 1) trials with 8-hill plots are sufficient to select high yielding clones and, 2) it is important to evaluate clones as early as practicable, in more than one location.

Selection for Virus Resistance

In Poland much attention is paid to virus resistance because Polish farmers require cultivars which may be reproduced for several years without purchasing certified seed. Serious virus losses are mostly caused by Potato Virus Y (PVY) and Leafroll (PLRV). In our breeding work attention is paid to six potentially important viruses: PVX, PVY, PVA, PVS, PVM and PLRV.

TABLE 2. — *Mean starch yield of clones in 2nd trials of parental line development program, compared with a standard cultivar, Lenino.*

Year	Number of clones	Starch yield t/ha	
		Lenino	clones[1]
1975	24	7.1	+0.2
1976	5	7.2	−0.8
1977	17	6.7	+0.3
1978	15	7.2	+0.1
1979	7	6.3	+1.1

[1]Deviations from cv. Lenino

In the development of new cultivars, virus resistance is evaluated in clones for eight years, starting with the fifth year of selection (Table 1). Very little early generation selection is currently applied for virus resistance in cultivar development programs.

On the other hand, in parental line breeding, various new sources of virus resistance are being introduced and, where possible, young seedlings are inoculated and selected for virus resistance. The genes Rx, Ry and Ns are being introduced to confer resistance to PVX, PVY, PVA and PVS (8, 22). Young resistant seedlings are selected in progenies where these genes have recombined with other desirable characteristics (3). The first inoculation with PVY is done in seedling flats in the cotyledon stage followed two and four days later with inoculation with a combination of PVX and PVY and then seven and ten days later with PVS. For these inoculations, strains of PVX, PVY and PVS are selected which are highly infective and produce good symptoms on potato plants. Symptoms begin to appear 15 days after initial inoculation and continue to appear as seedlings are transplanted to pots and later to the field. Only healthy looking plants are saved and they are tuber indexed the following winter by growing plants from extracted eyes. The plants are observed for virus symptoms and healthy-appearing plants indexed for viruses by serology and detached leaf inoculations. Next spring tubers from virus free plants are planted and the resulting crop is further indexed and screened by graft inoculation (Table 3). In general, selection for resistance to these viruses is efficient and escapes are rare.

Selection of clones resistant to PVM is more difficult. This virus multiplies slowly in potatoes and there are great differences from plant to plant (4). Resistance to PVM has not been found among cultivars tested, only tolerance (4, 7). A higher level of resistance has been found in wild *Solanum* species. The gene Rm, found in *S. megistacrolobum* (12) provides more resistance than has been available in cultivars (9). We recently found a high level of PVM resistance in *S. gourlayi* (10, 19, 26) and are trying to introduce this into *S. tuberosum* gene backgrounds. Because of the slow and variable spread of PVM in potato plants, graft inoculation is used in selec-

TABLE 3. — *Selection for the presence of genes Rx, Ry and Ns in Polish parental-line development program.*

Stage	Plants	Treatment	
First year	cotyledon stage	inoculation with viruses:	PVY
	+2 days		PVX, PVY
	+4 days		PVX, PVY
	+7 days		PVS
	+10 days		PVS
	+15 to 20 days		
seedlings	transfer into pots		
	plant in the field	elimination of plants with symptoms	
	a sample of 2 tubers	1. observe plants from extracted eyes 2. index for PVX, PVY, PVS	
First tuber progeny	a sample of 10 tubers	1. observe plants from extracted eyes 2. index for PVX, PVY, PVS 3. graft inoculate with PVX, PVY, PVS	

tion of resistant clones. This makes it difficult to handle large populations in early generation screening.

The selection of clones resistant to PLRV is difficult because no extreme resistance and no convenient methods of selection are available. It is necessary to artificially inoculate several plants of each clone with viruliferous aphids and testing must be repeated on several successive clonal generations (3). This method is more reliable than evaluation under natural infection in the field (1). Results of testing three cultivars of different resistance level, over a 12-year period, each year inoculating 10 to 50 plants of each, are shown in Figure 1.

Inoculating young seedlings with leafroll has yielded disappointing results (2, 5). Inoculation of young seedlings may be useful in selecting resistant progenies but more research needs to be done on this selection technique.

In summary, we have been able to effectively select young seedlings resistant to PVX, PVY, PVA and PVS but have not been successful in selecting for PLRV resistance before the first tuber progeny. Possibilities of early selection for PVM resistance are not yet clear.

The early generation selection methods used in parental line breeding are being adopted by cultivar breeders in Poland. Two are now inoculating young seedlings with PVY when working with material segregating for gene Ry.

Results of breeding potatoes in Poland resistant to viruses are summarized in Table 4. Within the last 12 years there has been considerable increase

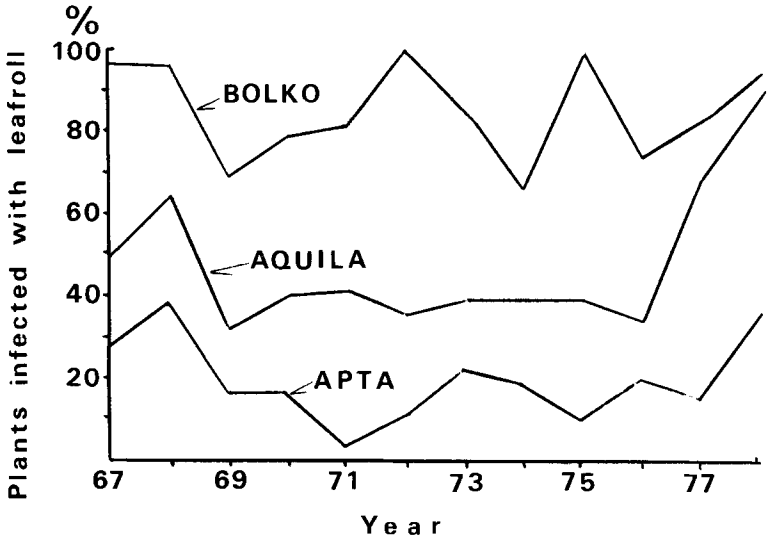

FIG. 1. Reaction to PLRV inoculation of three cultivars: APTA, AQUILA and BOLKO over a 12-year period.

TABLE 4. — *Mean level of resistance to viruses in Polish potato cultivars.*

Year	PVY	PLRV
1968	4.9[1]	4.3
1975	5.3	4.5
1980	6.3	5.3

[1]1 = susceptible, 9 = resistant

in the general level of resistance to PVY and PLRV in Polish cultivars. In 1977 parental lines carrying the genes Rx, Ry and Ns became available to breeders and in 1980 the first cultivar carrying gene Ry was released.

Dry Matter or Starch Content

A large proportion of Polish potatoes is utilized for feeding animals and production of potato flour or alcohol. Therefore, breeding for high starch content is very important.

As a measure of starch content, specific gravity is determined in tuber samples. A high correlation was found between starch content, dry matter content, and specific gravity. A 5-kg sample is usually sufficient to determine starch content with satisfactory accuracy. Three features of variation in starch content influence methods of early generation selection: 1) Between hills within a clone, yield is much more variable than starch content (Table 5). Therefore, to determine tuber yield larger plots and/or more replications are needed than to determine starch content. 2) If clones are compared in

successive years, their starch content is usually more repeatable than tuber yield. However, the range of variation of correlation coefficients was found to be greater for starch content than for tuber yield (Table 6). The reason is years with abnormal weather conditions in the autumn, such as a rainy period following prolonged drought. In such years very erratic results are obtained for starch content. This is one of the reasons why we harvest half of the field replications in early August. Early harvested tubers may supply more reliable starch content information than those harvested later (20). 3) No genetic correlation was found between starch content and starch yield (20). It follows that it is possible to breed cultivars with high starch content and high starch yield.

TABLE 5. — *Variation of hills within cultivars in yield and starch content.*

Cultivar	No. of hills	Coefficient of variation	
		tuber yield	starch content
Swit (early)	50	33	9
Kolektyw (late)	50	34	9
Everest (very late)	50	35	5

TABLE 6. — *Correlation coefficients between results in 11 pairs of years for tuber yield, starch yield and starch content.*

Character	Values of correlation coefficients			
	Mean	Maximum	Minimum	Range
Tuber yield	0.65	0.82	0.37	0.45
Starch yield	0.52	0.75	0.27	0.48
Starch content	0.73	0.85	0.30	0.55

The best Polish cultivars have high starch content and specific gravity but there is potential for much higher levels to be introduced from parental lines and selections of *S. chacoense* (Table 7).

Selection Based on Evaluation of Individual Tubers

After obtaining preliminary evidence that selection based on evaluation of individual tubers may be effective (15, 16), we compared the efficiency of the following three selection methods in field-grown seedlings: 1) selection of best plants, 2) selection of all tubers with high starch content, satisfactory size and shape, and 3) selection of only the best high-starch tubers. Selecting only the best high-starch tubers was found to be the most efficient selection method (Table 8). To select one valuable clone it was necessary to grow 1232 plants from those selected as "best plants," but only 767 plants from those selected as "best tubers" (17).

TABLE 7. — *Some results of breeding for high starch content in Poland.*

Years	Group	Starch content %	Specific gravity
	Best cultivars		
1976-79	1. Poprad	19.5	1.106
	2. Odra	19.3	1.105
	3. Narew	19.1	1.104
	Best parental lines		
1978-79	PS 18	24.2	1.128
	PS 15	22.0	1.118
	Best selections in S. chacoense		
1978-79	LI 852	30.8	1.159
	LI 847	30.7	1.158

TABLE 8. — *Results of three selection methods in field grown seedlings (17).*

Source of clones	Clones collected	Clones found valuable nr.	Clones found valuable %	Nr. of plants grown to select one valuable clone	No. of years
Best plants	125	10	8.0	1232	3
All high-starch tubers	832	17	2.0	1612	4
Best high-starch tubers	23	6	26.1	767	3

In another experiment tubers with smooth shape were selected from field-grown seedlings (18). A correlation coefficient $r = 0.50$ was found between shape of selected tubers and that of their clonal progeny. Tubers with smooth shape usually produced clones with smooth shape (Table 9). A weak positive correlation was also found between smooth tubers and yield. In the same experiment it was demonstrated that individual tubers can be effectively selected for tuber size (18).

TABLE 9. — *Regularity of shape in tubers selected from field-grown seedlings as compared to that of their clonal progeny.*

Tuber shape rating	Number of tubers	Number of progeny clones with shape rating of: 5[1]	6	7	8	9	Mean values
9	13			8	5		7.4
8	30		3	16	10	1	7.3
7	39	1	14	19	5		6.7
6	17	2	20	4	1		6.2

[1] 1 = very poor, 9 = very good

We have recently attempted to select sprouting tubers for earliness. Tubers which produce shoots and roots rapidly tend to produce clones with high early yields and a short vegetative period. A weak positive correlation was also found between early growth and yield in later harvests (22).

It follows that individual tubers may be effectively selected for high starch content, smooth shape, tuber size, and early tuber bulking. Tuber selection makes it possible to handle larger numbers of genotypes and thus, improve chances of selecting desired combinations of characters. Its drawback is that propagation of best clones is delayed since the first clonal generation must be planted from a single tuber and not from the yield of a plant. It is not yet clear to what extent the selection of individual tubers will find application in Polish potato breeding. At present it is used mainly in parental line breeding to select clones outstanding in starch content, supplementing the selection of best plants.

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