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Optimising visual selection in early clonal generations of potato based on genetic and economic considerations

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Summary. In 1985, 1986 and 1987, 600 clones were visually assessed at harvest on plant appearance. The clones were harvested 80 days after planting in the first year, in the following years after approximately 80 days as well as after 145 days. The correlation coefficients between years and between harvest times were low to medium. Simulating different selection intensities using the performance of these 600 clones in two successive years, the relation between selection pressure in the first year and the retained proportion of well performing clones in the second year was described. Including the costs of testing, the most economic selection procedure was calculated. This procedure consisted in testing 1,579 first-year clones and 499 second-year clones for every 100 third-year clones required. The optimal period of the main evaluation in the second clonal year is at ware potato harvest time. This selection procedure also provides good selection possibilities for underwater weight and foliage maturity.

Key words: *Solanum tuberosum* – Genetics – Breeding – Plant appearance – Economy

Introduction

Potato breeders mainly select clones in the first two clonal generations by visual preference and this preference determines whether the plant is selected or not. The visual preference can be compared to a multiple-trait selection, including traits concerning the smoothness, colour and shape of the tubers, tuber yield and number, stolon length and clinging stolons and the foliage type, and will be referred to as 'plant appearance' in this paper. Furthermore, the selection in these generations is rigorous (Neele et al. 1988) and after the second clonal generation only 2% of the initial population is left.

The efficiency of the selection, however, is low (Blomquist and Lauer 1962; Maris 1962, 1966, 1988; Swiezynski 1968; Davies and Johnston 1965, 1968, 1974; Krug et al. 1974; Kameke 1975, 1978; Tai 1975; Anderson and Howard 1981; Brown et al. 1984, 1987; Caligari et al. 1986; Brown and Caligari 1986; Pfeffer et al. 1988; Neele et al. 1988). Despite abundant evidence for low efficiency of rigorous selection on plant appearance, it has not resulted in major changes in the procedures used in potato breeding. The breeders stick to the old method, probably because the economic parameters of alternative selection schemes are unknown. A new scheme must be both genetically and economically attractive, but since the economic advantages of alternatives selection schemes are hardly predictable, breeders are not apt to change to another system. This paper gives estimates of economic and genetic parameters of selection for plant appearance at harvest in the first and second clonal generations.

Materials and methods

In the summers of 1985, 1986 and 1987, 600 clones were assessed visually on their performance at harvest. These 600 clones belonged to 20 hybrid populations, equivalent to those used in commercial breeding. Each population was represented by 30 clones. Alcmaria, a very early maturing cultivar, was used as a standard.

In 1985 the clones were planted on 23 April in a trial near Lelystad, in two plant plots. The limited number of seedling tubers excluded replications. Only 80 days after planting, the plants were evaluated and harvested (11 July), in order to obtain virus-free seeds for the next generation.

The 1986 and 1987 experiments were performed on the same farm as that of 1985, and each clone was represented each year by four plots of two plants. In 1986 the plots were planted on 26 April, two plots were harvested after 74 days and the other two after 142 days. In 1987 planting took place on 21 April and two plots were harvested after 86 and the other two after 145 days.

In all field experiments, plant spacing was 35 cm within and 75 cm between ridges. A split-plot experimental design was used with the harvests as main plots and the populations as subplots. The clones were randomized in the populations.

In the first, second and third clonal generation, plots were assessed at harvest on plant appearance (1 = poor to 9 = excellent) and correlations between all generations were calculated. Furthermore, at the late harvest of the second and third clonal generations, the foliage maturity (1 = green to 9 = dead) and the underwater weight (in grams per 5 kg tubers) were assessed.

For a comparison between first- and second-year clones, first-year clones were simulated by one two-plant plot at early harvest and the second clonal generation by the mean of two two-plant plots at either early or late harvest. Data of single two-plant plots were obtained from the 1985 experiment and from both replications of the early harvests of the experiments in 1986 and 1987. Six comparisons were made between first-year clones and second-year clones both at early harvest, and between first-year clones at early harvest and the second-year clones at late harvest (see also legend Fig. 1).

Correlations were calculated between years and between harvests within years. For the calculations the means of the replications of each clone were used. For the determination of the genetic variance, the year variance, the error variance, and the genotype-year interaction, analyses of variance were performed for the experiments of 1986 and 1987 using the random model.

In the assessment of the economic parameters, special attention was paid to the time involved in activities during the breeding cycle, since labour costs contribute significantly to the costs of a breeding programme. In several large experiments, using either one-plant plots or four-plant plots, the time for each activity was determined over a period of many years by a group of experienced people. For other costs, data of the Dutch Agricultural Economics Research Institute (LEI) and the Netherlands Central Bureau of Statistics (CBS) were used (Anonymous 1988) as well as those of Noordam and Ham (1988). This means that the calculated economic optimal selection scheme reflects the Dutch situation, and should be interpreted as an example. The method, however, can be applied worldwide.

To identify the selection scheme with minimal costs in the first and second clonal generation, economic parameters were combined with the comparisons between plant appearance of first and second year clones.

Assuming that a more or less fixed number of entries are tested in the third clonal generation, the costs of the first and the second clonal generation is described as follows

$$C = c_1 \times N_1 + c_2 \times N_2 \text{ or,}$$
$$C = c_1 \times N_3/F + c_2 \times (S \times N_3/F) \quad (1)$$

where C is the total costs, c_1 the cost of a first-year clone, c_2 the cost of a second-year clone N_1, N_2 and N_3 the number of first-, second- and third-year clones, respectively, S the selection intensity in the first clonal generation, and F the retained fraction of the well-performing second-year clones in the first selection cycle.

Results and discussion

A moderate similarity was found between different years and harvests for plant appearance (Table 1). This agrees with the findings of the authors referred to in the introduction. For the calculation of the correlation coefficients, the means of the replications of each clone were used for the 1986 and 1987 experiments. Therefore, compared to breeding practices of the first field generations, where in general small single-field plots are used, the presented coefficients will be higher and breeders should take into account that relationships between years are weaker.

Table 1. Correlations for plant appearance between and within years and different harvest times

	Early vs. early	Early vs. late	Late vs. early	Late vs. late
Between years				
1985–1986	0.69**	0.54**		
1985–1987	0.66**	0.45**		
1986–1987	0.77**	0.46**	0.66**	0.63**
Within years				
1986		0.66**		
1987		0.61**		

** significant at $P < 0.01$

Correlations within years or between years at the same harvest period were moderate, those between years at different harvest times were weak to moderate. Consequently, the appearance of the plants at early harvest of the first year clones predicts poorly the appearance at maturity in the following generations. Therefore, the mature and immature plant appearance should be used independently in the selection.

Moderate correlations between years at early and at late harvesting can be caused by high environmental variances and/or high genotype-environment interactions. As indicated in Table 2, the genotype-year interaction [YC(P) + YP: 0.26 for the early harvest and 0.24 for the late harvest evaluation] was of minor importance; the environmental variance was about four times as high. Therefore, an improvement in estimating the value of the clones by using more plants per clones improves the correspondence between years. However, it has already been reported earlier that using more than one plant per first-year clone was economically not feasible (Neele et al. 1988). Using two-plant plots instead of one-plant plots resulted only in a minor improvement of the resemblance of the first and the second clonal generation. The heritability for the late harvest was lower than that for the early harvest. Selection for plant appearance at late harvest should, therefore, be carried out with even more caution than at early harvest.

Studying correlation coefficients and heritabilities does not give information on the economically best selection scheme. In such a scheme loss of some potentially valuable material is acceptable if it is compensated for by

Table 2. Analysis of variance for plant appearance of 600 clones at early harvest and at late harvest of 1986 and 1987

Source of variation	abbr.	*df*	Early harvest		Late harvest		Expected mean squares
			SS	MS	SS	MS	
Year	Y	1	388.0	388.03**	2.1	2.11	error + 2 YC(P) + 60 YP + 600 B(Y) + 1,200 Y
Populations	P	19	3,086.8	162.46**	1,141.7	60.09**	error + 2 YC(P) + 4 C(P) + 60 YP + 120 P
Blocks within years	B(Y)	2	45.9	22.97**	4.0	2.02	error + 600 B(Y)
Years × populations	YP	19	79.2	4.17**	56.9	3.00**	error + 2 YC(P) + 60 YP
Clones within populations	C(P)	580	3,423.2	5.90**	2,769.4	4.78**	error + 2 YC(P) + 4 C(P)
Years × clones within populations	YC(P)	580	738.1	1.37**	825.6	1.42**	error + 2 YC(P)
Error	error	1,165	1,117.5	0.96	1,176.7	1.01	error
Mean			4.888		5.441		
Heritability[a]			0.560		0.509		

** significant at $P < 0.01$

Estimated variances: early harvest: error = 0.96; YC(P) = 0.21; C(P) = 1.13; YP = 0.05; B(Y) = 0.37; P = 1.28; Y = 0.30
late harvest: error = 1.01; YC(P) = 0.21; C(P) = 0.84; YP = 0.03; B(Y) = 0; P = 0.45; Y = 0

[a] Heritability = (P + C(P))/(error + YC(P) + C(P) + YP + B(Y) + P + Y)

Table 3. Performance at the early harvest of 1986 (one two-plant plot) and the late harvest of 1987 (mean of two two-plant plots) for the plant appearance character (1 = poor, 9 = excellent)

		Late harvest 1987									
		1	2	3	4	5	6	7	8	9	Total
Early harvest 1986	9	0	0	0	0	1	2	1	1	0	5
	8	0	0	0	0	1	5	2	3	1	12
	7	0	0	0	0	4	13	22	10	2	51
	6	0	0	0	7	16	32	24	11	4	94
	5	0	0	1	18	35	33	36	13	1	137
	4	2	1	4	12	27	22	19	9	0	96
	3	0	1	2	17	18	21	15	2	1	77
	2	0	0	11	20	26	11	4	0	0	72
	1	0	3	5	11	14	8	3	0	0	44
Total		2	5	23	85	142	147	126	49	9	588

a reduction of costs. For determining the optimal scheme, the number of third-year clones is assumed to be fixed, due to the relatively high costs involved in testing these clones. So in the best scheme, from an economic point of view, a fixed number of clones is retained after two selection cycles at the lowest cost.

In the first selection cycle not all potential clones are recognized, as is shown in Table 3. The data given in contingency tables, e.g. Table 3, can be used to optimise the selection in the first and second clonal generation (Simmonds 1985). However, due to the limited number of classes used in the assessment of plant appearance, contingency tables offer a limited number of selection intensities in the first clonal generation. Figure 1 presents the proportion of the selected first-year clones performing well in the second-year clones [F in Eq. (1)] plotted against the selection pressure in the first generation [S in Eq. (1)]. The relation is continuous and deviates from those expected with random selection, y = x line, and those with perfect selection in the first clonal generation, curve P.

The calculated relationship between the evaluation at early harvest of the first clonal generation and the early harvest evaluation in the second-year clones is

$$\ln(1+F) = -1.144 + 1.847/(1 + e^{(-7.147\,(\ln(1+S)+0.0708))}), \qquad (2)$$

that with the late harvest evaluation in the second-year clones is

$$\ln(1+F) = -0.804 + 1.527/(1 + e^{(-5.790\,(\ln(1+S)+0.0220))}). \qquad (3)$$

Equations (2) and (3) describe the observed relationship between the selection intensity at early harvest of the first clonal generation and the retained proportion of the well-performing clones in the second clonal generation at

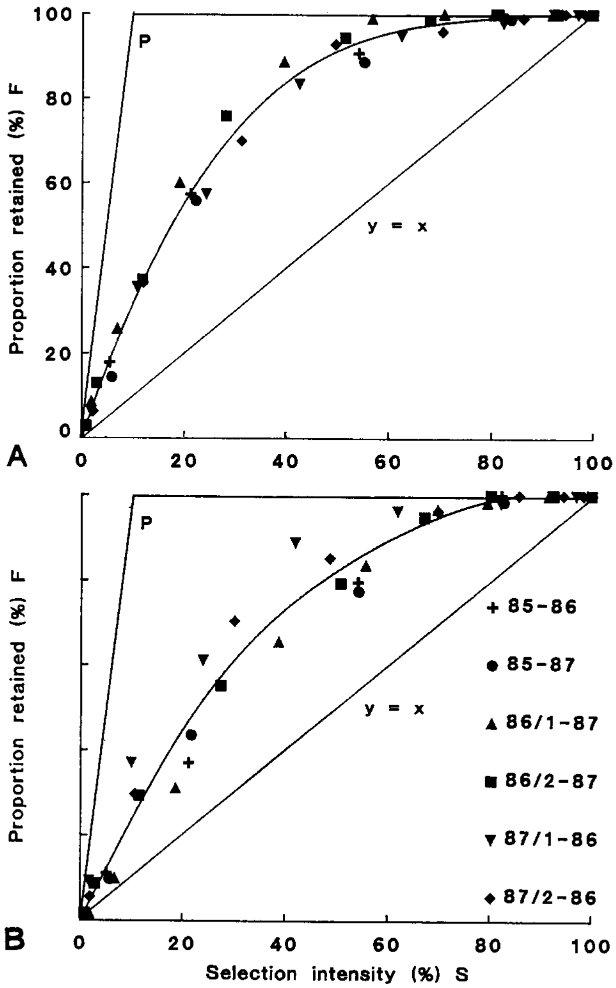

Fig. 1 A and B. The proportion of clones performing well in the second clonal generation (F, $\pm 10\%$ of the population) recognised at different selection intensities in the first clonal generation (S). The first-year clones were represented by the experiment of 1985 and each of the two replicates of the early harvest of the experiments of 1986 or 1987. These were compared with the mean scores of either (**A**) the early or (**B**) the late harvest of the experiments of 1986 or 1987. The x = y-line represents random selection, the P-curve perfect recognition of all well-performing clones in the first clonal generation.

early and at late harvests. These formulas agree with the relationship found by Neele et al. (1988) and those calculated with data of Maris (1962). The retained proportion was higher at early harvest than at late harvest. This means that with selection at late harvest, either more first-year clones are to be grown or the selection must be milder if a breeder wants to have an equal number of third-year clones.

The optimal selection scheme depends not only on the reliability of the assessment, but also on the costs of testing. Costs can be divided into costs that are plot-size independent, such as agricultural maintenance and plant protection, and those that are plot-size dependent, such

Table 4. Costs of experiments in terms of labour time or in Dutch guilders. The costs are divided into plot-size independent (per hectare) and plot-size dependent (per 1,000 clones). The plot-size dependent costs are seperated into costs for growing 1,000 first-year clones in one-plant plots or 1,000 second-year clones in one four-plant plot (only early harvest evaluation) or two four-plant plots (early and late harvest evaluation). The harvest costs are dependent on the selection intensity S of the first clonal generation, the initial and the retained proportion of well-performing clones (I and F). At harvest all tubers were collected and put into nylon bags. Calculation of the total costs per clone was based on an average wage of a field worker of Dfl 26.50 per hour[a]

Plot-size independent (per hectare = 38,000 plants)

Ploughing, harrowing, mauring, etc.			565 min[a]	
Plant protection (including 12 sprays against Phytophthora infestans)			550 min[a]	
Cost of manure	250 kg N	à Dfl 1.20	Dfl	300.–[b]
	120 kg P_2O_5	à Dfl 0.90	Dfl	108.–[b]
	250kg K_2O	à Dfl 0.52	Dfl	130.–[b]
Cost of plant protection chemicals			Dfl	1,168.–[b]
Loss of commercial harvest				
– main product	44,000 kg	à Dfl 0.18	Dfl	7,920.–[b]
– rest	4,000 kg	à Dfl 0.05	Dfl	200.–[b]
Land rent			Dfl	580.–[a]
Total plot-size independent costs				
– per hectare			Dfl	10,900.–
– per plant (15% border plants and paths)			Dfl	0.337

Plot-size dependent (in minutes per 1,000 clones)

	One-plant plot	Four-plant plot
Planting	45	320
Field determinations (3)	540	540
Harvesting		
– Early harvest		
selection-independent	465	1,565
selection-dependent	$585 \times S$	$1{,}985 \times (F \times I)/S$
– Late harvest		
selection-independent	675	2,405
selection-depent	$800 \times S$	$2{,}795 \times (F \times I)/S$
Total plot-size dependent costs per 1,000 clones (Dfl)		
– Early harvest	$464 + 258 \times S$	$1{,}071 + 877 \times (F \times I)/S$
– Early and late harvest	*****	$3{,}151 + 1{,}234 \times (F \times I)/S$

Total costs per 1,000 clones (Dfl)

	One-plant plot	Four-plant plot
– Early harvest	$801 + 258 \times S$	$2{,}419 + 877 \times (F \times I)/S$
– Early and late harvest	*****	$5{,}847 + 1{,}234 \times (F \times I)/S$

[a] Anonymus (1988)
[b] Noordam and Ham (1988)

as time required for planting and harvesting. Table 4 shows labour time and costs of relevant activities.

The main costs of field trials with first- and second-year clones are the loss of commercial harvest and the plot-size dependent costs (Table 4). With respect to the plot-size dependent costs, the costs for planting one seed tuber per clone is considerably less than for planting the same number of seed tubers in four-plant plots. However, harvesting of the four-plant plots is relative to the number of plants, less time consuming, and the relative difference in time exceeds the difference in planting the seed potatoes.

No differences were found in time needed for the field assessments between one- and four-plant plots. The larger plots were found easier to evaluate, compensating for the extra time used for walking along four-plant plots.

For comparing the economics of one-plant plots versus four-plant plots, the total costs for each have been calculated (Table 4). The costs of testing first- and second-year clones depend on the selection intensity in the first clonal generation [S in Eq. (1)], the initial proportion of well-performing clones (I) and the retained proportion of well-performing second-year clones [F in Eq. (1)].

In these populations the proportion of well-performing clones (I) was found to be approximately 10%. Comparable proportions were also found by Maris (1962) and Neele et al. (1988). Brown (1987) found a proportion of 24% of satisfactorily performing clones, having a score over 5 in a 1–9 scale, and 7% of well-performing clones with a score over 6.

Besides I, F and S, three other parameters are important, namely N_3, c_1 and c_2 [Eq. (1)]. The number of third-year clones, N_3, is taken to be fixed; the costs per first- and per second-year clone (c_1 and c_2) are calculated in Table 4. The relations between F and S are described in Eqs. (2) and (3), and by substitution in these formulas and the costs in the cost formula [Eq. (1)], the selection procedure with minimal costs can be calculated.

It is calculated that the most economic selection scheme with selection for plant appearance at early harvest in the first and the second clonal generation is obtained by using a selection intensity (S) of 32.4% in the first-year clones. Thus, the retained proportion of the well-performing second-year clones ($=F$) is 75.8%.

Assuming 10% of well-performing clones in the initial population, the first clonal generation should contain 1,319 [$=100/(0.758 \times 0.10)$] clones, the second clonal generation 427 ($=1{,}319 \times 0.342$) clones to obtain 100 third-year clones. The total number of plants to test is $(1{,}319 \times 1) + (427 \times 4) = 3027$.

For a scheme of visual evaluation at late harvest of the second clonal generation, the most economic selection scheme is obtained by using a selection intensity of 31.6% in the first clonal generation. The retained proportion of potentially well-performing clones at the late harvest is 63.3%. This implies testing 1,579 [$=100/(0.633 \times 0.10)$] first-year clones and 499 ($=1{,}579 \times 0.316$) second-year clones, or $(1{,}579 \times 1) + (499 \times 8) = 5571$ plants, to obtain 100 third-year clones. The number of plants is higher than in the scheme involving early harvest evaluation only. This is because the early harvest performance and the performance at late harvest are less well correlated (Table 1), and the extension of the selection scheme to a late harvest evaluation gives additional information.

The most economical selection scheme uses a selection intensity of 32.4% (early harvest evaluation in the second clonal generation) or 31.6% (late harvest evaluation in the second clonal generation) in the first clonal generation. It is also interesting to know what the effects are of different selection schemes on the costs. Costs and plant numbers for alternative selection schemes are listed in Table 5.

Selection schemes involving selection intensities of 20%–50% in the first clonal generation do not differ much in costs. Therefore, breeders are advised to adjust the selection schemes to a selection intensity in the first clonal generation between 20% and 50%, preferably 32%. Schemes with selection intensities of 10% or less are not recommended, since these are even more costly than the scheme without selection in the first clonal generation.

Effects on other traits

Since selection for plant appearance at early harvest might influence the mean of the foliage maturity and underwater weight of the selected population, a measure of the dry matter content, these characters were determined at late harvest.

For foliage maturity, the correlation coefficient with plant appearance at early harvest was moderate (Table 6). This means that selection for plant appearance will favour early-maturing clones. In fact, selection of the best 10% clones at the early harvest in the first clonal generation and 20% in the second clonal generation results in a population containing mainly very early-maturing clones. The mean score of the selected clones for foliage maturity was 8.6 in 1986 and 7.3 in 1987 (Tabel 7). Since the very early standard variety, Alcmaria, had a mean score for foliage maturity of 8.9 in 1986 and 7.8 in 1987, a large proportion of the selected clones were even earlier than Alcmaria. Rigorous selection at early harvest of both the first and the second clonal generation will result in a relative early-maturing population. A selection intensity of about 35% at early harvest in the first year and 20% in the second year decreased the mean maturity score to 8.3 in 1986 and to 6.3 in 1987. Late harvest

Table 5. Fourteen alternative selection schemes to obtain 100 third-year clones from a population containing 10% well performing clones. For each scheme are listed the selection intensity in the first clonal generation (S), the number of first- and second-year clones (N_1 and N_2), the costs of testing a first- and second-year clone (c_1 and c_2) and the total costs (C).The schemes involve selection in the second clonal generation at either the early harvest or the late harvest

S (%)	c_1	Selection in second clonal generation at							
		early harvest				late harvest			
		N_1	c_2	N_2	C (Dfl)	N_1	c_2	N_2	C (Dfl)
1	0.803	25,258	2.766	253	20,989	32,925	6.222	329	28,498
2.5	0.807	11,562	2.722	289	10,120	15,613	6.164	390	15,009
5	0.814	6,102	2.706	305	5,790	8,296	6.145	415	9,299
10	0.827	3,209	2.692	321	3,517	4,296	6.135	430	6,187
15	0.840	2,252	2.679	338	2,796	2,937	6.127	441	5,165
20	0.852	1,794	2.663	359	2,485	2,271	6.119	454	4,715
30	0.878	1,374	2.632	412	2,292	1,639	6.098	492	4,439
40	0.904	1,196	2.603	478	2,326	1,355	6.075	542	4,518
50	0.930	1,107	2.577	554	2,456	1,204	6.052	602	4,765
60	0.957	1,059	2.557	635	2,636	1,117	6.032	670	5,109
70	0.982	1,031	2.541	721	2,844	1,063	6.013	744	5,517
80	1.007	1,013	2.527	811	3,070	1,028	5.997	822	5,967
90	1.033	1,003	2.516	903	3,307	1,004	5.984	904	6,447
100	1.059	1,000	2.507	1,000	3,566	1,000	5.972	1,000	7,033

Table 6. Phenotypic correlation coefficients between plant appearance of the 600 clones at either the early or the late harvest and foliage maturity and underwater weight of tubers, both at the late harvest

Correlated characters	Early harvest		Late harvest	
	1986	1987	1986	1987
Plant appearance				
– foliage maturity	0.69	0.40	0.38	−0.05
– underwater weight	−0.41	−0.37	−0.28	−0.10

Table 7. Effects of selection for plant appearance on the mean scores of the selected clones for maturity and for underwater weight. For the schemes including early harvest evaluation (e) only, the proportion of clones having a plant appearance score over 7 at late harvest is listed. In the scheme marked with (l), late harvest evaluation is included

	Unselected population	Mean of the population after application of the selection scheme (proportion selected first/second year)		
		10%/ 20% (e)	35%/ 20% (e)	35%/ 20% (l)
1986				
Maturity	5.9	8.6	8.3	7.4
Underwater weight	493	420	450	469
Plant appearance late	21.7%	65%	63%	100%
1987				
Maturity	4.6	7.3	6.3	5.2
Underwater weight	402	337	370	392
Plant appearance late	18.9%	55%	48%	100%

evaluation of plant appearance in the second clonal year resulted in a mean maturity of the selected clones of 7.4 in 1986 and 5.2 in 1987. Very early clones were not retained by the latter selection. This shows that high selection pressure at early harvest is not only economically sub-optimal, but also induces a shift of the mean maturity of the selected clones. With milder selection, more clones in later maturity classes are retained.

For underwater weight the situation is less critical, as can be concluded from the lower correlation coefficients (Table 6). However, mainly clones with low underwater weight were selected if selection was rigorous in both clonal generations (Table 7). In the starch, French fries or chips industry a minimum level of the dry matter content is required. So if the major part of the selected population has a low dry matter content, many clones will not be suitable for industrial processing and this will reduce the agronomical value of the breeding material. If a higher proportion is selected, the population mean of underwater weight is higher. This is especially so if the selection is done at the late harvest.

Late harvest evaluation in the second clonal generation does not only improve the total level of the underwater weight and maintain the variation in maturity, but also all clones have a satisfactory plant appearance at late harvest. In selection at early harvest, only 50%–65% of the retained population will perform satisfactorily as ware potato. This means that the number of entries in the third field-year must be 1.5–2 times larger than if the main determination occurs at late harvest in the second clonal generation.

Increasing the number of third-year clones also implies testing of more first- and second-year clones. This will lead to an increase in costs, compared to a scheme including late harvest evaluation. The higher costs of evaluating the second clonal generation at early and at late harvest will be compensated for by a reduced number of entries at the first, second and third clonal generation. For obtaining 100 third-year clones in a scheme including late harvest evaluation, 1,579 first-year clones have to be tested and 499 second-year clones, as mentioned earlier. Total costs are Dfl 4,435 (calculated from data in Table 4). To obtain the same number of third-year clones using a scheme with early harvest evaluation only, 1,319 first-year clones and 427 second-year clones must be evaluated. Costs for the first two years are Dfl 2,287. This figure must be multiplied by 1.5–2 to obtain an equal number of well-performing third-year clones at late harvest. For the costs of the first two field generations, this will be within the range of Dfl 3,430.50 to Dfl 4,574, equaling the costs of a scheme including late harvest evaluation. However, in the latter scheme the number of the third-year clones is lower and so are the costs of tests. Therefore, a scheme including late harvest evaluation will be more economical.

Conclusions

The commonly used selection scheme with severe visual selection on plant appearance in the first clonal generation and somewhat milder selection in the second is not optimal. To obtain a certain number of third-year clones, the most economic selection procedure is to apply a selection intensity of about 32%. This selection intensity is almost equal to that suggested by Maris (1988). He suggested a selection intensity of 40% for the first clonal generation, but did not support it by economic data. A favourable aspect of milder selection is that later maturing clones with high underwater weight are being retained.

It should be considered that the suggested selection intensity is based on Dutch economic parameters and these parameters differ from those of other countries. However, the approach used in this study can be applied worldwide, and by substituting local economic parameters in the model, the economic optimal selection procedure can be adjusted. Furthermore, breeders are advised to include late harvest evaluation on plant appearance in the second clonal generation, since in such a scheme selection can be applied at the lowest relative costs.

References

Anderson JAD, Howard HW (1981) Effectiveness of selection in the early stages of potato breeding programmes. Pot Res 24:289–299

Anonymous (1988) Agricultural data 1988. The Agricultural Economics Research Institute (LEI) and the Netherlands Central Bureau of Statistics (CBS), The Hague and Voorburg

Blomquist AW, Lauer FI (1962) First clonal generation potato progeny performance at two Minnesota locations. Am Potato J 39:460–463

Brown J (1987) A comparison between single plant plots and five plant plots for the initial selection stage of a potato breeding programme. Euphytica 36:711–718

Brown J, Caligari PDS (1986) The efficiency of seedling selection for yield and yield components in a potato breeding programme. Z Pflanzenzuecht 96:53–62

Brown J, Caligari PDS, Mackay GR, Swan GEL (1984) The efficiency of seedling selection by visual preference in a potato breeding programme. J Agric Sci 103:339–346

Brown J, Caligari PDS, Mackay GR, Swan GEL (1987) The efficiency of visual selection in early generations of a potato breeding programma. Ann Appl Biol 110:357–363

Caligari PDS, Brown J, Abbot RJ (1986) Selection for yield and yield components in the early generations of a breeding programme. Theor Appl Genet 73:218–222

Davies HT, Johnston GR (1965) First clonal generation potato seedling generation selection at two locations. Am Potato J 42:186–189

Davies HT, Johnston GR (1968) Second clonal generation potato seedling selection at two locations. Am Potato J 45:150–153

Davies HT, Johnston GR (1974) Reliability of potato selection in the first clonal generation. Am Potato J 51:8–11

Kameke K von (1975) Untersuchungen zur quantitativen Variabilität in Kreuzungsnachkommenschaften der Kartoffel. Hefte für den Kartoffelbau 19, Hohenheim

Kameke K von (1978) Untersuchungen zur Erblichkeit einiger Merkmale bei der Kartoffel. Der Kartoffelbau 5:172–173

Krug H, Wriedt G, Weber WE (1974) Untersuchungen zur Frühselektion in der Kartoffelzüchtung. II Merkmalsbeziehungen zwischen den Generationen und innerhalb der Klonengenerationen. Z Pflanzenzuecht 73:141–162

Maris B (1962) Analyse van aardappelpopulaties ten dienste van de veredeling. PhD Dissertation, Pudoc, Wageningen

Maris B (1966) The modifiability of characters important in potato breeding. Euphytica 15:18–31

Maris B (1988) Correlations within and between characters between and within generations as a measure for the early generation selection in potato breeding. Euphytica 37:205–224

Neele AEF, Barten JHM, Louwes KM (1988) Effects of plot size and selection intensity on efficiency of selection in the first clonal generation of potato. Euphytica S:27–35

Noordam WP, Ham M van der (1988) Kwantitatieve informatie voor de akkerbouw en de groenteteelt in de volle grond. Bedrijfssynthese 1988–1989. PAGV, Lelystad

Pfeffer Ch, Möller K-H, Scholz M, Zschüttig H-G (1988) Die Zuverlässigkeit der visuellen Selektion in der ersten Klongeneration von Kartoffeln. Pot Res 31:7–24

Simmonds NW (1985) Two-stage selection strategy in plant breeding. Heredity 55:393–399

Swiezynski KM (1968) Field production of first year potato seedlings in the breeding of early varieties. Eur Potato J 11:141–149

Tai GCC (1975) Effectiveness of visual selection for early clonal generation seedlings of potato. Crop Sci 15:15–18