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Variation in the duration of tuber dormancy within a seed potato lot

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Summary

The variation in duration of dormancy within a seed tuber lot was studied over three years by harvesting individual plants of cvs Diamant and Désirée from field plots and by storing the tubers at 18 °C. The variation in dormancy within a tuber lot was large (especially for cv. Diamant) and was mainly caused by variation within plants.

For cv. Diamant there was a close negative relation between dormancy and the cube root of tuber weight, whereas for cv. Désirée a relation with tuber weight was almost absent.

The duration of dormancy of a seed lot comprising tubers with a narrow range in weight can be well described by two parameters. It is proposed to maintain the moment of 80% sprouting as the criterion for the end of dormancy of a tuber lot and to characterize the spread in dormancy duration by the time lapse between 10% and 90% sprouting.

Introduction

Dormancy of tubers of potato (*Solanum tuberosum* L.) varies among genotypes. Within a genotype, the duration of dormancy may vary between tuber lots of different origin or year. It may also vary within a seed lot of one cultivar from a particular origin and year. This latter variation is of both scientific and practical interest, but there are hardly any data on it. Emilsson (1949) reported that the range in duration of dormancy of individual tubers (50 – 90 g) within a sample of ten tubers could vary from 1 to 8 weeks in extreme cases. Krijthe (1962a) found that the variation within a tuber sample was larger for small tubers than for large tubers. The time lapse between 50% and 90% sprouting at 15 – 20 °C was about 15 – 20 days for cv. Bintje (40 – 45 mm).

One of the causes of variation in dormancy within a seed lot may be difference in tuber size. Emilsson (1949) and Krijthe (1962a,b) found that the duration of dormancy of 40 – 50 mm tubers was about 4 weeks shorter than that of 28 – 35 mm tubers. Reust (1982) also found that large tubers usually had a shorter dormancy than small tubers, but that with some cultivars or sources the difference in dormancy between the tuber sizes was not significant.

The EAPR definition for the end of the dormancy period of a tuber lot is the moment when 80% of the tubers have formed sprouts (Reust, 1986). This characterization of the duration of dormancy is rather incomplete. For a better characterization, more information is necessary on the probability distribution of the duration of dormancy of individual tubers.

In this paper, the variation in duration of dormancy within a seed tuber lot is analysed for two cultivars differing in length of dormancy by quantifying the variation between and within plants. The relation between the duration of dormancy and tuber weight is described, and a way of characterizing the duration of dormancy of a tuber sample is proposed.

Materials and methods

Three experiments (Expts 1 – 3) were carried out on sandy soils near Wageningen (52 °N lat.) during the years 1988 – 90. Individual plants of cvs Diamant (short dormancy period) and Désirée (long dormancy period) were harvested. Presprouted basic-seed was used; in Expt 1, 80 g tubers with multiple sprouts were planted, whereas in Expts 2 and 3 small (25 or 20 g) and single-sprouted tubers were used. Before haulm removal, the number of stems per plant was recorded. The haulms were removed (by cutting or pulling) at a time depending on aphid pressure and tuber size. Care was taken to collect all tubers of an individual plant. Detailed information is given in Table 1.

After harvest, each tuber was weighed and then stored in a dark chamber at 18 °C and 80% RH to assess the duration of dormancy. Dormancy was defined as having ended when a tuber had at least one sprout 2 mm long. The number of sprouted

Table 1. Details of the experiments with individually harvested plants.

	Expt 1	Expt 2	Expt 3
Year	1988	1989	1990
Seed tuber weight (g)	80	25	20
Planting date	April 18	April 20	April 19
Plant spacing (cm)	25×75	25×75	18×75
Nitrogen application (kg N/ha)	140	175	150
Number of stems per m^2			
cv. Diamant	18.5	5.3	7.4
cv. Désiree	11.9	5.3	7.4
Tuber initiation (DAP[a])			
cv. Diamant	45	48	46
cv. Désiree	39	38	34
Haulm removal (DAP[a])	93	93	78
Harvest (DAP[a])	115	107	99
Number of harvested plants per cultivar	26	30	33
Total number of tubers per lot			
cv. Diamant	324	194	198
cv. Désirée	244	140	206
s.d.[b] tuber weight within tuber lot (g)			
cv. Diamant	40	49	43
cv. Désirée	49	65	47
Mean duration of dormancy (DAH[a])			
cv. Diamant	80	72	110
cv. Désirée	139	130	156

[a] DAP = days after planting; DAH = days after haulm removal.

[b] s.d. = standard deviation.

tubers was counted at least three times a week. The duration of dormancy of a tuber was defined as the period between haulm removal and the end of dormancy (for further definitions and details on the way of storage, see Van Ittersum, 1992).

For each experiment and cultivar, all tubers of all harvested plants were considered to be one tuber lot. Possible differences in the duration of dormancy between plants within the lots were tested statistically by means of an analysis of variance with plant (on which a tuber grew) as a random factor (analysis of components of variance; Snedecor & Cochran, 1980). The relation between duration of dormancy and tuber weight was analysed by means of regression analysis. The proportion of variance accounted for by the model is given by the adjusted R^2 statistic (Snedecor & Cochran, 1980) based on mean squares: $R^2_{adj} = 100 \times [1 - (\text{Residual mean square/Total mean square})]$.

The frequency distribution of the duration of dormancy of tubers with a narrow range in weight was tested for skewness by calculating the coefficients of skewness (Snedecor & Cochran, 1980) for many tuber samples of cvs Diamant and Désirée. These samples consisted of seven weight classes (0 – 5, 5 – 20, 20 – 40, 40 – 60, 60 – 80, 80 – 100 and 100 – 120 g) of tubers from Expts 1 – 3. Moreover, analyses were carried out on 100 samples comprising 30 healthy and undamaged tubers of 50 – 90 g each, stored at 18 °C and grown on field plots in 1989 (haulm pulling and harvest: 91 and 111 days after planting, respectively). Subsequently, the cumulative percentage with time of sprouted tubers of each of the samples was analysed with a probit regression analysis. It is not possible to give a measure (mean scaled deviance; McCullagh & Nelder, 1989) for the goodness-of-fit of these analyses since the data of a sample concerning the cumulative number of sprouted tubers with time were not mutually independent. Therefore, the goodness-of-fit was assessed by eye.

The statistical analyses were performed with Genstat 5, Release 2.1 (Genstat 5 Committee, 1987).

Results and discussion

Variation between and within plants. The variance of the duration of dormancy within the three tuber lots of cv. Diamant amounted to 239 – 485 days^2 (Table 2). This variance can be split into two components: the variance between plants and the variance within plants. The latter was the most important one: 86% or more of the variation within a lot was accounted for by the variation within plants. Nevertheless, the variation caused by differences between plants was statistically significant for cv. Diamant in all experiments. The range in duration of dormancy within a single plant was 38 – 51 days on average in the three experiments. There was no clear relation between the variation in duration of dormancy and the mean duration of dormancy of a tuber lot.

For cv. Désirée, the variance of the duration of dormancy within a tuber lot amounted to 82 – 104 days^2, which was much less than that of cv. Diamant. Again, more than 84% of this variation was accounted for by the variation within plants. The variation between plants was statistically significant only in Expt 1. The range in duration of dormancy within a single plant amounted to 19 – 24 days on average in the three experiments.

These results imply that the variation of duration of dormancy within a tuber lot is large, but cultivar dependent. Most of the variation within a lot is caused by variation within a plant and much less by differences between plants.

Table 2. Variation in the duration of dormancy within a tuber lot of individually harvested plants, Expts 1-3.

Parameters on duration of dormancy	Experiment		
	1	2	3
cv. Diamant			
Total variance within a tuber lot ($days^2$)	239	485	313
Component of variance between plants ($days^2$)	14**	71**	40**
Component of variance within plants ($days^2$)	225	418	276
Variation in tuber lot accounted for by plants (%)	6	14	12
Average range within a single plant (days)	47	51	38
cv. Désirée			
Total variance within a tuber lot ($days^2$)	82	97	104
Component of variance between plants ($days^2$)	13***	10	3
Component of variance within plants ($days^2$)	69	88	101
Variation in tuber lot accounted for by plants (%)	16	9	3
Average range within a single plant (days)	24	19	21

, * Indicate that the component of variance between plants differs statistically from zero at $P<0.01$ and $P<0.001$, respectively.

Relation to tuber weight. For cv. Diamant, tuber weight and duration of dormancy were closely related (Fig. 1). The heavier the tubers the shorter the dormancy. The relation was not linear, since for small tubers dormancy was shortened more with increasing tuber weight than it was for larger tubers. Of all simple terms of tuber weight, the cube root gave the best relation to the duration of dormancy for all experiments (Table 3). The percentage of variance accounted for by these models varied from 39% to 72%. The difference in mean duration of dormancy between small tubers (ca 10 g) and heavier tubers (ca 150 g) was about 37 days on average. The difference between two more practical weights for seed tubers, 50 g and 100 g, was about 11 days on average.

For cv. Diamant, the variation in individual tuber weights within the seed lot was lowest in Expt 1 and highest in Expt 2 (Table 1). In Expt 1, the stem density was much higher than in the other experiments (Table 1) because much heavier seed tubers with multiple sprouts were used. Consequently, the number of tubers per m^2 was also

Table 3. The relation between the duration of dormancy and tuber weight for cv. Diamant in three experiments (see also Fig. 1).

Experiment	Regression equation[a]	R^2_{adj} (%)	F-value[b]
1	$D = 109 - 8.7TW^{0.33}$	39.2	209***
2	$D = 127 - 14.0TW^{0.33}$	41.3	141***
3	$D = 156 - 12.8TW^{0.33}$	72.0	504***

[a] D = duration of dormancy (days after haulm removal); TW = tuber weight (g).
[b] F-value of regression.
***Indicates significance at $P<0.001$.

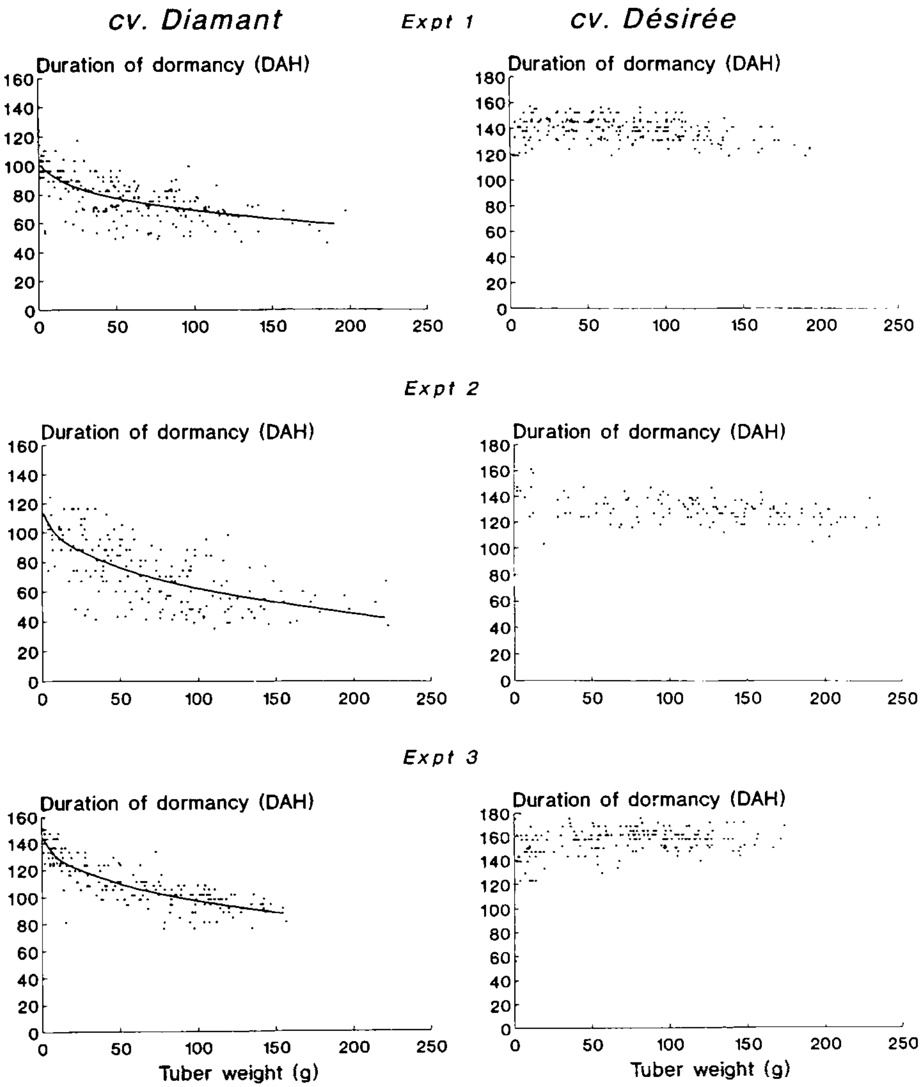

Fig. 1. Relation between the duration of dormancy (DAH = days after haulm removal) and tuber weight, for cvs Diamant and Désirée in Expts 1 – 3. Curves were fitted by means of regression analysis. For regression equations see Table 3.

highest in Expt 1. MacKerron et al. (1988) showed that there is a negative correlation between the relative variability in individual tuber weight and the number of tubers per unit area. Because of the relation between dormancy and tuber weight for cv. Diamant, the variance in duration of dormancy within the seed lot was also lower in Expt 1 than in Expt 2 (Table 2).

For cv. Désirée, the duration of dormancy hardly changed with a change in tuber weight (Fig. 1), though the relation between both variables was significant because of the high numbers of tubers in the analyses. The percentage of variance accounted for by the models was only 7 – 15 %, and the relation also varied slightly between the experiments. In Expt 2, there was a significant trend for dormancy of the heaviest tubers to be slightly shorter than that of lighter tubers ($R^2_{adj} = 15\%$), but in Expts 1 and 3, dormancy of very small tubers was sometimes even shorter than that of heavier tubers.

The relation between the duration of dormancy and tuber weight appears to be cultivar dependent. Several researchers have found that dormancy was shorter for large tubers than for smaller ones (Emilsson, 1949; Krijthe, 1962b; Abeygunawardena et al., 1964; Reust, 1982), but they compared only two practical seed sizes (ca 40 – 50 vs 28 – 35 mm). Even for cv. Désirée, dormancy of large tubers tended to be shorter than that of small tubers in Expts 1 and 2 (Fig. 1). Lommen & Struik (1990) compared different weights of minitubers and also found a shorter dormancy for the heavier tubers. The current results and the data in the literature indicate that for most cultivars the duration of dormancy (expressed in days after haulm removal or harvest) decreases with increasing tuber weight, but the magnitude of the decrease is cultivar dependent and probably there are cultivars that show hardly any relation between dormancy and tuber weight.

Since dormancy is defined as ending when the tuber has formed a sprout of at least 2 mm long (some researchers use 3 mm), differences in dormancy defined in this way may partly be differences in the rate of initial sprout growth. Krijthe (1962b) observed that small and large tubers of cv. Bintje started their sprout growth at about the same time, but the rate of sprout growth of the large tubers was higher, leading to differences of several weeks to the time when a sprout of 3 mm (her criterion for the end of dormancy) was formed. However, my results with cv. Diamant (Van Ittersum et al., 1992) did not support this observation. The rate of sprout growth up to 2 mm hardly differed between tubers of 25 g and tubers of 80 g, but the moment when sprouting started did differ. Therefore, it can be assumed that for cv. Diamant, dormancy (expressed in days after haulm removal) of heavy tubers ends earlier than that of lighter tubers.

The relation between the duration of dormancy (in days after haulm removal) and the cube root of tuber weight for cv. Diamant is descriptive and not necessarily causal. Tuber weight may be related to other tuber characteristics. For example, the smallest tubers may have been initiated later than larger tubers, although not necessarily so (Struik et al., 1991). Therefore, the relation between the duration of dormancy and tuber weight could be different when the duration of dormancy is expressed in days after tuber initiation of the individual tubers (not recorded in the current experiments). However, it is unlikely that differences in date of initiation were so large that the relation between dormancy and tuber weight would disappear (cf. Van Ittersum & Struik, 1992).

A high variation in duration of dormancy is relevant when tubers are planted soon after harvest, since it may cause an irregular emergence. Cultivar Diamant showed a much larger variation in duration of dormancy within a tuber lot than did cv. Désirée. However, a large part of the variation of cv. Diamant is accounted for by tuber weight and this characteristic of tubers is very easy to select for.

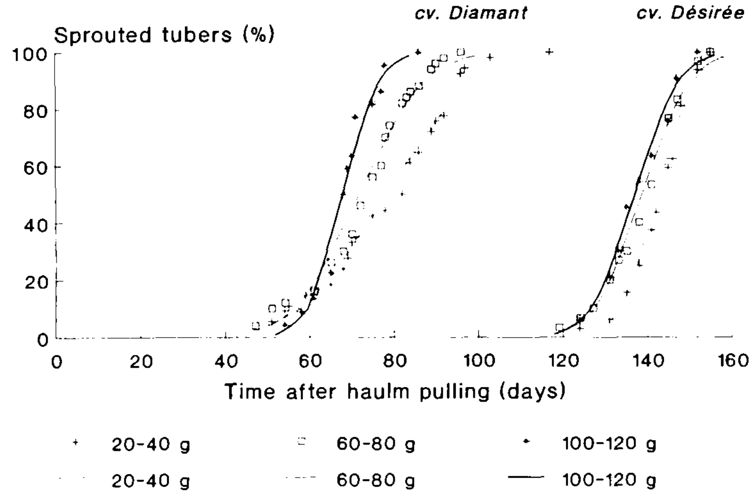

Fig. 2. The cumulative percentage of sprouted tubers in time for different tuber weight classes of cvs Diamant and Désirée in Expt 1. The curves were fitted by means of probit regression analysis.

Characterization of the duration of dormancy of a tuber lot. Since dormancy in cv. Diamant was closely related to the tuber weight, the frequency distribution of the duration of dormancy of individual tubers of a seed lot was highly dependent on its tuber-size distribution. Therefore, the frequency distribution was analysed only on tuber samples with a narrow range in individual tuber weight.

For cv. Diamant, the coefficient of skewness was significant ($P<0.05$) only for the lowest weight classes (0 – 5 and 5 – 20 g) of Expt 1 and for the weight class 5 – 20 g of Expt 3. For cv. Désirée, the skewness was significant for the weight class 60 – 80 g of Expt 3. In all these cases, the skewness was negative and caused by one to three relatively early sprouting tubers.

The general absence of skewness in the frequency distribution of the duration of dormancy of individual tubers of a seed lot was confirmed in the analyses of samples of cvs Diamant and Désirée from the field plots of 1989.

The percentage of sprouted tubers in time was described well by a cumulative normal distribution for most of the samples, although the fit was poorer for those samples with a significant skewness. As an illustration, the data and the fitted probit curves for some weight classes of both cultivars in Expt 1 are given in Fig. 2. One of the causes of the (small) deviations from normality is that the ranges in weight of the classes/samples are still too large.

From the foregoing, it may be concluded that the duration of dormancy of a tuber lot is well characterized by only two parameters, the mean and the standard deviation. In case of a normal distribution, the mean equals the median and therefore the mean duration of dormancy equals the moment at which 50% of the tubers has ended dormancy. The EAPR (Reust, 1986) defined the end of dormancy of a sample as the moment at which 80% of the tubers has sprouted (which equals the mean duration of dormancy $+0.84\sigma$, if the duration of dormancy of individual tubers is normally distributed). Instead of the standard deviation, the time lapse between 10% and 90% sprouting (which equals 2.56σ, with a normal distribution) is proposed as a practical measure for the spread in duration of dormancy within a sample or lot. Thus dormancy of a tuber sample or lot can be characterized by its duration/end (EAPR definition: 80% sprouting) and its spread (time lapse between 10% and 90% sprouting).

Several workers used probit analysis to estimate the moment of 80% sprouting (e.g. Cho et al., 1983; Saunders & Hutchinson, 1984). This seems to be justified for many samples with a narrow range in weight, but there might be some systematic skewness or other deviations from normality for the frequency distribution of the duration of dormancy of tubers stored at fluctuating temperatures (e.g. with cold or hot pre-treatments) or treated with dormancy breaking chemicals causing a final sprouting percentage lower than 100% (data not shown). In these cases more than two parameters are necessary to account for attributes such as the skewness or the lower ultimate sprouting percentage. Brown & Mayer (1988a,b) discussed several models with one to four parameters describing the cumulative germination of non-dormant true seeds of *Aristida armata*. Their conclusion was that the Weibull function was the most suitable function for describing cumulative germination, because it provided a consistently close fit to the data, as it did in cases with an asymmetric germination curve and for samples not achieving 100% germination.

Conclusions

(1) The duration of dormancy varies greatly within a seed tuber lot, but this variation is cultivar dependent.

(2) Most of this variation is caused by variation in duration of dormancy within plants.

(3) The relation between the duration of dormancy and tuber weight is cultivar dependent. For cv. Diamant, there was a good negative relation to the cube root of tuber weight, but for cv. Désirée a relation was not clear.

(4) The duration of dormancy of a tuber lot can be described well by two parameters, provided that the tubers have a narrow range in weight.

(5) The moment of 80% sprouting can be maintained as a parameter to characterize the end of dormancy, although the moment of 50% sprouting would be more logical. The time lapse between 10% and 90% sprouting is proposed as a spread parameter for the duration of dormancy of a tuber lot.

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