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Advancing growth vigour of seed potatoes by storage temperature regimes

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Abstract

The advancing effect of four storage temperature regimes on the growth vigour of seed potatoes harvested immature was investigated in one field experiment and two glasshouse experiments, using up to 9 cultivars. The storage regimes were: 18 °C; 28 °C; 20 days at 28 °C and subsequently 18 °C (hot pre-treatment); and 20 days at 2 °C and subsequently 18 °C (cold pre-treatment). In all cultivars except one, tubers stored at 28 °C were superior in growth vigour at early plantings (≤ 120 days after haulm removal=DAH) to those stored at the other temperature regimes. The growth vigour was also advanced by a hot pre-treatment and a cold pre-treatment. Growth vigour was least with storage at 18 °C. At later plantings (up to 180 DAH), the differences between the regimes diminished. There is much potential for using high storage temperatures to advance the emergence and to improve the initial crop growth of seed tubers that have to be planted soon after their harvest. This will result in higher tuber yields in regions with a relatively short growing period, especially for cultivars with an intermediate or long dormancy period.

Keywords: ageing, cultivar, dormancy, growth vigour, physiological age, potato, seed tuber, *Solanum tuberosum* L., sprouting, storage temperature

Introduction

In many areas in the world, potatoes are grown more than once a year. In these areas, locally grown or imported seed tubers often have to be planted soon after their harvest. This gives rise to a considerably delayed and irregular emergence and poor initial growth, because at planting the tubers are still in the phase of dormancy or poor growth vigour (Pushkarnath, 1976).

Dormancy can be curtailed by means of dormancy-breaking chemicals, but the most effective ones are very dangerous to use (Burton, 1989; Allen et al., 1992). In a previous paper (Van Ittersum & Scholte, 1992) it was shown that, compared with storage at 18 °C, dormancy can be shortened greatly by storage at other temperatures.

especially higher ones. Dormancy was defined as having ended when a tuber had at least one sprout 2 mm long. The effects of the temperature regimes on dormancy depended on the cultivar, but they were related to the duration of dormancy of a cultivar at 18 °C. Storage at 28 °C slightly prolonged dormancy of cultivars with a very short dormancy period but shortened that of cultivars with a long dormancy by up to 7 weeks. A hot pre-treatment (20 days at 28 °C, followed by storage at 18 °C) shortened dormancy by 2-3 weeks on average for all cultivars investigated. Storage with a cold pre-treatment (20 days at 2 °C, followed by storage at 18 °C) shortened dormancy by 2 weeks on average in some cultivars with a short dormancy and in all cultivars with a long dormancy.

After the end of dormancy, the change in physiological properties of a tuber with time is reflected in a changing sprouting behaviour. Since the real time scale of changes in the sprouting behaviour differs between cultivars and is influenced by storage conditions (Krijthe, 1962; Van der Zaag & Van Loon, 1987), the term 'physiological age' of tubers is commonly used (Reust, 1986). The physiological age of a tuber is reflected in its growth vigour after planting, which is the potential to produce a well-developed plant within a relatively short period of time. The growth vigour of seed tubers increases initially upon termination of dormancy and levels out at a maximum (Van der Zaag & Van Loon, 1987). When the tubers become physiologically relatively old, the growth vigour gradually declines again and ultimately this leads to the loss of the ability to produce new plants. The effect of the physiological age of seed tubers on crop growth is particularly clear in the first phases of plant growth; thereafter, the influence of the environmental conditions becomes dominant.

In the current research it was investigated whether the regimes which were found to be effective in curtailing the dormancy period, were also effective in inducing a high growth vigour when seed tubers were planted soon after their harvest.

Materials and methods

General procedure

One field experiment in Israel (Experiment 1) and two glasshouse experiments in Wageningen (Experiments 2 and 3) were carried out. All experiments were conducted with tubers produced in the East Flevoland polder (52 °N). The tubers were harvested while immature (the haulms were removed at a date between 70 and 90 days after planting depending on tuber size, aphid pressure and maturity class of the cultivar), and were stored at different temperature regimes in the dark in controlled environments with 80 % RH. Dormancy and growth vigour were assessed on tuber samples with a limited range in individual tuber weight and chosen so that the range in the total weight of individual samples did not exceed 1.5 % within a cultivar.

The end of dormancy of a tuber sample was defined as the time when 80 % of the tubers showed at least one sprout 2 mm long. Data from Experiments 2 and 3 concerning the duration of dormancy were presented in a previous paper (Van Ittersum & Scholte, 1992: Experiments 3 and 4).

Experiment 1

The origin and treatment of the tubers of cvs Diamant and Désirée until the start of storage were similar to those described earlier (Van Ittersum & Scholte, 1992: Experiment 1). The haulm of the seed crop was removed on 10 July 1989 (68 days after planting) and tubers were harvested 7 August (=28 days after haulm removal, 28 DAH). At 31 DAH, four storage temperature regimes were started: 18 °C (T18); 28 °C (T28); 20 days at 28 °C, and subsequently 18 °C (T28/18); and 20 days at 2 °C, and subsequently 18 °C (T2/18). Four samples (24 tubers of 30-50 g each) per treatment were used. At 79 DAH the T28 samples were transferred to 18 °C. At 87 DAH all tubers were desprouted (if sprouts were present), packed and then, 5 days later, they were transported to Israel by air. Between desprouting and planting, the tubers were exposed to temperatures between 18 and 22 °C.

At 106 DAH (24 October 1989) the samples were planted in the Negev (31 °N) on a poor sandy soil with 0.5 % organic matter. The experimental design was split-plot, with four blocks, cultivars as the main factor and storage temperature regimes as the split factor. Twenty-four tubers per plot were planted by hand, in a 20×92 cm arrangement. The plots were irrigated every 4-5 days with a total amount of 300 mm until haulm killing. Nitrogen was supplied in the irrigation water, to a total of 315 kg N/ha. The potatoes received the usual farm practice. At 93 days after planting (DAP), the haulm was killed at an immature stage by a night frost. The experiment was harvested 125 DAP.

The start of emergence (i.e. the moment when the first green plant parts became visible) of each plot was recorded. At 43, 54 and 68 DAP, the number of plants and the number of stems per plant was determined and a visual crop stand score was given. The score (0-10) represented the relative haulm development (0=no emerged plants, 10=best plot per cultivar and block). At harvest, total tuber fresh yields were determined, tubers were counted and they were graded (< 35 mm, 35-60 mm, > 60 mm, and misshapen tubers).

Experiment 2

Experiment 2 was a pilot experiment for Experiment 3. The haulm of the seed crop was removed on 11 July (69 days after planting; cvs Draga and Jaerla) or 17 July 1989 (75 days after planting; cvs Désirée and Diamant). The tubers for the experiment were harvested on 4 August. For all cultivars, the growth vigour of seed tubers following four temperature regimes was compared: 18 °C constant (T18); 28 °C constant (T28); 20 days at 2 °C and subsequently 18 °C (T2/18); and 10 days at 0 °C, 10 days at 28 °C and subsequently 18 °C (T0/28/18). Three samples (six 40-80 g tubers each) per treatment were used.

The assessment of the growth vigour started at the same date for all treatments of the same cultivar, i.e. once all T18-samples of that cultivar showed at least 90 % sprouting. Therefore, for most cultivars the planting dates for the tests were rather late compared with those in Experiments 1 and 3, i.e.: 23 October 1989 (98 DAH – cv. Diamant), 29 November (141 DAH – cv. Jaerla), 22 December (158 DAH – cv.

Désirée) and 8 January 1990 (181 DAH – cv. Draga). For each cultivar, a randomized complete block design with three blocks was used. Twelve days before the planting of a test, the tubers were desprouted and pre-sprouted again in darkness, at 18 °C and 80 % RH. Tubers were planted in a plastic tray (L×B×H=30×23×10 cm) filled with enriched peat soil. Trays were placed in a glasshouse at 18/12 °C day and night temperatures with a 12 h day; artificial light (35 W/m^2; 400-700 nm) was given in addition to daylight for the whole day period. The test ended 28 DAP (cvs Diamant and Jaerla) or 35 DAP (cvs Désirée and Draga).

At harvest, the number of plants (i.e. seed tubers that produced green plant parts) and the number of main stems was recorded. The haulm was cut at soil level and weighed both fresh and dry. The number of stems was expressed per plant and the haulm weight was expressed per planted tuber.

Experiment 3

Three groups of three cultivars each were used in this experiment (Table 1). The groups differed markedly in duration of dormancy at 18 °C. The haulm of the seed crop of the different cultivars was removed between 26 June and 6 July 1990 (77-87 days after planting). Tubers were harvested on 20 July. Four temperature regimes were started from 27 July: 18 °C constant (T18); 28 °C constant (T28); 20 days 28 °C, and subsequently 18 °C (T28/18); and 20 days 2 °C, and subsequently 18 °C (T2/18). Three samples of 20 tubers of 40-80 g each were used per treatment (30-70 g in cv. Eigenheimer).

The tubers for T28 were transferred to 18 °C, one week after the time that all the T28-samples of a cultivar showed at least 90 % sprouting to create uniform storage conditions for all treatments after the end of dormancy. At the time these samples were moved to 18 °C, they had been stored at 28 °C for 52 days (cv. Sirtema) to 98 days (cv. Draga).

The growth vigour of each group of cultivars was assessed twice (Tests 1 and 2). The planting dates were the same for all cultivars of each group (Table 1). For each

Table 1. Planting dates (in parentheses: days after haulm pulling = 1 July 1990) and the growth period in the growth vigour Tests 1 and 2, for groups of cultivars with a short (Diamant, Eigenheimer, Sirtema), intermediate (Nicola, Saturna, Sirco) or long (Désirée, Draga, Marfona) dormancy at 18 °C. Experiment 3.

Descriptor	Dormancy of cultivar groups at 18 °C		
	Short	Intermediate	Long
Test 1			
Planting date	17 September (79)	12 October (104)	29 October (121)
Growth period (days)	28	28	28
Test 2			
Planting date	19 October (111)	12 November (135)	10 December (163)
Growth period (days)	28	23	24

test, the experimental design was split-plot with three blocks, cultivars as the main factor and storage regimes as the split factor; an experimental unit consisted of a sample of ten tubers. Test 1 started when dormancy had ended in about 6 of the 12 treatments within a group of cultivars (four storage regimes for three cultivars = 12 treatments) (Table 1). Test 2 started when all treatments of a group of cultivars had reached 100 % sprouting. The tubers were desprouted and pre-sprouted again in darkness at 18 °C and 80 % RH for 10 days. The tubers were planted as in Experiment 2, in a plastic tray (L×B×H=45×30×10 cm). Trays were placed in a glasshouse at 18/12 °C (day 12 h/night). Artificial light (35 W/m^2; 400-700 nm) was given from 08.00 till 20.00 h and in addition plants were exposed to natural light from 10.00 till 14.00 h to prevent malformations of the leaves. Test 1 ended 28 DAP. In Test 2, the growth period for the cultivars with an intermediate or long dormancy was ended before 28 DAP to avoid strong mutual competition for light among the plants within trays (Table 1).

The same observations were conducted as in Experiment 2. The start of emergence in a tray was defined as the moment when the first green plant parts became visible. In Test 2, for some cultivars, tuber initiation had started at harvest. In these cases tuber weights were also determined. After 75 days storage, the weights of the tuber samples (including sprouts) stored at 18 and 28 °C were determined to assess weight losses due to evaporation and respiration after storage at high temperatures.

Results

The analyses of variance revealed that the interaction between cultivars and storage treatments was statistically significant for all parameters in all experiments. Therefore, effects of storage treatments were tested for significance within each cultivar.

Experiment 1

Dormancy had ended in all the treatments on tubers of cv. Diamant before their transport to Israel (92 DAH). T28/18 resulted in the shortest dormancy (Table 2).

The emergence of plants in T28 was a little earlier than that in the other treatments (Table 2). The final emergence hardly differed between treatments. At 43 DAP, the number of stems per plant was highest for T28, the stem number in T28/18 was also significantly higher than that in T18. At the same date, the crop stand score was highest in T28 and lowest in T18. However, 25 days later there was a tendency for the reverse to be true, although differences between the treatments were not significant.

Tuber yields did not differ between storage treatments at 93 DAP, after growth had ceased due to frost damage. The number of tubers per m^2 was 10-15 % higher in T28 than in the other treatments and the proportion by weight of tubers larger than 60 mm was slightly less in T28 than in the other treatments (data not presented).

For cv. Désirée, only tubers in treatment T28 had ended dormancy (87 DAH) before they were transported to Israel.

The emergence of plants in T28 was slightly earlier than those in T2/18 and

Table 2. The effect of four storage temperature regimes on the growth vigour and tuber yields of cvs Diamant and Désirée, in a field experiment in Israel. Experiment 1.

Parameter	Storage temperature regime[a]				LSD
	T18	T28	T28/18	T2/18	P=0.05
cv. Diamant					
Duration of dormancy (DAH[b])	87	79	61	70	2
Start of emergence (DAP[c])	17	12	15	20	4
Emergence (%) (43 DAP)	99	99	96	99	
Number of stems/plant (43 DAP)	1.3	2.4	2.0	1.5	0.3
Crop stand score[d] (43 DAP)	6	10	8-9	7	1-2[e]
Crop stand score (68 DAP)	9-10	8-9	8-9	9	ns
Tuber yield (kg/m^2)	3.18	3.19	3.13	3.18	0.39
Number of tubers per m^2	27	32	29	28	4
cv. Désirée					
Start of emergence (DAP)	35	17	22	20	4
Emergence (%) (43 DAP[f])	24a	99c	79b	97c	
Number of stems/plant (43 DAP)	1.1	1.4	1.0	1.0	
Crop stand score (43 DAP)	0-1	10	4	6-7	1-2[e]
Crop stand score (68 DAP)	2-3	9-10	6	8	1-2[e]
Tuber yield (kg/m^2)	0.84	2.69	1.82	2.27	0.39
Number of tubers per m^2	13	25	18	23	4

[a] T18=18°C constant; T28=storage at 28 °C for 48 days; T28/18=20 days 28 °C and subsequently 18 °C; T2/18=20 days 2 °C and subsequently 18 °C.
[b] DAH=days after haulm killing.
[c] DAP=days after planting.
[d] 0=no emergence; 10=best relative haulm development per cultivar.
[e] The LSD should be used as an indication for significant differences. The LSD is smaller for scores near 0 or 10 than for scores around 5-6; ns=not significant.
[f] The data were analysed after a logit transformation. Means followed by the same letter were not significantly different at P≤ 0.05 (t-test).

T28/18 and much earlier than those in T18 (Table 2). By 43 DAP the emergence of plants in T28 and T2/18 was almost complete, whereas in treatments T28/18 and T18 emergence was only 79 and 24 %, respectively. By 68 DAP the plants in T28/18 and T18 had reached 80 and 56 % emergence, respectively (not tabled). The number of stems per plant in T28 was slightly larger than that in the other treatments. At 43 DAP the crop stand in T28 was superior to that in the other treatments and the crop stand in T2/18 and T28/18 was much more developed than that in T18. At 68 DAP the differences were slightly smaller, but still obvious.

Tuber yield in T28 was much higher than that in the other treatments (Table 2). T2/18 yielded 84 % of T28, T28/18 68 % and T18 31 %. The number of tubers per m^2 was also highest for T28 and lowest for T18. In T28 the proportion by weight of tubers larger than 60 mm was higher than that in T18 (data not presented).

Table 3. The effect of four storage temperature regimes on the growth vigour of four cultivars in a glasshouse test. Plants were harvested 28 (cvs Diamant and Jaerla) or 35 (cvs Désirée and Draga) days after planting (for planting dates see Materials and methods). Experiment 2.

Cultivar	Storage temperature regime[a]				LSD
	T18	T28	T2/18	T0/28/18	P=0.05
Haulm dry weight (g/planted tuber)					
Diamant	0.67	2.32	1.52	1.28	0.36
Jaerla	1.53	2.08	1.17	1.81	0.46
Désirée	1.74	1.30	1.92	2.02	0.36
Draga	2.60	0.28	2.74	2.78	0.32
Number of stems per plant					
Diamant	1.1	3.3	1.2	1.4	0.41
Jaerla	1.7	3.0	1.3	2.0	0.42
Désirée	1.7	3.0	2.3	2.1	0.56
Draga	1.8	2.4	2.3	3.1	0.82

[a] T18=18°C constant; T28=28 °C constant; T2/18=20 days 2 °C and subsequently 18 °C; T0/28/18=10 days 0 °C, 10 days 28 °C and subsequently 18 °C.

Experiment 2

In the growth vigour test (carried out on each cultivar when dormancy had ended in all treatments of that cultivar), T28 resulted in the highest haulm dry weights for cvs Diamant and Jaerla and in the lowest dry weight for the cultivars with the longest dormancy (Désirée and Draga) (Table 3). In T28 of cv. Draga, only 45 % of the tubers produced a plant and the haulm dry weight was very low. The other tubers only produced sprouts that did not emerge within the duration of the test or produced no sprouts at all, indicating that the tubers were very aged. For cv. Diamant, T2/18 and T0/28/18 resulted in a significantly greater haulm dry weight than T18.

The number of stems per plant was much higher in treatment T28 than in the other treatments of cvs Diamant, Jaerla and Désirée. In cv. Draga, only the difference in number of stems per plant between T0/28/18 and T18 was significant.

The effects of the storage regimes on dormancy were described by Van Ittersum & Scholte (1992, Table 5).

Experiment 3

Effects of the storage regimes on the dormancy were presented by Van Ittersum & Scholte (1992, Table 6). After 75 days storage, the tuber weight losses due to evaporation and respiration, averaged over nine cultivars, were about 8 and 11 % after storage at 18 °C and 28 °C, respectively.

Test 1. The trends in the effects of the storage regimes on the start of emergence (in days after planting) were similar for the different cultivars. On average, the emergence of plants in T28 started 12 DAP, whereas that in T28/18, T2/18 and T18 started 18, 19 and 21 DAP, respectively. Treatment T18 of cv. Draga was the only treatment that showed no emergence within the duration of the test. In T28 of all cultivars, the final emergence was (almost) 100 %, whereas in the other treatments of cvs Diamant, Saturna, Désirée and Draga the final emergence was less than 100 %; this was especially true in T18.

T28 gave the highest haulm dry weight for all cultivars (Table 4; Fig. 1). Differences with the other regimes were very large, except in cv. Draga. The growth in T28 of this cultivar was poor. For eight cultivars the treatment with the second highest haulm dry weight was T28/18. T2/18 gave a higher haulm dry weight than T18 in most cultivars, but differences were not always significant. In some cultivars, T18 produced hardly any haulm dry weight.

Table 4. The effect of four storage temperature regimes on the growth vigour of nine cultivars. Plants were harvested 28 days after planting (for planting dates see Table 1). Experiment 3 - Test 1.

Cultivar	Storage temperature regimes[a]			
	T18	T28	T28/18	T2/18
Haulm dry weight (g/planted tuber)[bc]				
Diamant	0.01 a	1.36 c	0.35 b	0.07 a
Eigenheimer	0.12 a	1.60 c	0.77 b	0.56 b
Sirtema	0.16 a	2.56 c	0.76 b	0.24 a
Nicola	0.37 a	1.88 d	1.27 c	0.68 b
Saturna	0.03 a	1.83 c	0.19 b	0.09 ab
Sirco	0.32 a	1.72 c	0.69 b	0.22 a
Désirée	0.72 a	1.79 c	1.35 b	1.16 b
Draga	0	0.30 b	0.19 ab	0.06 a
Marfona	0.45 a	2.62 b	0.34 a	0.45 a
Mean	0.24	1.74	0.66	0.40
Number of stems per plant[c]				
Diamant	1.1 a	1.5 b	1.2 a	1.1 a
Eigenheimer	1.2 a	1.9 b	1.8 b	1.7 b
Sirtema	1.1 a	2.5 c	1.4 b	1.1 a
Nicola	1.3 a	3.1 c	1.9 b	1.5 a
Saturna	1.0 a	2.4 b	1.1 a	1.0 a
Sirco	1.1 a	1.9 c	1.5 b	1.2 a
Désirée	1.4 a	2.2 b	2.0 b	1.6 a
Draga	0	3.7 b	1.2 a	1.0 a
Marfona	1.4 a	3.8 c	2.0 b	1.6 a
Mean	1.2	2.5	1.6	1.3

[a] T18=18°C constant; T28=28 °C constant; T28/18=20 days 28 °C and subsequently 28 °C; T2/18=20 days 2 °C and subsequently 18 °C.

[b] The analysis of variance was carried out per group of cultivars, after a log(x+1)-transformation. Values of treatment T18 of cv. Draga were not used in the analysis of variance.

[c] For each cultivar: different letters indicate that differences between storage regimes are significant at P≤ 0.05 (t-test).

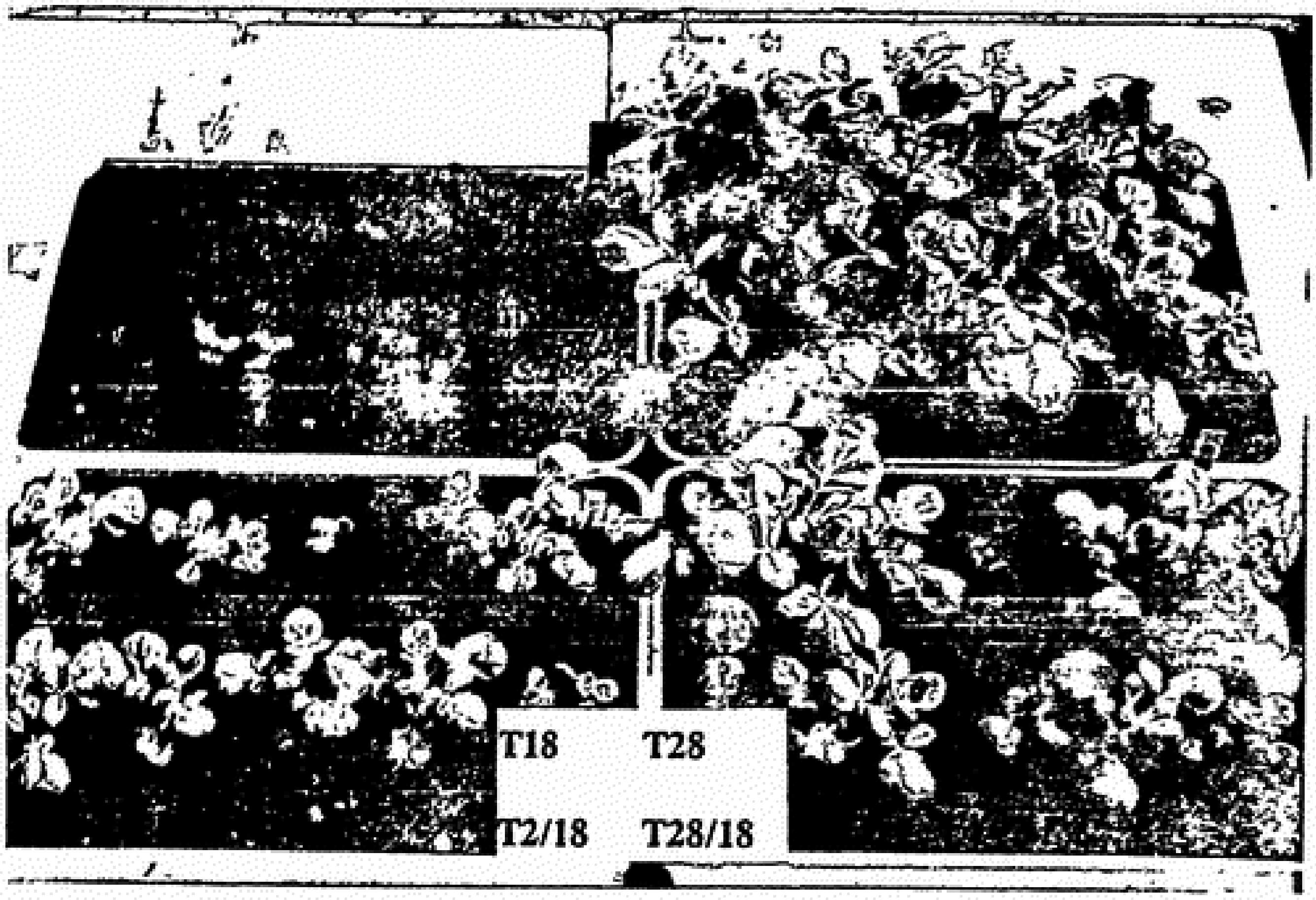

Fig. 1. The effect of storage temperature regimes on the growth vigour of seed tubers of cv. Eigenheimer, planted 17 September 1990 (79 days after haulm pulling) and photographed at harvest (28 days after planting). Experiment 3 – Test 1. For codes and data, see Table 4.

For all cultivars the number of stems per plant was highest in T28 (Table 4). T28/18 also gave a higher stem number than T18, whereas T2/18 and T18 rarely gave more than one stem per plant.

Test 2. On average, the emergence of plants in T28, T28/18, T2/18 and T18 started 9, 11, 11 and 12 DAP, respectively. There was 100 % of emergence by the end of the test in all treatments, except in T28 of cv. Draga, in which only 93 % of the tubers produced a plant (two tubers produced small sprouts only).

T28 gave the highest haulm dry weight for seven out of the nine cultivars, but the differences with the other regimes were not always significant (Table 5). For cv. Désirée differences between the regimes were small, whereas in cv. Draga T28 gave a much lower haulm dry weight than the other regimes. Generally, the differences between T28/18 and T2/18 were small, whereas both tended to produce a higher haulm dry weight than T18. For cvs Diamant, Eigenheimer and Sirtema tubers had been formed, especially in T28.

T28 produced the highest number of stems per plant, except for cv. Désirée (Table 5). For some cultivars, the number of stems in T28/18 or T2/18 was slightly higher than that in T18.

Table 5. The effect of four storage temperature regimes on the growth vigour of nine cultivars. The plants were harvested 23-28 (Table 1) days after planting (for planting dates see Table 1). Experiment 3 – Test 2.

Cultivar	Storage temperature regime[a]				LSD
	T18	T28	T28/18	T2/18	P=0.05
Haulm dry weight (g/planted tuber)					
Diamant	1.19	1.95 (0.1)[b]	1.77	1.67	0.22
Eigenheimer	1.61	2.10 (0.4)	1.88 (0.2)	1.90 (0.3)	0.22
Sirtema	1.35	1.73 (0.3)	1.62	1.32	0.22
Nicola	1.16	2.15	1.68	1.87	0.29
Saturna	0.45	3.11	1.02	0.89	0.29
Sirco	1.11	1.87	1.47	1.15	0.29
Désirée	1.17	1.41	1.28	1.58	0.39
Draga	0.91	0.26	1.44	1.22	0.39
Marfona	1.18	1.91	1.14	1.12	0.39
Mean	1.12	1.83	1.48	1.41	
Number of stems per plant					
Diamant	1.3	2.6	1.9	1.6	0.39
Eigenheimer	2.9	3.9	2.7	3.0	0.39
Sirtema	1.4	2.8	2.0	1.2	0.39
Nicola	2.6	3.2	2.5	2.7	0.50
Saturna	1.7	4.1	2.4	2.0	0.50
Sirco	2.1	2.5	2.3	2.4	0.50
Désirée	2.3	2.7	2.8	3.0	0.62
Draga	2.9	3.5	3.3	2.6	0.62
Marfona	3.0	3.3	3.1	2.6	0.62
Mean	2.2	3.2	2.5	2.3	

[a] For explanation: see Table 4. [b] In parentheses, tuber dry weight per tuber planted.

Discussion

Effects on growth vigour

Shortly after dormancy, an increasing physiological age of the seed tubers (provided that the tubers are not very aged and the growth vigour decreases again) results in an earlier emergence, more stems per tuber, faster initial growth, and earlier tuber initiation (Madec & Perennec, 1955; O'Brien et al., 1983; Bodlaender & Marinus, 1987). This higher growth vigour is particularly reflected in a higher haulm weight soon after planting. Therefore, haulm weight is a good parameter for measuring growth vigour soon after planting.

The effects of the different storage temperature regimes on the growth vigour of seed tubers, planted 80-120 DAH (i.e. during or soon after the end of dormancy; Experiment 1 and Experiment 3 – Test 1), were very clear and similar for the different cultivars. For all cultivars, except for Draga, the highest growth vigour was obtained after storage at 28 °C. T28/18 also advanced the growth vigour, generally more than T2/18, although in Experiment 1 the growth vigour in T2/18 of cv. Désirée was remarkably high. The differences in growth vigour between the treatments diminished when planting was postponed, but for most cultivars T28 still resulted in the highest growth vigour (Experiment 3 – Test 2). Thus, storage at 28 °C until the end of dormancy of the tubers was most favourable to advance growth vigour. However, it can be unfavourable for cultivars with a long dormancy period and a relatively fast rate of physiological ageing (Van Ittersum et al., 1990) as the results with cv. Draga showed. The fact that in this cultivar T28/18 was more favourable for the growth vigour than T28 (Table 5) suggests that for this type of cultivar the period of storage at 28 °C should be shorter.

Desprouting the sprouted tubers before planting probably increased the number of stems per plant since it broke apical dominance. High storage temperatures also increased the number of stems per plant, as can be concluded for instance from Experiment 1 with cv. Diamant. Before transport to Israel all storage treatments were desprouted, but nevertheless T28 showed the largest stem number.

Absolute data from Test 1 are difficult to compare with those from Test 2 (Experiment 3), since in Test 2 the light intensity in the glasshouses (4 h daylight per day, in autumn) was somewhat lower, and for cultivars with an intermediate or long dormancy the growth period was shorter (Table 1). Therefore, a lower in haulm weight in Test 2 compared with Test 1 may have had several causes, but a higher haulm weight is a very strong indication for an increase in growth vigour between Test 1 and Test 2. The haulm weights in Test 2 were always as high as or much higher than those in Test 1, except in T28 of some cultivars. Therefore, it can be concluded that in most treatments the tubers did not age so much under the influence of high storage temperatures, that the growth vigour was lower in Test 2 than in Test 1.

It might be expected that tuber weight losses due to evaporation and respiration would be large at 28 °C. However, in these experiments storage of young tubers at 28 °C and 80 % RH only resulted in slight extra losses over and above those with storage at 18 °C.

Data in the literature on the effect of storage temperature regimes on the growth vigour of seed tubers planted *soon* after their harvest are scarce. Rosa (1928) compared storage temperatures ranging from 4 °C to 30 °C. After 4 weeks storage, the tubers were cut and planted. He found that storage at 30 °C gave the earliest emergence. When planting took place after about 2 months storage, differences between the treatments diminished. Various researchers reported a higher total sprout length per tuber and, for some cultivars, slightly more sprouts per tuber after a cold pretreatment (Wurr & Allen, 1976; Allen et al., 1978; Susnoschi, 1981; Van Loon, 1983).

Dormancy and growth vigour

Since both the effects of the storage regimes on dormancy (Van Ittersum & Scholte, 1992) and on growth vigour were assessed, it is of theoretical and practical interest to analyse whether the regimes that resulted in the shortest dormancy also resulted in the highest growth vigour at early planting.

In contrast to the effects of the temperature regimes on the growth vigour, the effects on dormancy were very cultivar-dependent (Van Ittersum & Scholte, 1992). T28 resulted in the highest growth vigour for all cultivars at *early* plantings, whereas dormancy of this treatment was not necessarily the shortest. For example, in cv. Diamant T28 resulted in ca 3 weeks longer dormancy than T28/18 (Tables 2 and 6), and in cv. Eigenheimer T28 had a dormancy period 2 to 3 weeks longer than all other treatments (Table 6). In Experiment 3, after all T28-tubers of a cultivar had ended dormancy, the T28-samples were transferred to 18 °C. Thus, for cvs Diamant and Eigenheimer, at planting the accumulated day-degrees after the end of dormancy was less in T28 than in other treatments. Nevertheless, T28 was superior in growth vigour. O'Brien et al. (1983) suggested that the physiological age of tubers is characterized by the temperature sum experienced after the start of sprouting (measured as the appearance of a 3 mm sprout). However, these experiments show that the temperature during dormancy until the formation of a 2 (or 3) mm sprout is also important.

Van Ittersum & Scholte (1992) suggested that 28 °C is a favourable temperature for releasing dormancy, but this temperature is unfavourable for subsequent sprout growth. The current experiments show that high temperatures, such as 28 °C, also enhance physiological ageing (resulting in a rapidly changing *potential* to produce sprouts and plants). This also explains why at early planting T28/18 resulted in a higher growth vigour than T18, but in a lower vigour than T28.

Effects on tuber yield

Generally, plants from physiologically older seed tubers ultimately develop less foliage and show earlier senescence. However, the effects of the age of the seed tubers on tuber yield are hard to predict, because of possible interactions with environmental conditions during growth in the field (Perennec & Madec, 1980; Van der

Table 6. The effect of storage temperature regimes on the duration of dormancy (data from Van Ittersum & Scholte, 1992) and the growth vigour of tubers planted at 79 days after haulm pulling (haulm dry weight - data from Table 4 of the current paper: Test 1 – Experiment 3) for cvs Diamant and Eigenheimer. Experiment 3.

	Storage temperature regimes[a]			
	T18	T28	T28/18	T2/18
cv. Diamant				
Duration of dormancy (DAH[b])[c]	86d	80c	57a	69b
Haulm dry weight (g/planted tuber)[c]	0.01a	1.36c	0.35b	0.07a
cv. Eigenheimer				
Duration of dormancy (DAH)	62b	79c	55a	65b
Haulm dry weight (g/planted tuber)	0.12a	1.60c	0.77b	0.56b

[a] For explanation see Table 4. [b] DAH=days after haulm pulling. [c] Different letters indicate that differences between storage regimes are significant at P≤ 0.05 (t-test).

Zaag & Van Loon, 1987). Several researchers (Allen et al., 1979; Reust, 1982; O'Brien et al., 1983) suggested or found that at harvests early in the season the yield produced by physiologically older seed is higher than that produced by younger seed; the reverse is more often true at later harvest.

The results with cv. Diamant (short dormancy period) in Experiment 1 showed that the seed tubers in T28 emerged earlier, produced more stems and resulted in a rapid initial growth, but by 68 DAP the haulm in T28 already looked slightly more senesced than that in the other treatments (Table 2). After the haulm was killed by a night frost 93 DAP, the tuber yields did not differ between the regimes and it cannot be excluded that, in case of a mature harvest, tuber yields in T28 would have been less than those in the other treatments. For cv. Désirée (long dormancy period), the advancing effects of T28 (and to a lesser extent in T2/18 and T28/18) were so large, and the final emergence in T18 was so low, that the tuber yields differed greatly and it is very unlikely that the differences would have disappeared at mature harvest.

Conclusions

1. There is much potential for using storage temperature regimes to advance the growth vigour of seed potatoes that have to be planted soon after harvest.
2. Compared with storage at 18 °C, storing seed tubers at 28 °C until the end of dormancy has the greatest advancing effect on the growth vigour. However, this treatment can be disastrous for cultivars with a long dormancy period and a rapid rate of physiological ageing. For this type of cultivar, shorter storage periods at 28 °C probably give better results.
3. Storage with a hot pre-treatment (20 days at 28 °C, and subsequently 18 °C) also advances the growth vigour compared with storage at 18 °C.
4. Generally, storage with a cold pre-treatment (20 days at 2 °C, and subsequently 18 °C) advances growth vigour slightly more than storage at 18 °C.
5. The regime that results in the shortest dormancy does not always result in the greatest advancing effect on growth vigour.

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