

Sprout development of seed potato tuber after different storage conditions

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Abstract

Sprout growth and development of 'Fraser' seed potato tubers were quantified after a period of 'Early' storage (5-16 weeks from crop defoliation) of tubers in the 'ground', 'shed' or 'cooler' (storage at approximately 4°C) in mid-Canterbury, New Zealand. 'Late' storage treatments exposed the tubers to either one or three months further warm-up prior to planting (mid-October). The seed potato tubers stored at lowest temperature ('cooler') required 760 ± 17.2 °C days (°Cd) ($T_b=0^\circ\text{C}$) to sprout compared with 1,614 °Cd for 'shed' and 1,791 °Cd for 'ground' stored potatoes. The number of major sprouts on a tuber and the number of nodes formed on the main sprout were both affected by the 'Late' storage treatment. Tubers with three months warm up produced fewer sprouts (approximately 3.5) with more nodes (approximately 5.0) and longer sprouts than those warmed up for one month. There was an inverse relationship between dominant sprout number and warm-up duration, with fewer dominant sprouts from a longer warm up duration. These results show that storage treatments can be used to manipulate vegetative development in tubers in anticipation of planting.

Additional keywords: sprouting, seed potato tubers, *Solanum tuberosum* cv. Fraser, winter storage, thermal-time

Introduction

At harvest, potato (*Solanum tuberosum* L.) tubers will not sprout even if placed in suitable environmental conditions for growth (Delaplace *et al.*, 2008). This state can be affected by both the pre- and post-harvest environment (Suttle, 2004) and differs among cultivars (Hay and Porter, 2006). Therefore, the individual sprouting behaviour of a cultivar needs to be characterised under different storage conditions to optimise storability and keeping quality (Carli *et al.*, 2010).

In most cases, sprouting should be restrained in potatoes sold to consumers

and, those which have to be stored for a long period. However, for seed potato tubers that are planted soon after their harvest it is necessary to have them primed to sprout (Van Ittersum and Scholte, 1992).

According to Struik and Wiersema (1999), in some cultivars sprouting can be hastened by storage at high temperatures. In others, sprouting is quicker after cold or heat shock during the early storage period. Struik (2006), found 'Desirée' potatoes sprouted at 464 °Cd after two weeks of storage at 4°C followed by three weeks of warm-up at 20°C. This compares with 1,168 °Cd when initial storage was for two weeks at 20°C

followed by another three weeks at 4°C.

The onset of sprout growth is also influenced by the development stage (physiological age) of the potato tuber (Struik and Wiersema, 1999). The progress from physiologically young to physiologically old tubers affects yield parameters of the subsequent crop. These include date of emergence, stem numbers, canopy growth pattern, maturity date, total tuber yield and tuber size distribution (Christiansen *et al.*, 2006). According to Firman *et al.* (1991) over 40 leaf primordia may be formed on the sprout of some cultivars during storage. In others, the apical differentiation (and thus the production of new leaf primordia or nodes) is arrested after some time of storage. The same authors showed that the initiation of flower primordia may commence on sprouts before planting. This means that in some cultivars, and under certain storage conditions, the size of the first level of the main stem of the following potato plants is determined before planting. The investigation of sprout behaviour during storage contributes to understanding the physiological ageing process of seed potato tubers and can be used to develop appropriate storage strategies prior to planting.

The objective of this study was to examine how sprouting development on 'Fraser' potatoes was affected by storage temperature. The treatments were based on common seed potato tuber storage practices in Canterbury. 'Fraser' is a main crop cultivar with high processing quality and resistance to cold induced sweetening.

Material and Methods

Seed potato tuber storage treatments

A single crop of 'Fraser' potatoes was

grown in mid-Canterbury, New Zealand and, following usual commercial growing practices, was desiccated with diquat dibromide (20%) on 3 February 2011. The potatoes were then left to mature for five weeks. After hand harvest, tubers were allocated to one of six storage treatments, integrated into an experiment of three 'Early' and two 'Late' regimes with 12 replicates monitored over seven months during autumn and winter 2011.

The 'Early' storage treatments lasted eleven weeks (from digging) (Figure 1). During this period the potato seeds were stored in one of three locations (treatments): 'ground' tubers were stored *in situ* in the field; 'shed' tubers were held at ambient temperature in an un-insulated light-proof building and 'cooler' tubers were stored at 2-4°C with a relative humidity of 80 to 90%. Tubers for the treatments 'cooler' and 'shed' were removed from the ground on 10 March 2011 and then held at ambient temperature for seven days. These tubers were then moved to the 'cooler' and the 'shed'. For 'shed' tubers the temperature ranged from a maximum of 22°C in March to a minimum of 2°C in May. For the tubers left in the 'ground', soil temperatures (measured at 15 mm of depth) ranged from a maximum of 23°C in March to a minimum of 8°C in April. These tubers were dug from the 'ground' using a fork on 18 May 2011 and then moved to the same 'shed' until 26 May when all the 'Early' treatments were completed. From then all tubers were kept in the 'cooler' at 4°C.

The 'Late' regime involved the removal of tubers from the 'cooler' on 12 July 2011 and 9 September 2011 and placing them in the 'shed'. This allowed a post-chill warm up for three months ('3M') or one month ('1M'). These late treatments were completed on 14 October 2011, to coincide

with the usual sowing time for potato crops in the mid-Canterbury region. The

treatments and their timing are illustrated in Figure 1.

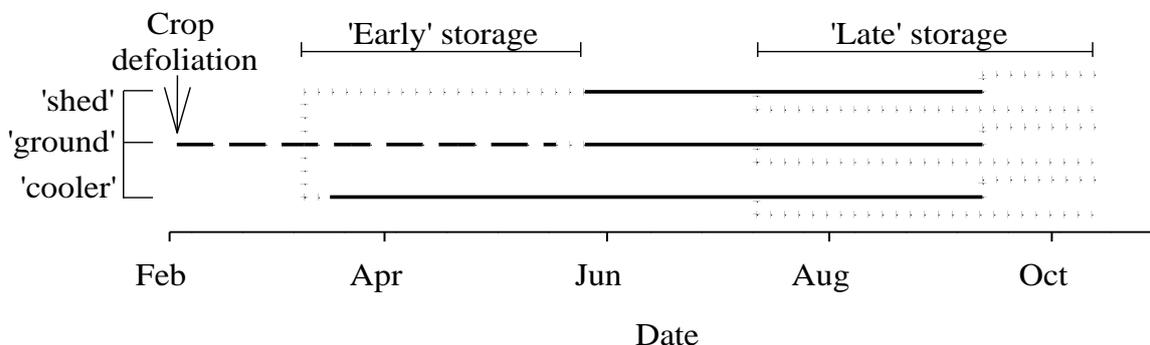


Figure 1: Time line diagram of the storage treatments applied ('shed', 'ground' and 'cooler') for the whole time of the experiment. The lines indicate the location where the tubers were stored (ground --, shed ••• and cooler —). The duration of 'Early' and 'Late' storage treatments are specified.

For all treatments, temperature and humidity were recorded hourly using HOBO 4-Channel data loggers and the thermal time ($^{\circ}\text{Cd}$) during each storage phase was calculated as the mean daily temperature, using maximum and minimum daily temperature, minus a base temperature (T_b). In this study a T_b of 0°C (Jefferies *et al.*, 1989) and 4°C (O'Brien *et al.*, 1983) were used to calculate the $^{\circ}\text{Cd}$.

Potato assessments

From the start of the 'Late' storage regime, 12 randomly selected tubers, sized 60-75 mm in length, from each treatment were assessed every three days for degree of visible meristems (eye openness) and sprout length. The degree of eye openness was calculated as the ratio of open eyes to total tuber eyes. Sprout length (the longest sprout) was determined using a MAX - Series Electronic Digital Caliper. The number of days and the thermal time accumulation from crop defoliation to sprout initiation (visually assessed) was calculated for each treatment. A tuber was considered sprouted at the first visual sign

of at least one sprouted eye.

A second set of 12 randomly selected tubers from each treatment was assessed on 12 October 2011 for the same attributes. On this date, other measurements included the number of nodes, developed on the longest sprout (main sprout) and total number of major sprouts (the most dominant sprouts, lengthwise). The thermal time ($^{\circ}\text{Cd}$) needed to reach the onset of sprouting was also determined.

Data analysis

Data were analysed using GenStat (version 14, VSN International Ltd, UK), and means were separated using the least significant difference (LSD) procedure ($P=0.05$). For figures in the text confidence intervals are given for the average (i.e. $\pm \text{LSD}/2$).

Results and Discussion

Time of sprouting

There was an interaction between the treatments for the amount of thermal time accumulated ($P<0.03$ for $T_b=0$ and $P<0.01$

for $T_b=4$) before visible sprouting (Table 1). This is in agreement with Struik and Wiersema (1999) who stated that not only storage temperature, but also timing of warmer phases of storage can be used to manipulate dormancy and physiological ageing. The ‘cooler’ treatment required less thermal time to onset sprouting on average (Table 1) compared with ‘shed’ and ‘ground’ regardless of the ‘Late’ treatment and the T_b (‘0’ or ‘4’) used. However, the base temperature used for the ‘Late’

treatment affected the amount of thermal time calculated for sprouting (Table 1). For example, tubers stored in the ‘cooler’, started sprouting after 755 and 760 ± 17 °Cd (for ‘3M’ and ‘1M’ respectively, $T_b=0$) and 288 and 224 ± 18 °Cd (for ‘3M’ and ‘1M’ in that order, $T_b=4$). This shows that the thermal time responses are affected by the base temperature used to calculate thermal time accumulation during winter storage so an appropriate base temperature must be used.

Table 1: Sprouting patterns of ‘Early’ and ‘Late’ ‘Fraser’ potatoes stored under different conditions in 2011.

Storage (Early+Late)	Sprout onset (days) ¹	Thermal time (°Cd) ²		Fraction of open eyes ⁴	Number of major ⁵ sprouts	Number of nodes on the main ⁶ sprout	Main sprout length (mm)
		³ $T_b=0$	$T_b=4$				
ground+3M	207	1,791	1,092	0.81	3.42	5.58	65.10
ground+1M	232	1,859	1,060	0.88	4.83	2.33	11.20
shed+3M	208	1,614	978	0.84	3.00	5.66	64.50
shed+1M	233	1,669	948	0.85	5.25	2.25	11.70
cooler+3M	207	755	288	0.89	4.17	6.75	104.4
cooler+1M	228	760	224	0.84	5.92	2.75	18.10
LSD _(0.05)	3.10	34.54	35.48	0.10	0.71	0.31	11.56
Early x Late ⁷	ns	<0.03	0.01	ns	ns	ns	<0.001
Early ⁷	0.05	<0.001	<0.001	ns	ns	<0.001	<0.001
Late ⁷	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001

¹Sprout onset: number of days from crop defoliation to onset of sprouting.

²(°Cd): thermal time (°Cd) accumulated until onset of sprouting.

³ T_b : base temperature used to calculate thermal time (°C).

⁴Fraction of open eyes: number of eyes open eyes in relation to the total number of eyes in a seed potato.

⁵Major sprouts: most dominant sprouts (lengthwise) on the tuber.

⁶Main sprout: longest sprout on a tuber (first dominant sprout to appear).

⁷P-value (ns = not significant).

When tubers were given a three month warm up period before the end of storage, sprouts were initiated after approximately 208 days after mother crop defoliation (Table 1), compared with approximately 230 days after one month warm up. This shows that prolonged cold storage delayed

the initiation of sprouts in ‘Fraser’. In practice, when the ‘Fraser’ mother crop is defoliated in the first week of February and the potatoes are expected to be planted in the first week of October, the seed potato tuber, if stored at low temperatures (e.g. cooler) during the entire storage season, will

initiate sprouts either in the first week of August; when allowed a three month warm up prior to planting, or in the first week of September; when allowed a one month warm up.

Sprouting Pattern

For all treatments the seed potato tubers had about 85% of visible meristem tissue (eye openness) at the end of the 'Early' storage period with no effect of storage treatment. This suggests that the "potential" number of sprouts (shoots) produced in 'Fraser' seed potato tuber was unaffected by 'Early' or 'Late' storage treatments.

The number of major sprouts on a tuber was affected ($P < 0.001$) solely by the 'Late' treatments ('3M' and '1M') (Table 1). A longer period of temperature accumulation resulted in fewer major sprouts ('1M', 4.83 to 5.92 ± 0.35 and '3M', 3.00 to 4.17 ± 0.35). The number of sprouts which develop on a tuber depends on the physiological stage at which environmental conditions allow the sprout growth to start. Delaying exposure to conditions that permit sprouting will reduce apical dominance and allow more sprouts, once exposed to conditions conducive to sprout growth (Struik and Wiersema, 1999).

In practice, potato varieties that have reached the end of "normal" sprouting (illustrated by the three month warm up treatment), are recommended for early maturing crops, because tuber initiation starts earlier and the crop matures earlier. On the contrary, potato varieties that are at the end of their apical dominance period (as observed by the one month warm up treatment) are recommended for medium and late maturing crops, since they mature later (Carli *et al.*, 2010).

There is strong evidence that the number of nodes formed on the main sprout is

affected ($P < 0.001$) by the 'Late' treatment. There were 5.58 to 6.75 ± 0.15 nodes formed on the main sprout for the '3M' warm up and 2.25 to 2.75 ± 0.15 sprouts for the '1M'. There were also some evidence of the 'Early' treatments affecting ($P < 0.001$) this variable. However, the differences found for number of nodes in the main sprout is more prominent for the 'Late' compared with 'Early' treatments (Table 1). This suggests that the duration from sprout initiation to planting time was an important determinant of the number of nodes on main shoot stems (Hay and Porter, 2006).

An interaction ($P < 0.001$) was found between the storage treatments and the length of the main sprout. The estimated means vary for all treatments applied (LSD=11.56) (Table 1). Sprout length was greater (104.4 mm) for the tubers stored in the 'cooler' after a three month warm up compared with other treatments. The length of the longest sprout has been recognized as a useful estimator of sprout development and is associated with physiological age (O'Brien, 1983; Hartmans and Van Loon, 1987).

Conclusions

- (1) The number of days from defoliation of the mother crop until sprout initiation was solely affected by the length of warm up during the 'Late' phase of storage. This period is therefore crucial to manipulate the breaking of dormancy for planting.
- (2) The "potential" number of sprouts produced in 'Fraser' seed potato tubers was unaffected by the storage treatments used in this work.
- (3) The number of major sprouts on the potato was affected exclusively by the duration of 'Late' warm up treatment. A longer period of warmer temperatures

and hence ^{90}Cd accumulation resulted in a smaller number of major sprouts.

- (4) The number of nodes developed on the main sprout (longest sprout) of tubers increased when the tubers were exposed to three compared with the one month warm up after the 'cooler' treatment.

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