Seed potato physiological age and crop establishment

J.S. Oliveira[1], D.J. Moot[1] and H.E. Brown[2]
[1]Lincoln University, PO Box 84 Lincoln University, Canterbury, New Zealand
[2]The New Zealand Institute for Plant & Food Research Limited, Private Bag 4704, Christchurch 8140, New Zealand

Abstract

Seed potato physiological age progressively advances with time (chronological age), but is also influenced by temperature during storage. In this work, different combinations of constant temperatures (2, 8 and 20°C) were applied to ‘Bondi’ and ‘Fraser’ seed potatoes at different times during the storage period. By the end of storage, potatoes differed in the temperature sum they had been exposed to or the timing and duration of warmer periods. The range of accumulated temperature was 180 to 3,600 °Cd. Any sprouts produced during storage were removed before being planted at 20°C at one month intervals from 4-10 months after storage. In most cases delaying planting (chronologically older seed) resulted in earlier emergence and an increase in the number of stems emerged. Increased storage temperature from 2-8°C (thermally older seed) had no effect. Prolonged storage of seed potatoes at 20°C gave a significant reduction in the fraction of plants that emerged and produced a decline in the number, growth and stage of development of the stems emerged, but only when the seed potato had accumulated over 3,060 °Cd for both cultivars. It seems that using expensive cool storage in winter in Canterbury, with cool winter ambient temperatures, is unnecessary for crop establishment and by inference subsequent crop production.

Additional keywords: *Solanum tuberosum*, winter storage, chronological age, crop emergence, number of stems, growth, development

Introduction

The environment in which seed potatoes (*Solanum tuberosum* L.) are held during the storage phase influences crop growth and development through the effects of physiological age (Bodlaender and Marinus, 1987; Hartmans and Van Loon, 1987; Van Der Zaag and Van Loon, 1987; Van Loon, 1987). According to Struik and Wiersema (1999) seed potato physiological age is mostly influenced by storage duration and the temperature experienced during this phase, but the responses are determined by genotype. Reportedly, younger seed potatoes emerge later, have fewer stems per seed tuber, show later tuberization but less secondary growth, have more foliage growth, more tubers per stem and a later maturity.

In Canterbury, New Zealand, seed potatoes of main crop cultivars are generally stored within a few weeks after harvest in March in a cool store at 2 to 4°C, and then allowed a warmer period of less than a month outside the cooler at ambient temperature before they are planted in the field in mid-October. This refrigerated storage is costly and there is little information on how it affects seed potato physiological age and potential yield of the main crops used in New Zealand.

In a recent study, Oliveira *et al.* (2014) showed there were no final tuber yield differences or substantial changes in yield distribution from different storage regimes applied to 'Bondi' and 'Fraser' seed potatoes. The duration of the refrigerated storage period could be lowered from 162 days, which is currently applied, to 80 days with no impact on yield or tuber size distribution. It follows that physiological age may be of little practical consequence for potato growers in Canterbury. This could have major financial implications if growers stopped using refrigerated storage over winter. To confirm these results a wider range of physiological age treatments were tested in the study presented here.

A series of constant low, moderate and high temperatures were applied to stored seed potatoes to create an extended range of physiologically aged seed potatoes. There were two aims:

1. decouple chronological and thermal effects on physiological ageing using the temperature treatments and the chronological series of plantings, and

2. assess the impact of different storage regimes on crop establishment.

Moreover, the impact of seed potato physiological age on tuber yield quality aspects, like yield distribution, can occur from its influence on the number of stems emerged per plant (Struik *et al.*, 2006). According to previous reports (Knowles and Knowles, 2006) tuber yield distribution can be shifted to smaller weight or size grades from an increase in stem population. This is particularly important for potato growers. In New Zealand for example, a major complaint of processors is that 'Bondi' tubers are too long. Therefore, a further aim is to assess the possibility of manipulating the number of stems emerged by using different storage temperatures.

Materials and Methods

Seed potato

'Bondi' and 'Fraser' seed potatoes were collected from local growers on 17 May, 2012. The seed potatoes were produced under field conditions with known and strictly controlled agricultural practice and selected for uniformity in size and absence of disorders and infections of pests or diseases. 'Bondi' seed size ranged from 70-110 mm and 'Fraser' from 50-80 mm. Table 1 shows the time of desiccation of the crop and harvest.

Table 1: Description of seed potato production for 'Bondi' and 'Fraser' grown during the summer of 2011-212 at Lincoln, Canterbury, New Zealand.

Seed production / Cultivar	'Bondi'	'Fraser'
Planting date of the MC[1]	3 November 2011	1 November 2011
Haulm desiccation of MC	17 February 2012	19 February 2012
Harvest date of the seed tubers	"early May"	7 May 2012
Days stored in growers shed	approximately 14	12
Date of de-sprouting	at planting	at planting

[1]MC=mother crop.

Storage facilities (pre-treatments)

Data were analysed as a split-split-plot design with temperature treatments as the main-plot, cultivars ('Bondi' and 'Fraser') as the sub-plot and planting dates as the sub-sub-plots. Storage treatments used three temperature controlled rooms located at Plant & Food Research Limted, Canterbury, New Zealand (43° 39 'S and 172° 28 'E). The rooms were kept at low (2°C), moderate (8°C) or high (20°C) temperatures and relative humidity was between 80 and 90%. Air temperature and relative humidity were monitored inside the storage rooms using HOBO 4-Channel data loggers. The seed potatoes were stored in the dark for the duration of the study.

All temperature treatments were replicated four times. Each replicate had seven seed potatoes. The seed potatoes of each replicate were kept inside a cardboard box containing holes to allow for air circulation for the entire period in controlled storage. The boxes were randomly distributed inside the temperature controlled rooms.

Treatments were different combinations of temperatures. This was done to assess the cultivars response to the timing of warmer temperatures as well as the total thermal-time accumulated by the seed at the end of the storage period (Wurr, 1979; Struik *et al.*, 2006). To create these different temperature combinations, some treatments were moved between storage rooms at an interval of approximately 30 days. The treatments were coded to identify the seed storage temperature and the time of transition from one storage temperature to another (Figure 1). The codes consist of two letters; which represent the early and late storage temperature, each one followed by a number that represents the amount of time in months at that temperature in the early and late storage, respectively (e.g., L6H1=the first six months stored at 2°C and the last month stored at 20°C). Other treatments included seed stored at a constant low temperature for the entire storage period. In this case only one letter and one number were used for the treatment code (e.g., L7=stored at 2°C for seven months). All seed potatoes entered storage on 19 May, 2012. During the controlled temperature storage period, all treatments were kept for the first 10 days stored at 20°C (Figure 1).

Planting

The pre-treated seed potatoes of 'Bondi' and 'Fraser' were planted in pots at the end of each storage treatment. These pots were kept inside a dark room at 20°C for the duration of growth after planting on six dates (Table 2). The seed potatoes were planted 150 mm deep in a nine litre pot filled with potting mix. Each litre of the potting mix was prepared using 495 g of aged bark, 413 g of washed crusher dust, 5.10 g of dolomite lime, 0.32 g of Osmocote, 1.15 g of superphosphate, 0.35 g of sulphate of potash and 0.90 g of calcium nitrate.

The interval between planting and digs ranged from 28 to 36 days as shown in Figure 1. There were four replicates (pots) of seven seed potatoes. Pots were arranged randomly inside the room and were watered with 50 ml/pot at two day intervals after at least one stem had emerged.

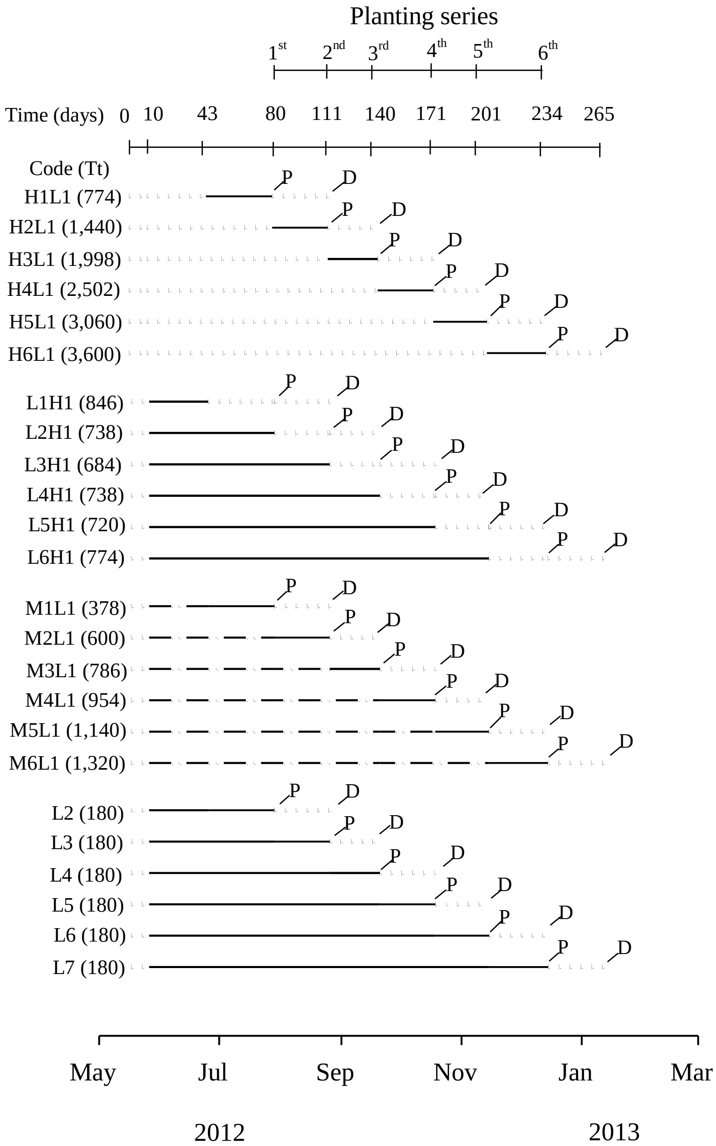

Figure 1: Temperature treatments and their codes applied to the seed potatoes during storage; ‘Low’, L=2°C (——), ‘Moderate’; M=8°C (•—•), and ‘High’; H=20°C (•••), Tt=thermal-time accumulated during the controlled storage (T_b=2°C) prior to planting, P=planting and D=dig.

Measurements and calculations

Plant measurements included emergence rate and number of above-ground stems. The time to full emergence was considered when seven stems had emerged from each pot (plot) and was calculated as days after planting (DAP) and in thermal-time from planting (Tt or °Cd, T_b=2°C; Oliveira *et al.*, 2014). Each stem emerged from the seed potatoes had an above ($stem_A$) and a below-ground ($stem_B$) portion. $Stem_A$ and $stem_B$ were counted and combined as $stem_{AB}$ after the seed potatoes were excavated. Then 10 $stem_{AB}$ were randomly selected to measure dry matter (DM, g), length (cm) and number of nodes present on $stem_A$. $Stem_{AB}$ length was measured using a ruler from the bottom of the below-ground stem to the terminal end of the apical above-ground stem emerged. In addition, the fraction of emergence was measured.

Data analysis

All $stem_{ab}$ data presented were interpolated for 30 DAP since the potato excavation dates varied between 28 and 36 DAP among planting dates. Statistical analysis was performed using GenStat (version 14, VSN International Limited, UK). Least significant differences (LSD) at the α=0.05 probability level were calculated to compare temperature treatments for each cultivar both within and among planting dates.

Results

Emergence

The fraction of seed potato emergence was, in most cases, 100% for 'Bondi' and 'Fraser' regardless of treatment and planting date (Table 2). However, for the December planting, after seed potatoes had accumulated 3,060 °Cd (H5L1) during storage, 'Bondi' had 61% plant emergence while 'Fraser' failed to emerge. Both cultivars failed to emerge from the January planting (planting 6), after around 3,600 °Cd (H6L1) of accumulated thermal-time.

Time of emergence was mostly affected (P<0.02) by cultivar and planting date. 'Bondi' emerged earlier than 'Fraser'. Time to emergence progressively decreased with planting dates for the two cultivars. This decrease was from around 20 DAP (396 °Cd) in the September planting to around 16 DAP (288 °Cd) in December (Table 2) for 'Fraser'.

Table 2: Time of crop emergence calculated in days after planting (DAP) and fraction of plants emerged (bracketed values) for desprouted 'Bondi' and 'Fraser' potato tubers stored at different temperature regimes before being grown in the dark at 20°C for around 30 days on six planting dates.

Cultivar (C)	Treatment (T)	Planting dates					
		7 August 2012	7 September 2012	5 October 2012	5 November 2012	5 December 2012	7 January 2013
'Bondi'	HL	–(1)	17.7(1)	14.6(1)	16.1(1)	16.0(0.61)	no(0.07)
	L	–(1)	20.3(1)	17.1(1)	13.8(1)	14.2(1)	15.2(1)
	LH	–(0.89)	15.0(1)	15.4(1)	13.4(1)	13.7(1)	13.6(1)
	ML	–(1)	19.1(1)	15.8(1)	16.9(1)	15.0(1)	15.9(1)
	Mean		18.0	15.7	15.0	14.7	15.4
'Fraser'	HL	–(0.89)	19.3(1)	15.6(1)	17.6(1)	20.5(0.07)	no(0.03)
	L	–(0.76)	25.3(1)	20.9(1)	18.1(1)	15.5(1)	18.0(1)
	LH	–(0.89)	18.7(1)	16.2(1)	17.0(1)	14.7(1)	14.7(1)
	ML	–(0.87)	22.9(1)	16.7(1)	17.6(1)	14.7(1)	16.3(0.9)
	Mean		21.5	17.4	17.6	16.3	16.3
Cultivar (C)		P<0.02					
Temperature treatments (T)		ns					
Planting date (PD)		P<0.02					
$LSD_{(0.05)}$		1.7					

Note: Time of emergence was not assessed on the 1st planting for technical reasons.

Number of above-ground stems emerged

The number of above-ground stems increased from earlier to later planting dates in all temperature and cultivars. The HL regime caused the number of stems to decrease on both cultivars after being held at 20°C for five months (H5L1, 3060 °Cd accumulated during storage) or longer (Figure 2).

The variation among storage treatments (or thermal treatments) was more evident in ‘Fraser’ than in ‘Bondi’. The ‘Fraser’ seed potatoes stored in high temperatures (HL or LH) produced the highest ($P<0.001$) number of above-ground stems in the first three planting dates (August-October). However, in most cases these differences disappeared for the November planting. The H3L1 and the L6H1 produced the highest ($P<0.001$) number of above-ground stems per seed potato (around 9) for this cultivar.

‘Bondi’ above-ground stem number increased with planting date. With the low temperature treatment (L) this increased ($P<0.018$) from around 2 in the August planting to up to around 5 in the January planting.

Stem measurements

The stem parameters measured from the warmer temperature regimes (HL and/or LH) were similar (e.g., ‘Bondi’) or in most cases higher ($P<0.001$, e.g., ‘Fraser’) than the low temperature treatments (ML or L) from the August to the November plantings (Figure 3). They all increased up to a maximum value for the October planting date in all treatments. From then, these values constantly decreased for the HL treatment but stem development was in most cases similar for the other treatments.

In the October planting date the number of nodes produced on the above-ground stem was similar ($P<0.66$) across the HL, LH and ML treatments and lowest ($P<0.003$) for L. For this planting, ‘Bondi’ and ‘Fraser’ developed on average 11 and 8.5 nodes per above-ground stem, respectively.

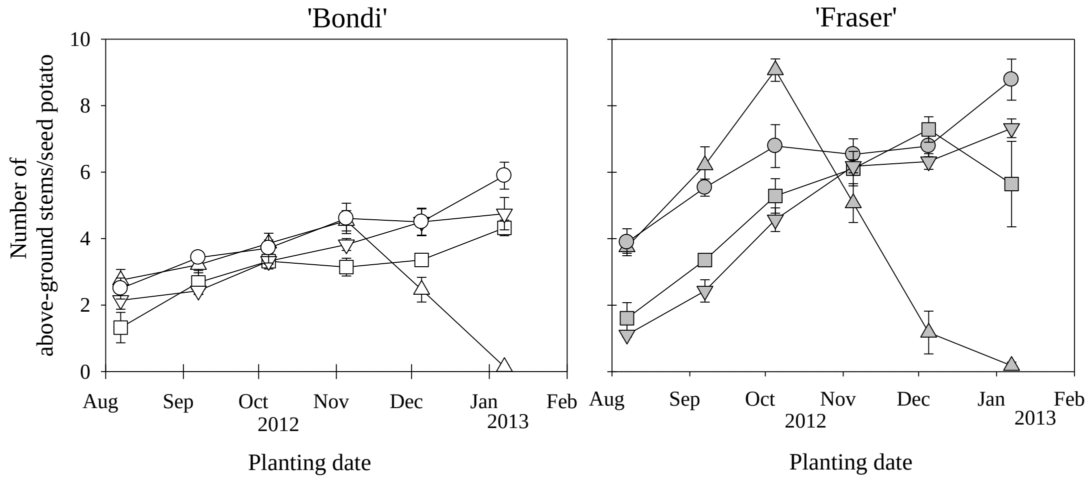

Figure 2: Average number of stems emerged per seed potato against planting dates (August to January) for ‘Bondi’ and ‘Fraser’ seed potatoes stored under different temperature regimes, desprouted and then grown in the dark at a 20°C for around 30 days at Lincoln, Canterbury, New Zealand. Treatment and symbols are: HL (▲), LH (●), ML (■) and L (▼). Bars represent one standard error above and below the mean values (n=4).

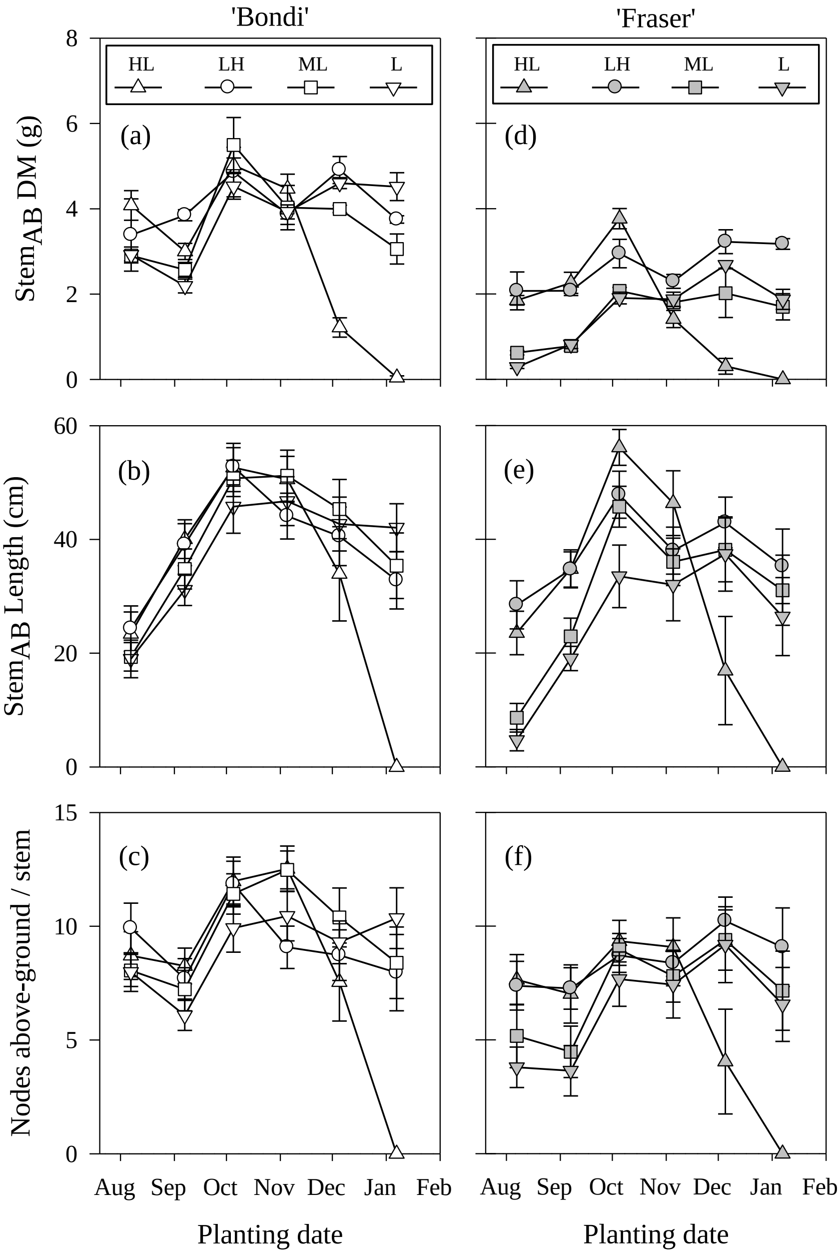

Figure 3: Average $stem_{AB}$ (above and below-ground) dry matter (a and d), $stem_{AB}$ length (b and e) and number of nodes on the above-ground stem (c and f) per stem from six planting dates (from August to January). Seed potatoes were stored at different temperature regimes and then grown in the dark at 20°C for around 30 days. Bars represent one standard error above and below the mean values (n=4).

Discussion

The current work suggests that for the main crop production of 'Bondi' and 'Fraser' in the Canterbury region, the use of expensive cool storage temperatures was unimportant for crop establishment and by inference, subsequent crop production. There was 100% emergence of seed potatoes up to 2,502 °Cd accumulated during storage. In practice, if these cultivars were stored in a shed at ambient temperature during most of the storage season, which is commercially from mid-February to mid-October, the seed potatoes would not accumulate sufficient thermal-time to compromise emergence. Assuming that the seed potatoes were held at ambient temperature during the whole storage period, and the average air temperature registered in this area during the months of January-September was from 6 to 17°C (being maximum at around 22°C and minimum at around 1°C), around 2,240 °Cd (T_b=2°C) would be accumulated at the end of the storage before planting. This highlights the plasticity of these cultivars, particularly in 'Bondi', in terms of storage possibilities during the autumn-winter season in Canterbury.

The number of stems emerged above-ground per seed potato can be manipulated by using different storage temperatures, but this may depend on the cultivar. Similar conclusions were made by Struik *et al.* (2006). For the early October planting this ranged from four stems with L3H1 to nine with H3L1 (Figure 2). This may have some practical implication for the manipulation of the tuber weight yield distribution in this cultivar. Increasing the number of above-ground stems in 'Fraser' resulted in fewer larger tubers produced without altering final tuber yield (Oliveira, 2014).

Conversely, 'Bondi' stem number manipulation by means of thermal storage treatments should not be encouraged because the costs involved in this process will not return significant differences (Figure 2). In general 'Bondi' produced fewer stems compared with 'Fraser'. It is possible a strong paradormancy existed among the eyes of the 'Bondi' seed potato (Lang *et al.*, 1987; Suttle, 2007; Vreugdenhil, 2007). It seems that the hormonal regulation involved in the process of potato dormancy break (Suttle, 2004) was unaffected by temperature in 'Bondi'. In most cases, the number of above-ground stems emerged progressively increased with time regardless of thermal-time accumulation. This represents an opportunity to increase the number of stems per plant and reduce the size distribution of this cultivar, which is currently a problem for its production in New Zealand (Oliveira, 2014). This could involve an earlier production of the seed. In warmer places like Pukekohe, for example, 'Bondi' could be harvested as early as November for seed production. In this case the current storage period of eight months would be extended to 11 months for the crop planted in October in Canterbury. This could potentially produce up to 6 above-ground stems if stored under mild temperatures as shown in Figure 2.

The stem parameters analysed suggests that crop establishment and final tuber yield will be determined by the environmental conditions during crop growth and the length of the growing season, rather than previous storage conditions of the seed potatoes (Oliveira, 2014). It can be concluded that there was no need to use refrigerated storage for seed potatoes during the winter period in Canterbury and bear the additional monetary costs involved in this process. For all temperature treatments applied, the pattern of stem growth, expressed in stemab DM and stemab length and stem development, expressed in number of nodes developed on the above-ground stem, were similar within each planting date (Figure 3), particularly for 'Bondi' but there were some differences for 'Fraser'. In the October planting, which represents the potato planting time in Canterbury, for example, the stem parameters were either unaffected by the warmer (HL or LH) temperatures (Figure 3 (a), (b), (c); 'Bondi') or benefitted from them in terms of growth and development (Figure 3 (d), (e) and (f); 'Fraser').

Conclusions

Physiological ageing was not a key component in early crop establishment of 'Bondi' and 'Fraser'. These results suggest potato growers do not need use cold storage facilities for storage of these seed potatoes.

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