Effect of seed tuber physiological age on leaf area production of potato cultivars Russet Burbank and Atlantic

Ifayanti Ridwan¹, Shaun Lisson², and Phil Brown³

¹Department of Agronomy, Faculty of Agriculture, Hasanuddin University, Jl. Perintis Kemerdekaan KM 10 Makassar 90245, Indonesia.
²School of Agricultural Science, University of Tasmania, Hobart TAS 7005, Australia.
³School of Medical and Applied Science, Central Queensland University, Bundaberg DC, QLD 4670, Australia.

E-mail: ifayanti@unhas.ac.id

Abstract. A pot trial was conducted to study the effect of seed tuber physiological age on the leaf growth of two potato cultivars. The study was conducted in a controlled stress free environment in a glasshouse at University of Tasmania Horticultural Research Centre. Seed tubers of two cultivars (Atlantic and Russet Burbank) with different physiological ages were used. The trial was set up as a complete randomized block design with four replicates. Some leaf growth characters were observed including the leaf phenology and production. ANOVA on the observed parameters show a significant difference between the physiological ages of the seed tuber used in the leaf growth characters. Higher node or leaf appearance rate was observed in cv. Russet Burbank (39.5 °Cd per leaf) in the plants from older tubers compared to the younger seed tubers (51.2 °Cd per leaf). On the contrary, no significant differences were found for the leaf senescence rate. Seed tuber ages also affected the size of fully expanded leaves in cv. Russet Burbank but not in Atlantic. More branching was found in the plant established from physiologically older seed tubers.

1. Introduction

The architecture of the potato plant is described by Vos [1] and in the later study by Fleisher & Timlin [2]. The main stem in potato plant is the stem that grows from the tuber. From the main stem, branching consists of branches on the basal lateral and apical lateral nodes (usually called sympodial branches). The basal lateral branches can occur either above or below ground (usually called secondary stems) while apical lateral branches occur above ground only on the top part of the branch, each terminating in inflorescences.

Potato cultivars are distinguished into two types, determinate and indeterminate [3]. Determinate type cultivars tend to be short and initiation of leaves ceases with the appearance of flowers and do not produce any successive order of branches. In indeterminate cultivars, initiation of new leaves does not cease with the appearance of the first flower on the main stem. Branches can emerge from any leaf axil on the main stem and can produce the next order of branches [1]. Leaf area growth in potato is a function of stem number per plant, leaf appearance and leaf number per stem (including branches), individual leaf area and leaf senescence.
Seed size and seed tuber physiological age are recognized as the key drivers of stem number per plant [4]. Seed size determines the number of eyes with larger seeds producing more sprouts. Seed age influences the proportion of eyes that produce sprouts and the proportion of sprouts that produce stems [5]. Older seed tends to generate more stems per plant compared to young seed.

The leaf appearance rate is strongly correlated with air temperature [6-8] with the reported base temperature for leaf production ranging from 0-9 ºC [7-10]; the maximum temperature from 31 – 36 ºC [10]; and the optimum temperature is 24 ºC [10]. The reported leaf appearance rate for potato varies from 31.5 – 41.2 ºC d per leaf (Tb 0 ºC) [7, 8, 11].

The total number of nodes on the main stem both below and above ground varies with cultivar and seed physiological age, but typically ranges between 17 and 27 [12]. Firman et al. [13] found that there was an increase in the number of nodes with increasing physiological age of the seed. This is attributed to a higher sprout development rate, which results in longer sprouts at planting and earlier canopy development [4].

According to Vos [1], leaf size can be analysed in terms of the rate of expansion and the duration of expansion. The leaf area expansion rate is affected by genotype, temperature, moisture, nitrogen and available leaf assimilate [6, 14, 15]. The rate of leaf expansion increases with temperatures up to an optimum temperature of 20 - 25 ºC and decreases thereafter [4]. The minimum temperature for leaf expansion is reported to be ~7 ºC [16]. Final leaf size and the maximum leaf area index vary with genotype [6, 15].

Kirk and Marshall [8] report that the thermal time duration for the expansion phase of leaves on the main stem is relatively constant at about 150 - 200 ºCd (> Tb 0 ºC) up to leaf position 10. At higher leaf positions, the thermal time duration was similar or greater. The same authors report that final leaf size increases with leaf position up to a maximum area and then decreased at higher leaf positions.

Despite a higher node and leaf number on the main stem, physiologically older seed may have a lower maximum leaf area [4]. Kirk and Marshall [8] report more stems and smaller fully expanded leaf area associated with older seed. It is assumed that this is due to competition between main stem leaves for growth substrate. In addition, the leaf expansion rate decreases with seed age [17].

The rate of leaf senescence in potato is reported to be 100 to 136 ºCd per leaf (> Tb 0 ºC) [7]. A fully expanded leaf is estimated to have a lifespan of 460 ºCd at 20 ºC. According to Vos and Biemond [7] the lifespan of leaves is influenced by leaf position in a similar manner to the dependency of full-grown leaf area on leaf number. Leaves with the largest full-grown area have the longest life span, i.e. middle leaves on the main stem. Plants from physiologically older seed tubers are known to senesce and mature earlier [4, 18] however no reference could be found for an estimate of leaf senescence rate for plant grown from seed tuber of different physiological age.

2. Methodology

2.1. Experimental design and treatments
The trial was established in a glasshouse at the University of Tasmania Horticultural Research Centre (42º50’S, 147º21’E). The experiment consisted of two treatment factors, namely cultivar (i.e. Atlantic and Russet Burbank) and seed tuber physiological age (i.e. young and old). Seed materials were obtained from commercial seed and previously hand graded to a range between 50-60 g. The physiologically older seed tubers were created by following the aging treatment described in Ridwan et al. [19]. The trial was set up as a complete randomized block design in a glasshouse with four replicates.

2.2. Plant management
The plants were grown in bag pots under non-limiting nitrogen and water conditions. One seed tuber was planted in each pot to a depth of 15 cm. Each bag was 35 L in volume and filled with potting mix comprised of composted pine bark and coarse sand (4:1 ratio) containing 3 kg/m³ Osmocote Plus (a slow release fertiliser with N:P:K:Mg ratio of 16:3.5:10:1.2 plus trace elements of S, B, Fe, Mn, Mo, Zn and Cu), 4 kg/m³ dolomite, 0.75 kg/m³ FeSO4 and 0.75 kg/m³ Wettasol Granules). A topdress application
of Osmocote Plus was made at 40 days after sowing at a rate of 50 g/bag. Each pot was irrigated to field capacity with drip irrigators (application rate of 24 litres per hour) at a frequency of once each day up until emergence and twice a day thereafter. Surplus water was allowed to freely drain from holes in the base of the bags. Pests and diseases were controlled using both chemical pesticides and biological control methods. The plants were sprayed with Neemtech (300 ml/10 Litres) and Crown 2 ml/10 litres) at 30 days after sowing to control white flies (*Trialeurodes vaporarioum*). After that the white flies were controlled with *Encarsia Formosa*, applied at 60, 70 and 95 days after sowing.

2.3. Observations and sampling procedure
Node (leaf) appearance was recorded by monitoring the occurrence of new nodes on the main stem. The number of nodes on the main stem and branches were counted throughout the experiment every two days and each new leaf was numbered on the lamina with a permanent felt pen until the occurrence of the first flower. The rate of node appearance on the main stem to the first flower was calculated as the slope of the linear regression fitted to the plot of leaf number versus thermal time (above a base temperature of 2 °C). The time of full leaf expansion was determined by monitoring (non-destructively) the length and width of each leaf (terminal leaflet only). When there was no change in these dimensions, the leaf was said to be fully expanded.

Leaves were considered to have senesced when 50% of the leaf turned yellow. The leaf was then detached from the plant and the time noted. Detached leaves were then brought back to the laboratory for determination of individual leaf area using the leaf scanner (EPSON Expression 10000 XL). Glasshouse temperature was monitored using a tiny tag data logger to enable thermal time calculation.

2.4. Statistical analysis
Analysis of variance procedures were performed using SPSS software (v. 14.0, SPSS Inc. 2005) to determine the significance of measured plant responses to treatments. The responses tested were leaf area and leaf number on main stem nodes and branches. Further analysis of leaf appearance and senescence rates was performed using SAS (v. 9, SAS Institute, Cary, North Carolina, USA) in order to fit linear regression lines and to analyse the significant difference of regression parameter values e.g. slopes of each treatment.

3. Results

3.1. Stem number per plant
Stem number per plant was significantly affected by cultivar only (p<0.05). Cultivar Russet Burbank had an average of 4.5 main stems (average across all treatments and replicates) per plant compared to 2.7 main stems for cultivar Atlantic. There was no significant differences (p=0.31) in stem number between older and younger seed tubers although older seed appeared to have higher stem number. Observation on the day of emergence also revealed that older seed had more leaves at emergence than younger seed for cultivar Russet Burbank but not for Atlantic.

3.2. Leaf appearance
The appearance rate of fully expanded leaves on the main stem increased linearly with thermal time (figure 1). There was no seed age effect on leaf appearance rate (p = 0.988) in the case of cultivar. Atlantic with leaves appearing at a similar rate of ~57 °Cd per both young and older tubers. In contrast, leaf appearance rates for cultivar Russet Burbank did vary significantly with seed age (p<0.001). That is, older seed tubers had a faster leaf appearance rate of 39.5 °C d per leaf (0.025 leaves per day degree) compared with 51.2 °C d per leaf (0.02 leaf per day degree) for younger seed. The total number of nodes on the main stem until the first flower ranged from 13 to 16 nodes and 14 to 15 nodes for cultivar Atlantic and Russet Burbank, respectively.
Figure 1. The appearance of fully expanded leaves of cultivar Atlantic (a) and R. Burbank (b) of plants from young seed (◊, -----) and old seed (□, -----).

3.3. Leaf senescence
Leaves on the main stem were observed to senesce linearly with time (figure 2). There was no significant effect of seed age and cultivar on the rate of senescence of the leaves on the main stem nodes. A single regression line fitted across all measured responses of cultivar and seed age treatments resulted in a rate of leaf senescence of 102 °Cd per leaf (0.01 leaves per day degree). While the differences were not significant, physiologically older seed tubers tended to senesce earlier (488.7 °Cd) than younger tubers (610.4 °Cd).

Figure 2. Senescence of leaves on the main stem nodes across all measured responses of cultivar and seed tuber physiological age treatments. Each data point is an average of 4 replicates.
3.4. Individual leaf area per main stem node
The leaf area of successive leaves on the main stem node initially increased up to about node 7 or 8, and then plateaued until about node 11 before decreasing at higher node numbers (figure 3). In the case of cultivar Atlantic, seed age did not significantly affect fully-expanded leaf size. However, in the case of Russet Burbank, leaves of plants established from young seed were larger than those associated with older seed (p<0.01).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Individual leaf size of leaf on main stem node for Atlantic (a) and R. Burbank (b) for young seed (∆) and old seed (□). Each data point is an average of 4 replicates.}
\end{figure}

3.5. Branching
Canopy architecture was found to vary between the two cultivars and seed ages in this study due to differences in leaf area profile, stem number per plant and the location of branches on the main stem and associated leaf area. Figure 4 shows the total fully expanded leaf area for each main stem node, comprised of the sum of the main stem leaf and branch leaf area (arising from that node). Across the cultivars and seed age treatments, branching varied according to node position on the main stem. More leaves due to branches were found on basal and apical region of the plant than on the nodes in the middle region (p<0.01).
Figure 4. Total leaf area (main stem + branch leaves) of cultivar Atlantic (a) and R. Burbank (b) established from physiologically younger seed tuber (-----□-----) and older seed tuber (___◇___). Each data point is an average of 4 replicates.

4. Discussion

This study has shown that seed age and genotype have a significant influence on many of the component processes of leaf growth. Russet Burbank had significantly more main stem nodes per plant compared to Atlantic. While not significant, older seed tended to have a higher number of main stems per plant. The response of leaf appearance to seed age was cultivar specific with older seed of Russet Burbank having faster leaf appearance compared with younger seed. As a consequence, leaf on plants grown from older Russet Burbank seed, senesced earlier than leaf derived from younger seed, although the difference was not significant. The response of leaf senescence to seed age was also cultivar specific with younger Russet Burbank having larger leaf area profiles than Atlantic. Genotype and seed age differences were found for the location and extent of branching on the main stem. These results are in line with previous findings by Fleisher & Timlin [2], Firman et al. [6], and Knowles and Botar [17], that plants from older tubers are more likely to have earlier emergence and a higher leaf number and development rate at an early growth stage. Similarly, Struik and Wiersema [4] and Asiedu et al. [18], report that plants from older seed have smaller maximum leaf area and earlier senescence. Cultivar differences have previously been reported by Firman et al. [6]. In their work, a decrease in the phyllocron
with advancing seed age was found with cultivars Home Guard and Estima but not with other cultivars that were evaluated. These authors argue that the existence of nodes in older seed tubers before planting can lead to a faster rate of leaf appearance. While no observations were made of the initial node number at planting; in the case of Russet Burbank, older seed had more leaves at emergence than younger seed.

5. Conclusions

Potato plants grown from physiologically old tubers had a significantly higher leaf appearance rate, senesced earlier, had more branching and smaller leaf size. The effect of the physiological age of the seed tubers varied between cultivar with Atlantic did not show any differences between the seed ages. Node appearance rate in cv. Russet Burbank plants were 39.5 °Cd per leaf and 51.2 °Cd per leaf for the plants grown from physiologically older and younger seed tubers, respectively. No significant difference was found in the leaf senescence rate either between seed tubers ages or cultivars. A leaf senescence rate of 102 °Cd per leaf was calculated. More branching was found in the plant established from physiologically older seed tubers.

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