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Seed Potato Performance after Storage in Light at Elevated Temperatures

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Abstract

In regions with short growth seasons it is of great importance to use potato (*Solanum tuberosum* L.) seed tubers with a high growth vigour and a short growth cycle. Such qualities may be obtained by treatments advancing the physiological age of the seed tubers. In this study we have exposed tubers from four cultivars to various combinations of temperature and light conditions (green-sprouting) for 3-7 months in controlled climate. Subsequent sprout quality, seed tuber health and performance were studied in laboratory, greenhouse and field trials. Satisfactory short, sturdy and leafy sprouts were produced even after 7 months storage at 15 °C under light exposure. An assay of black scurf (*Rhizoctonia solani*) on the tuber skin showed that light exposure significantly reduced the occurrence compared with dark-stored tubers, while the average effect of storage temperatures was insignificant. In general, green-sprouting advanced emergence and plant growth by 1-2 weeks, and showed early tuber initiation and growth, compared to untreated material. Yields, 107 days after planting in the field trial, did not deviate significantly from untreated tubers. However, plant development at harvest was in accordance with general responses to physiological ageing of potato seed tubers, i.e. still tall and immature plants from untreated tubers, and short and mature plants from aged tubers. Results demonstrated the possibility of successful long-term storage of potato seed tubers in light at elevated temperatures and a potential for earlier harvests and higher early yields from such treatments.

Keywords: Black scurf, Growth cycle, Light exposure, Physiological age, *Solanum tuberosum,* Sprouting

Introduction

Potato crops in short seasons are usually harvested at an immature green-haulm stage. Yield potentials are therefore seldom reached and tubers may be less robust against physical damage and pathogens during harvest. With such limited growth conditions it is of greatest importance to use suitable cultivars and also seed tubers with high early growth vigour and a short growth cycle, i.e. physiologically aged tubers (van der Zaag and van Loon 1987; Struik and Wiersema 1999). Although having a lower yield potential than at younger age, such seed tubers may also benefit growers in regions with longer seasons, e.g. to reach markets earlier, for better harvest conditions or to avoid late season disease spreading.

Elevated storage temperatures, a temperature ‘shock’ just prior to planting or pre-sprouting in light are normal procedures for increasing the physiological age of seed tubers (Essah and Honeycutt 2004; Eremeev et al. 2008; Johansen and Mølmann 2017). Exposure to light during pre-sprouting (‘green-sprouting’) secure short and robust sprouts, in contrast to long sprouts developed in darkness which easily falls off at planting (Moll 1985). Therefore, longer durations of pre-sprouting at elevated temperatures need to be performed with light exposure to keep sprouts attached to the tubers.

According to Scholte (1989), light increases the vigour of the sprouts and may also slow down the physiological ageing of the tuber itself. The tuber may thereby maintain the growth vigour even if sprouts are lost or removed. Light also increases the content of chlorophyll, chlorogenic acid, glycoalkaloids and other substances in the tubers that may have positive effects on resistance against pathogens (Dao and Friedman 1994; Naik and Sarkar 1997; Percival et al. 1998a, b).

Based on the knowledge of the effects of light on sprouts and tubers, diffuse light storage (DLS) of seed tubers at ambient temperatures has become an established practice in developing countries where cold-store facilities are unavailable (Potts et al. 1983; Babarinsa and Williams 2015). Seed tubers may in this way be stored successfully up to 8-9 months in small rustic ventilated stores in tropical regions with mean temperatures well above 20 °C. In temperate regions, and with the possibility for cold storage during winter, DLS may seem irrelevant. However, the potential of long-term green-sprouting for improved seed-tuber health, and for accelerated crop development, remains to be investigated.

The main aim of this study is therefore to investigate effects of various long-term green-sprouting treatments on potato seed-tuber quality and performance. We include four potato cultivars of various earliness and the study comprises the following objectives: 1) to monitor sprout development and quality, 2) to assess incidence and development of skin blemish diseases on tubers, 3) to assess early growth vigour in greenhouse trials, and 4) to assess plant growth and yields in a field trial.

Materials and Methods

General

Experiments were carried out in 2013-2015 at the phytotron of The Arctic University of Norway (UiT), and in greenhouse and field facilities at the Norwegian Institute of Bioeconomy Research (NIBIO), both located in Tromsø, Norway (69.7°N, 18.9°E). Treatments starting in 2013 were carried out in natural-daylight chambers (± 0.5 °C) with 24 h artificial light supplement (Philips TLD 58W/840: Eidhoven, The Netherlands). Likewise, in 2014, in dark chambers equipped with artificial light (Osram DULUX ® EL Longlife 20W/41-827, Made in Germany). Relative air humidity (RH) was 60-70% for treatments starting in 2013, and 80-90% for treatments starting in 2014. Photon flux at seed tuber level in the daylight chambers varied from 10-40 µmol m^{-2} s^{-1} depending on time of year and daily sunlight conditions. In the dark chambers, light conditions were stable at 6-8 µmol m^{-2} s^{-1}.

Cold-storing treatments (control) were carried out in a vegetable store at 4 °C, 80-90% RH and darkness.

After treatments, studies of seed-tuber growth vigour were carried out in a greenhouse at ambient temperatures (18-25 °C) and natural light conditions (150-200 μmol m^{-2} s^{-1}), during a growth period of less than two months (see Tables 1 and 2 for details). A field trial for growth and yield evaluations was planted on loam soil in late May 2015 and harvested in mid-September (end of season). Although average air temperature for the growth season (May – September) is low at these high northern latitudes (about 11 °C), acceptable yields can be obtained due to compensation from long daily photosynthetic light periods.

Seed Tuber Material and Treatments

On-site propagated potato seed tubers, based on pre-basic material of the cvs. Asterix (medium late, fresh market and processing) and Gullauge (medium late, fresh market), were used in the first experimental year. Tubers were harvested directly in mid-September without previous haulm killing. In the second year, pre-basic seed tubers of the cvs. Folva (medium early, fresh market and processing), Mandel (late, fresh market), Gullauge and Asterix were obtained from Overhalla Klonavlssenter, Namdalen, Norway. These tubers were harvested in mid-September after being exposed to haulm killing and skin set at moderate soil temperatures (10-14 °C, at 10 cm depth) for a period of about three weeks. After harvest in both years, all tubers were kept ventilated for drying and curing at about 10-12 °C until the treatments started in October. Then, about 100 tubers per treatment within each cultivar were selected and randomly distributed into cages (one layer) for winter storage (6-7 months) at various combinations of temperature and light exposure. The treatments are described below (see also tables and figures for details):

- Control: Cold storage (4 °C constant) in darkness until planting. Etiolated apical sprouts on some tubers (3-5 cm on Asterix and Folva) were removed before planting. Covered cages (only 2013) equipped with light in the dark cold-storage compartment for studying effect of light on seed-tuber health (see Dark-sprouting).
- Green-sprouting, four treatments: 1) Continuous storage in light at 9 °C, 2) Continuous storage in light at 15 °C, 3) Cold-storage in darkness (three months, autumn), followed by storage in light at 15 °C (spring), and 4) Storage in light at 15 °C (three months, autumn), followed by cold-storage in darkness (spring).
- Dark-sprouting: Covered cages beside the cages for light-exposed tubers for comparison with the vigour of green-sprouted tubers, and for study of the effect of light and temperatures on seed-tuber health (only 2013). De-sprouted after treatment.

Sprout Quality and Incidence of Skin Blemish Diseases

The sprouts resulting from the various treatments were visually assessed for overall standard in compliance with demands of practical use, and photographed. The incidence of blemish diseases on tuber skin were assessed only in the first experimental year, on Asterix and Gullauge. Before treatments, two samples per cultivar each containing 20 tubers were taken. Similarly, after treatments, two samples per cultivar were collected from all 10 treatments (5 temperature regimes, with and without light exposure). From each tuber, three 1.5 cm^2 sections of the skin were cut and incubated in darkness at 15 °C for 8 days and examined for occurrence of inoculum according to Nærstad et al. (2012). The disease incidence was calculated as the percentage of skin sections with visible fungal structures of the 60 skin sections per sample (3 sections × 20 tubers).

Early Growth Vigour - Greenhouse Trials

In April 2014 and 2015 respectively, 10 evenly sized tubers (40-50 g) from each green-sprouting treatment, along with control tubers, were planted in a 3:1 (*v*/*v*) fertilized peat/perlite mixture in 1.5-l pots. For each cultivar, rows with 10 pots for each treatment were arranged side by side on a greenhouse table. Inter-row and inter-pot space were increased during canopy expansion to avoid neighbour effects. A standard nutrient solution (Junttila 1980) was supplied on demand from about 20 cm plant height. Date of emergence for each plant was registered and plant height (highest upper leaf base), stem numbers, number of tubers (incl. stolon tip swellings above approx. 10 mm), tuber biomass and above-ground biomass were recorded on individual plants after a 7-8 weeks growth period.

Growth and Yield - Field Trial

In May 2015, green-sprouted and control tubers (50-70 g) were planted in a field trial with a randomized factorial split-plot design. The four cultivars were distributed to the large plots within each of three replicates. Within large plots, tubers from each treatment were hand-planted in small plots, each consisting of one 6 m row with twenty tubers each. Tubers were spaced 30 cm apart and rows spaced 72 cm apart. Guard plants were established at the ends of each small-plot row, and guard rows were planted on both sides of the field experiment. A standard fertilizer (Fullgjødsel ®, NPK 12-4-18) was broadcast and incorporated into the soil before planting, aimed at giving 80 kg N ha^{-1}. At emergence, a visual grading of plant establishment for each treatment was performed when the highest plants within the trial were about 15 cm (grading 1-9, 1 = no visible plants, 9 = plant height about 15 cm). Late in the growing season (mid-August), plant height (highest upper leaf base) was measured on five successive plants in each small plot. At harvest (end of season), a visual estimation of haulm maturity (percent green haulm) was performed, before tubers were dug by hand. Total tuber yield for each plot was registered and average tuber weight calculated from a sample of about

3 kg. Tuber dry matter concentration (DM) was calculated from the specific gravity of a 2-kg sample per plot.

Statistics

Analysis of variance (ANOVA) was used for data analyses (Minitab 16, GLM procedure, Microsoft, State College, PA, USA). Data for the skin blemish diseases after treatments were subjected to a two-way analysis (temperature, light) for each cultivar. Early vigour data from the greenhouse trials were subjected to a one-way analysis (storage conditions) for each cultivar, and for each year, due to different tuber seed material. For the field trial (2015, split-plot design), factors in the analysis were blocks (random), cultivar (large plots, fixed) and treatment (small plots within large plots, fixed). The interaction, cultivar × block, was used as the error for testing the effect of cultivars. Finally, results within each cultivar were subjected to one-way analyses with treatment as the sole factor. In analyses with significant differences between treatments ($p \leq 0.05$), Tukey's multiple comparisons test was used at significance level $\alpha = 0.05$.

Results

Sprout Quality and Incidence of Skin Blemish Diseases

Tubers exposed to light turned green and developed green, leafy and sturdy sprouts, with some root development (Fig. 1). Apical dominance was clearly pronounced, but number and length of sprouts varied with cultivar and treatment conditions. In general, for light-exposed tubers, continuous treatments at the highest temperature (15 °C) developed the longest sprouts. The autumn treatment at this temperature led to some development of green apical sprouts due to dormancy release. These sprouts continued some etiolated elongation during the following cold storage in darkness, and became weak with the risk of falling off at planting. Less shrinkage, but more root development, occurred after treatments starting in 2014 (high air RH) compared with the previous year with lower RH.

The occurrence of skin blemish diseases, before treatments started, varied between cultivars. For Asterix, about 26% of the incubated tuber-skin sections had black scurf (*Rhizoctonia solani*). Other diseases were absent (silver scurf, *Helminthosporium solani*) or present in less than one percent of skin sections (skin spot, *Polyscytalum postulans;* black dot, *Colletotricum coccodes*; and powdery scab, *Spongospora subterranea*). For Gullauge, about 42% of tuber sections had black scurf, about 6% had silver scurf and less than 3% contained skin spot. Black dot and powdery scab were not found on Gullauge.

After treatments, statistical analyses were performed for black scurf (both potato cultivars) and for silver scurf (Gullauge). Other diseases were still absent or with minor occurrence. Storage temperature showed no significant effect on the development of black scurf for both Asterix (P=0.281) and Gullauge (P=0.112). Light exposure, however, significantly inhibited the development of this disease on both Asterix (P=0.001) and Gullauge (P=0.041), compared to dark storage (Fig. 2). For Asterix, the average percentage of skin sections with black scurf were about 45% and 26% for dark-sprouted and light-exposed tubers, respectively. Similar numbers for Gullauge were 61% and 50%. The occurrence of silver scurf on Gullauge was not significantly affected by temperature or light exposure during storage (data not shown).

Early Growth Vigour - Greenhouse Trials

For the medium late cultivars Asterix and Gullauge, green-sprouting reduced time until emergence by 1-2 weeks compared to 4 °C control, and also increased tuber biomass significantly (Tables 1, 2). The autumn treatment had the least effect, but still with slightly earlier emergence and increased tuber biomass compared to control. For the earliest cultivar, Folva, only continuously or spring green-sprouting at 15 °C reduced emergence time (about one week), and increased tuber biomass compared to control (Table 2). The autumn treatment had only minor effects for this cultivar. The late cultivar Mandel had a strong effect from all treatments at 15 °C, with about two weeks reduction in emergence time and clearly increased tuber biomass. Only for this cultivar, the results from the autumn treatment were comparable to continuous or spring green-sprouting at 15 °C. The least influence, while still significant, occurred after green-sprouting at 9 °C (Table 2).

Early above-ground plant development (plant heights and haulm biomass) was also clearly affected by the treatments, although with varying results between trials and cultivars. Asterix and Gullauge, except the autumn treatment, had significantly greater heights and haulm biomass than the control in 2014 (Table 1). In 2015, however these two cultivars, along with Folva, were mainly at similar levels or lower than the control (Table 2). For Mandel, both plant heights and haulm biomass were significantly greater than the control in 2015 (Table 2). Stem numbers did not differ significantly from the control for any treatments, but for the cvs. Asterix and Gullauge there was an overall tendency for more stems after the autumn treatment than for the other green-sprouting treatments.

The effects of most dark-sprouting treatments were small compared to the cold-stored control (data not shown). Nevertheless, de-sprouted Gullauge, after dark-sprouting at elevated temperatures, emerged 3-6 days earlier than the control. Similarly, long-term treatments at 15 °C (continuously or only in spring) significantly increased early tuber biomass for Gullauge and Asterix, although at a much lower level than for green-sprouting (18 and 36 percent of the results for these two cultivars, respectively).

Growth and Yield - Field Trial

The complete analysis showed significant differences between treatments (all or some) and control for emergence (*P*<0.001), haulm maturity (percentage green haulm, *P*<0.001) and tuber yield (*P*=0.004), but not for average tuber weight (*P*=0.155) and dry matter concentration (*P*=0.160). Besides these effects, and differences in growth and yield between cultivars, the complete analysis also showed a cultivar × treatment interaction for emergence (*P*<0.001) and average tuber weight (*P*=0.008). Therefore, results for each cultivar are presented (Table 3).

For all cultivars, all treatments clearly accelerated emergence compared to the control. Overall, green-sprouting at 15 °C, no matter the duration, gave the highest scores. There was also a trend for these treatments to show most maturity symptoms at harvest (i.e. less percentage of green haulm), especially at the highest accumulation of temperature. Total yield and DM content at end of season did, however, not differ significantly from the control for any treatment, except for Mandel. This cultivar had a slightly higher yield at autumn light treatment than at control treatment. Analyses across cultivars, however, showed significantly higher yields than control for all treatments, except for continuously green-sprouting at 15 °C (data not shown). Other results for the various cultivars showed few significant differences between treatments and control, but rather some different tendencies. For example, for green-sprouted Asterix, average tuber weights seemed higher than the control, and oppositely for Mandel, with a tendency to lower tuber weights (Table 3).

Plant heights at late season in the field were clearly different between treatments, and showed approximately the same pattern for all cultivars (Fig. 3); plants from the physiologically youngest seed tubers (control) were clearly tallest and plants from the oldest seed tubers (green-sprouted at 15 °C) were shortest.

Discussion

The results indicate that long-term storage of potato seed tubers in light at elevated temperatures may be an alternative for some potato growers. Such continuous light exposure, or only during the last 3-4 months before planting, secures relatively short and robust sprouts, and the treatments advance emergence and plant growth considerably. It gives an opportunity for earlier harvests, for higher early yields, for more mature yields in short season regions and the use of later cultivars than otherwise. Our results also indicate that late maturity types may benefit most from such treatments. Light exposure also seems to inhibit development of black scurf on seed tubers during storage.

However, tuber yield and DM concentration after such treatments, may not always deviate much from use of untreated seed tubers. This was the case in our field trial, although temperature accumulation during treatments varied from 0 d° (day-degrees > 4 °C) for control to 2310 d° for continuous treatment at 15 °C. This may seem un-expected in the light of physiological age theories (van der Zaag and van Loon 1987), but can be explained by the time of harvest. Earlier harvests would normally favour the green-sprouted treatments over the control, in accordance with the earlier plant and tuber growth. And similarly, fully developed control plants would normally out-yield plants from green-sprouted seed tubers in a longer season.

Unfortunately, we were not able to include more than one harvest date, but a previous investigator (Rykaczewska 2013) had demonstrated the effect of using physiologically young and old (green-sprouted) potato seed tubers in a long season with a completed growth cycle. She found the highest tuber yields after use of the physiologically youngest seed tubers (dark-stored, 3 °C), in contrast to significantly lower yields for older seed tubers that had been green-sprouted for six months at 18 °C. Nevertheless, more precise knowledge on the effects of green-sprouting in various season conditions are required.

In the current study, apical dominance of sprouts was strongly pronounced without consistent effects on stem numbers per plant or average tuber weights at harvest. This is in accordance with a previous study showing similar inconsistent responses to green-sprouting between cultivars (Moll 1985). Our results demonstrate that controlled manipulation of size-grading by green-sprouting may be difficult, probably due to the many factors and interactive mechanisms that are involved in determining the number of tubers per stem (Struik et al. 1990). We did not investigate the effect of daily duration of light exposure on seed performance in our studies. However, our results showed high seed vigour after long-day light exposure, in accordance with a previous study showing minor effects of photoperiod at low temperatures (16 °C, Struik and Wiersema 1999, p. 126). In contrast, these authors found that long-term storage of seed tubers at high temperatures (e.g. 28 °C) in long days (24 h) may be disastrous for seed vigour, especially after de-sprouting. Neither did we investigate various levels of daily light intensity and air humidity for optimal sprout quality. Therefore, in addition to the effect on sprout growth, light intensity needs more attention due to the possible suppression of skin blemish diseases. Also, the variation in RH related shrinkage and root development on the seed tubers between the years, demonstrated the importance of finding an optimal air humidity for such long lasting treatments.

Previous studies in Norway have shown that sprouts falling off at planting, or being removed, may reduce yields by about 10% (Rønsen 1977). Also, McGee et al. (1988) refer to delayed emergence and senescence, and often reduced yields, after de-sprouting of both light- and dark-stored tubers compared to tubers with sprouts attached. Our results support these findings, although we did not investigate the growth vigour of de-sprouted seed tubers after green-sprouting. The benefits of pre-sprouting therefore presuppose that sprouts are kept on during planting, as stated by van der Zaag and van Loon (1987). Based on a review of studies, they concluded that only tubers planted in the state resulting from their physiological age, e.g. with or without sprouts, could support the general view of seed-tuber performance after physiological ageing.

Our results clearly demonstrate that the use of plant height as an indicator of seed tuber vigour may be confusing if carried out too late. Such growth vigour has been defined as the potential to develop a vigorous plant stand after a reasonable short period of time (Struik and Wiersema 1999), which is at an earlier growth stage than in some of our measurements of plant height. In accordance with the general physiological age theories (van der Zaag and van Loon 1987), the growth curve for physiologically young, and late developing seed tubers, will at some point in the growth season cross the curve for older seed tubers, with early development. A similar height at a certain date, as for some of our measurements, may therefore relate to the point of time where plants still developing from younger seed tubers are catching up with plants from the older seed tubers.

In conclusion, light exposure inhibits sprout elongation, and allows successful long-term storage of potato seed tubers at elevated temperatures (3-7 months at 9 and 15 °C). Treatments advance emergence by 1-2 weeks with the potential for earlier harvests, higher early yields, more mature yields in short season regions and the use of later cultivars than otherwise. Light exposure also seems to inhibit development of black scurf on seed tubers during storage.

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Figure captions

Fig. 1 Potato seed-tuber status after various storage conditions during 170 days from October 2014. Rows (cultivars) from top: Mandel, Gullauge, Folva and Asterix. Columns (treatments) from left: Control (dark-storage at 4 °C), light exposure at 9 °C, light exposure at 15 °C, dark-storage at 4 °C first 90 days followed by light exposure at 15 °C, light exposure at 15 °C first 90 days followed by dark-storage at 4 °C

Fig. 2 Occurrence of black scurf (*Rhizictonia solani*) (with SE indicated, *n*=2) on potato seed-tuber skin after 177 days storage in light and darkness from 1 October 2013. Light exposure continuously (cont.) or only at 15 °C for the last 87 days of storage (4 °C/15 °C) or at 15 °C for the first 90 days of storage (15 °C/4 °C). Occurrence was measured as percentage of 60 seed tuber pieces per sample with mycelium or sclerotia. Before treatments started, the percentages were 26 and 42 for Asterix and Gullauge, respectively

Fig. 3 Average potato plant heights (with SE indicated, *n*=15) in the field on 10 August 2015 after various storage conditions during 210 days from 27 October 2014. Bars within cultivars not having any lowercase letters in common are significantly different by Tukey's multiple comparisons test ($\alpha = 0.05$)

Table 1. Early growth vigour in the greenhouse (2014) after various storage conditions for potato seed tubers (*Solanum tuberosum* L.)

	Control 4°C Dark	9°C Light	15°C Light	4°C/15°C[a] Dark/Light	15°C/4°C Light/Dark	*P*-value
cv. Asterix						
Emergence (days)	20.3a	11.1c	8.3d	9.5d	15.1b	<0.001
Plant height (cm)	17.0b	38.6a	34.4a	34.1a	17.3b	<0.001
No. of stems	3.2	2.5	2.3	2.3	3.0	0.255
No. of tubers >10 mm	0.9b	4.5a	4.3a	3.5a	1.5b	<0.001
Tuber FW (g)	1.5c	61.0b	85.6a	69.6ab	5.8c	<0.001
Haulm FW (g)	30.0b	76.8a	66.0a	65.8a	29.1b	<0.001
cv. Gullauge						
Emergence (days)	23.2a	12.6c	7.8d	8.9d	15.5b	<0.001
Plant height (cm)	26.0c	64.0a	51.4b	51.0b	29.8c	<0.001
No. of stems	3.2ab	2.1b	3.0ab	3.2ab	4.2a	0.025
No. of tubers >10 mm	2.8b	6.7a	7.3a	7.2a	5.6a	<0.001
Tuber FW (g)	7.6d	61.2b	100.2a	86.5a	32.7c	<0.001
Haulm FW (g)	31.8b	70.2a	71.7a	74.6a	39.4b	<0.001

Average results (n = 10) after 177 days of treatments from 1 October 2013. Planted 18 March 2014 with final registrations after 58 days.

Values within rows not having any lowercase letters in common are significantly different by Tukey's multiple comparisons test ($\alpha = 0.05$).

[a] Conditions first 90 days / conditions remaining period

Table 2. Early growth vigour in the greenhouse (2015) after various storage conditions for potato seed tubers (*Solanum tuberosum* L.)

	Control 4°C Dark	9°C Light	15°C Light	4°C/15°C[a] Dark/Light	15°C/4°C Light/Dark	*P*-value
Cv. Asterix						
Emergence (days)	14.7a	6.1c	6.0c	5.4c	10.6b	<0.001
Plant height (cm)	67.9a	66.2a	56.4b	64.7a	64.1a	0.001
No. of stems	3.4ab	2.2b	2.7b	2.8ab	4.1a	0.003
No. of tubers >10 mm	3.4	3.9	4.8	4.0	4.2	0.179
Tuber FW (g)	20.9d	48.7bc	71.6a	57.1ab	33.2cd	<0.001
Haulm FW (g)	111a	86.5b	87.9b	90.1b	102.4a	<0.001
Cv. Folva						
Emergence (days)	13.0a	10.6ab	5.3b	5.3b	12.1a	<0.001
Plant height (cm)	46.2a	35.2c	38.1bc	35.2c	42.7ab	<0.001
No. of stems	3.4	3.0	3.9	3.2	3.2	0.280
No. of tubers >10 mm	5.4	4.2	4.2	4.6	4.4	0.299
Tuber FW (g)	77.3bc	71.9c	97.2a	84.8ab	71.6c	<0.001
Haulm FW (g)	72.3a	55.0b	55.4b	55.1b	57.0b	<0.001
Cv. Mandel						
Emergence (days)	22.2a	13.4b	8.3d	9.9cd	10.9c	<0.001
Plant height (cm)	38.4b	51.5a	51.7a	52.7a	50.3a	<0.001
No. of stems	5.3	5.1	5.4	5.8	5.8	0.567
No. of tubers >10 mm	1.4b	7.5a	9.3a	8.5a	7.8a	<0.001
Tuber FW (g)	2.1c	24.6b	51.3a	42.6a	32.9b	<0.001
Haulm FW (g)	65.1b	89.6a	82.5a	88.5a	81.2a	<0.001
Cv. Gullauge						
Emergence (days)	15.5a	8.9c	4.7d	6.6d	11.8b	<0.001
Plant height (cm)	63.6b	67.0ab	60.4b	74.5a	59.4b	<0.001
No. of stems	5.2ab	4.3ab	3.7ab	2.6b	6.1a	0.007
No. of tubers >10 mm	6.9	5.8	6.4	5.6	6.8	0.382
Tuber FW (g)	37.9d	59.0c	94.2a	74.8b	61.3c	<0.001
Haulm FW (g)	92.8	90.9	83.5	88.0	98.2	0.078

Average results ($n = 10$) after 170 days of treatments from 27 October 2014. Planted 15 April 2015 with final registrations after 50 days.

Values within rows not having any lowercase letters in common are significantly different by Tukey's multiple comparisons test ($\alpha = 0.05$).

[a] Conditions first 92 days / conditions remaining period

Table 3. Growth and yield in field trial (2015) after various storage conditions for potato seed tubers

	Control 4°C Dark	9°C Light	15°C Light	4°C/15°C[a] Dark/Light	15°C/4°C Light/Dark	*P*-value
cv. Asterix						
Emergence score (1-9, 9 best)	2.3c	6.3b	7.7ab	8.3a	7.0ab	<0.001
Green haulm at harvest (%)	91.7	78.3	73.3	75.0	80.0	0.051
Tuber yield (Mg ha^{-1})	35.7	40.0	34.5	42.5	38.4	0.130
DM (%)	19.5	20.4	20.9	20.6	20.4	0.055
Average tuber weight (g)	76.4	107.6	111.0	105.5	85.7	0.116
cv. Folva						
Emergence (1-9, 9 best)	2.3d	7.3b	9.0a	9.0a	6.3c	<0.001
Green haulm at harvest (%)	93.3	81.7	65.0	75.0	80.0	0.065
Tuber yield (Mg ha^{-1})	41.3	45.9	45.3	46.6	42.8	0.313
DM (%)	19.4	19.3	19.3	19.3	19.1	0.692
Average tuber weight (g)	62.5	52.2	70.9	53.4	54.4	0.195
cv. Mandel						
Emergence (1-9, 9 best)	2.0c	6.0b	8.0a	7.7a	5.7b	<0.001
Green haulm at harvest (%)	90.0	73.3	58.3	63.3	73.3	0.111
Tuber yield (Mg ha^{-1})	27.6b	30.9ab	28.5ab	28.1ab	31.4a	0.016
DM (%)	25.3	26.4	25.9	25.6	26.1	0.475
Average tuber weight (g)	35.8	31.3	30.3	29.8	39.0	0.068
cv. Gullauge						
Emergence (1-9, 9 best)	3.0 d	6.0 c	9.0 a	9.0 a	7.0 b	<0.001
Green haulm at harvest (%)	65.0	58.3	51.7	61.7	65.0	0.364
Tuber yield (Mg ha^{-1})	30.9	34.2	34.7	34.5	38.8	0.075
DM (%)	23.7	23.6	24.0	23.3	24.0	0.723
Average tuber weight (g)	41.3 b	41.1 b	46.7 ab	50.0 ab	55.2 a	0.018

Average results ($n = 3$) after 210 days of treatments from 27 October 2014. Planted 25 May 2015 and harvested 107 days later.

Values within rows not having any lowercase letters in common are significantly different by Tukey’s multiple comparisons test ($\alpha = 0.05$).

[a] Conditions first 92 days / conditions remaining period