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Influence of the thermal shock and pre-sprouting on potato tuber yield

V. Eremeev[1]*, J. Jõudu[1], P. Lääniste[1], E. Mäeorg[1], A. Selge[1], A. Tsahkna[2] and M. Noormets[1]

[1] *Department of Field Crops and Grasslands. Institute of Agricultural and Environmental Sciences. Estonian University of Life Sciences. Kreutzwaldi 1. EE-51014 Tartu. Estonia*
[2] *Jõgeva Plant Breeding Institute. Aamisepa 1. EE-48390 Jõgeva. Estonia*

Abstract

Thermal shock and pre-sprouting increase the initial development of potato (*Solanum tuberosum* L.) plants, allowing for earlier harvests. Growing early potatoes without pre-sprouting is not economically viable under Nordic climatic conditions. The aim of this research was to determine how seed tuber pre-planting treatments (untreated, thermal shock and pre-sprouting) influence time to emergence, mean tuber weight, the number of tubers per plant, and yield (including yield dynamics). The main findings of this work were that thermal shock shortened the time to emergence by 2-5 days, while pre-sprouting shortened it by 7-12 days. In addition, thermal shock significantly increased the number of tubers produced, although their mean weight was lower than that of the tubers produced by the pre-sprouted plants. The pre-sprouted tubers provided a very early harvest of large tubers; the harvest time for the thermal shock-treated tubers was a little later. The untreated seed tubers were the last to produce harvestable plants.

Additional key words: day after planting, emergence, growth rate, *Solanum tuberosum*, tuber formation.

Resumen

Influencia del choque térmico y pre-brotación en el rendimiento de la patata

El choque térmico y la pre-brotación temprana incrementa el desarrollo inicial de plantas de patata (*Solanum tuberosum* L.), lo que permite una recolección más temprana. El cultivo de patatas tempranas sin pre-brotación no es económicamente viable en las condiciones climáticas de los países nórdicos. El objetivo de este estudio fue determinar qué tratamiento de presiembra de tubérculos para semilla (sin tratar, choque térmico y pre-brotación) influyen en el tiempo de emergencia, el peso medio del tubérculo, el número de tubérculos por planta, y el rendimiento, incluyendo la dinámica del mismo. Se encontró que el choque térmico de los tubérculos acortó el tiempo de emergencia en 2-5 días y la pre-brotación entre 7-12 días. Además, el choque térmico incrementó el número de tubérculos, aunque su peso fue menor que los tubérculos producidos mediante pre-brotación. Un rendimiento muy temprano es posible con tamaño grande de tubérculo aplicando pre-brotación, siendo el periodo de recolección de tubérculos tratados con choque térmico algo posterior. Los tubérculos sin tratar fueron los que mostraron una menor producción.

Palabras clave adicionales: días después de siembra, emergencia, formación de tubérculos, *Solanum tuberosum,* velocidad de crecimiento.

Introduction[1]

Potato (*Solanum tuberosum* L.) consumption trends around the world show that consumers prefer locally-grown tubers, which tend to be fresher and therefore taste better. To satisfy the demand for locally grown potatoes, research is underway to determine the agrotechnical measures that help obtain the best yields of high quality tubers that retain their nutritional quality during storage. To be economically competitive, potato varieties must be able to provide high quality yields as early as possible. The pre-sprouting of seed tubers of early and late potato varieties is widely used in the Netherlands as a pre-planting, yield-increasing

* Corresponding author: viacheslav.eremeev@emu.ee
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[1] Abbreviations used: a.i. (active ingredient), CL (confidence limit), DAP (days after planting), LAI (leaf area index), SE (standard error).

technique (Struik and Wiersema, 1999). Thermal (or thermal shock) treatment is also used to encourage an early harvest; this increases the physiological age of seed tubers and shortens the time needed for the formation of a harvestable crop (Allen *et al.,* 1992; Van der Zaag, 1992a).

If seed tubers are kept at higher temperatures for certain lengths of time during spring, physiologically older tubers are obtained (Van Loon, 1987). This is vital when growing early as well as late potato varieties since the maximum haulm weight and leaf area index (LAI) are obtained earlier; it therefore becomes possible to harvest the economically optimum tuber yield at an earlier date. Physiologically younger plants can be more vigorous, however, and may produce larger yields somewhat later in the growing period (Wurr, 1979).

Temperatures over 30-35°C are rarely used in thermal shock treatment, even for a short time, since potato albumins curdle at 40°C (Kulaeva, 1997). While thermal shock is recognised as a good alternative to pre-sprouting the literature contains little in-depth information on this technique.

The pre-treatment of seed tubers is known to influence plant development and yield structure (Eremeev *et al.,* 2008). The working hypothesis of the present investigation was that a high temperature treatment for a short period has a positive influence on seed tuber maturation contributing to an earlier yield. The aims of this experiment were to analyse the influence of seed tuber thermal shock and pre-sprouting on time to emergence, mean tuber weight, the number of tubers per plant, and yield maturation.

Material and Methods

Experimental site and design

This work was performed during the growing seasons of 2000, 2001 and 2002 at the Plant Biology Experimental Station (58°23'N, 26°44'E), Department of Field Crop Husbandry, Estonian University of Life Sciences (EMU), Kreutzwaldi. A randomised complete block design with four replicates was used (Hills and Little, 1972). The size of the test plot was 21 m^2. The distance between seed tubers was 25 cm and the distance between rows was 70 cm. All experimental seed tubers had a diameter of 35-55 mm; the planting depth was 8 cm. The dynamics of the tuber yield, the number of tubers per plant and mean tuber weight were determined at intervals of 3-5 days; each sampling involved four plants.

Pre-planting treatments

All the seed tubers used in this work were kept in a storehouse at 4°C until the 30th March of each experimental year. Irrespective of the pre-planting treatment to which they were subjected, all were planted on 7th May of each year. Treatments were applied between 30th March and 6th May; the sum of the temperatures above 0°C differed according to each treatment.

The treatments applied were as follows:

1. Untreated seed tubers (T_o) (n = 126). These tubers were kept from 1st April to 6th May (i.e., 37 days) at 4°C. The total accumulated temperature was 148°C.
2. Thermal shock treatment (T_S) (n = 130). The seed tubers were removed from initial storage but, between 1st April and 30th April, were still kept at 4°C (accumulated temperature 120°C). They then spent two days, from 31st April to 1st May, at 30°C (accumulated temperature 60°C), and then another five days, from 2nd May to 6th May, at 12°C (accumulated temperature 60°C). These seed tubers therefore accumulated a total of 240°C (92°C more than in the T_o treatment).
3. Pre-sprouting (P_S) (n = 137). The seed tubers were removed from storage and kept for 37 days, from 1 April to 6 May, at 12°C. During this pre-sprouting treatment they accumulated a total of 444°C (204°C more than in the T_S treatment, and 296°C more than in the T_o treatment).

Plant material

The late maturing variety 'Ants' and the middle-maturing variety 'Piret', both bred at the Jõgeva Plant Breeding Institute in Estonia, plus the early maturing variety 'Agrie Dzeltenie', bred at the Latvian Priekuli State Plant Breeding Station, were used as the experimental plant material. 'Bintje', a middle-maturing variety of Dutch origin widely grown in Europe (Wolf and Van Oijen, 2003), has for years been used as a standard variety in comparative trials under Estonian climatic conditions at the Jõgeva Plant Breeding Institute. It was therefore chosen as the standard variety in the present work for the comparison of total yields.

Soil conditions and analysis

The soil of the experimental field was a *Stagnic Luvisol* according to the World Reference Base for Soil

Resources (1998 classification); the texture was that of a sandy loam with a humus layer of 20-30 cm (Reintam and Köster, 2006).

Soil analyses were performed at the laboratories of the Department of Soil Science and Agrochemistry, EMU. Air-dried soil samples were passed through a 2 mm sieve. The following characteristics were determined: pH (in 1M KCl and in 0.01M $CaCl_2$, 1:2.5 w:v), organic carbon (using the standard Tjurin method), and Ca and Mg in NH_4OAc at pH 7 (Soil Survey Laboratory Staff, 1996). Available P and K were analysed according to the Mehlich-3 method (Soil and Plant Analysis Council, 1992). The Kjeldahl method was used to determine the soil's total N content.

The humus layer of the experimental field had a pH_{KCl} of ≈6.2 and a C content of 1.4%. The plant-available elements in the soil were: Ca 674 mg kg^{-1}, Mg 101 mg kg^{-1}, P 183 mg kg^{-1} and K 164 mg kg^{-1}. The soil total N content was 0.11%. The soil texture was 56% sand, 35% silt and 9% clay.

Weather conditions

During the growth period (May to September), the rainfall in all experimental years was above average for June and July, and below average in May, August and September (Table 1). The air temperature remained similar to the mean for the 32 preceding years (1966-1998), although July was significantly warmer.

Experimental field techniques

The agrotechnical measures employed were typical for potato experiments. Composted manure (60 Mg ha^{-1}) was used as an organic fertilizer before autumn ploughing. The tubers in all treatments were planted on the 7th May each year; inorganic fertilizer (78 kg N, 72 kg P, 117 kg K ha^{-1}) was applied locally at the same time.

The insecticide Fastac 50 [BASF Ag, Germany; active ingredient (a.i.) 100 g L^{-1} alpha-cypermethrin] and the fungicides Ridomil Gold MZ 68 WG (Syngenta, Poland; a.i. 64% Mankozeb and 4% Metalaksyl-M), Acrobat Plus (BASF Ag, Germany; a.i. 90 g kg^{-1} Di Ethomorph and 600 g kg^{-1} Mankozeb) and Shirlan 500 SC (ISK Bioscience Europe S.A, Belgium; a.i.: 500 g L^{-1} Fluazinam) were used for plant protection. Stock solutions were made to provide maximum application rates of 400 L ha^{-1}.

The dynamics of the tuber yield, the number of tubers per plant and the mean tuber weight were determined at intervals of 3-5 days. Four plants were harvested by hand from the test plot at each sampling point. The experiment was terminated at 120 days after planting (DAP).

Statistical analysis

The results were subjected to regression analysis (Mead *et al*., 1993; Lauk *et al*., 1996), using the formula: $y = a + bx + cx^2$; where «*y*» is the argument function, i.e., tuber yield, number of tubers per plant or mean tuber weight, «*a*» is a constant term, «*b*» and «*c*» are regression coefficients, and '*x*' is the number of days after planting. The derivative of the function $(b - 2c)$ indicates the increase in the growth rate of the mean tuber weight or potato yield (Figs. 1 and 2) per day, calculated according to the regression formula ($y = a + bx + cx^2$). Separate regression formulae were found for every variant and the average formulae for multiple years were calculated. Standard errors (SE) and confi-

Table 1. Average monthly temperatures and precipitation in Estonia during the growth period

Month	Temperatures (°C)		Precipitation (mm)	
	Average for 2000-2002*	Average for 1966-1998**	Average for 2000-2002*	Average for 1966-1998**
May	12.0	11.6	42.7	55
June	15.2	15.1	75.7	66
July	19.8	16.7	101.2	72
August	17.1	15.6	75.6	79
September	10.8	10.4	22.2	66

* According to the Eerika weather station. ** Jaagus (1999).

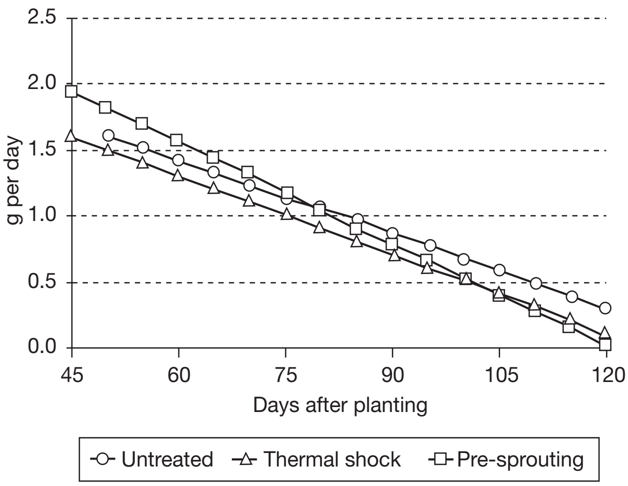

Figure 1. The effect of the different pre-planting treatments on the growth rate of mean tuber weight (mean for 2000-2002 results). Data point values defined according to regression analysis.

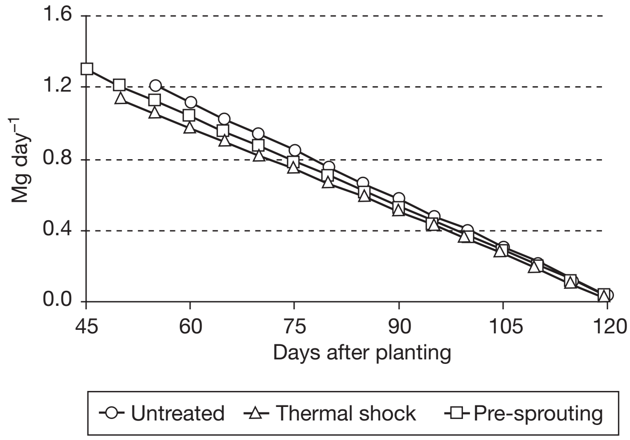

Figure 2. Effect of the different pre-planting treatments on potato yield increase (mean for 2000-2002 results). Data point values defined according to regression analysis.

dence limits (CL_{05}, $P = 0.05$) were calculated using the method of Lauk and Lauk (2000). The calculation of confidence limits was based on Student's theoretical criterion (Mead *et al.,* 1993).

All the data in Tables 2, 3 and 4 were calculated according to the regression formula ($y = a + bx + cx^2$).

To determine the probability of differences between the treatment programmes, least significant differences (LSD_{05}) were calculated according to Lauk *et al.* (2004). Statistica 7 software (Statsoft, 2005) was used for all statistical analyses.

All experimental data are presented as the means for the three years of 2000-2002.

Table 2. Effect of the different pre-planting treatments on the number of tubers produced per plant (mean of 2000-2002 results)

Days after planting	Untreated (T_o)	Thermal shock (T_S)	Difference	Pre-sprouting (Ps)	Difference	
			T_S-T_o		P_S-T_o	P_S-T_S
45		3.5		4.7		1.2
50	4.0	5.6	1.6*	6.2	2.2*	0.6
55	6.0	7.4	1.4*	7.6	1.6*	0.2
60	7.7	9.0	1.3*	8.8	1.1	–0.2
65	9.2	10.4	1.2	9.8	0.6	–0.6
70	10.4	11.5	1.1	10.7	0.3	–0.8
75	11.5	12.5	1.0	11.4	–0.1	–1.1
80	12.2	13.2	1.0	12.0	–0.2	–1.2
85	12.8	13.7	0.9	12.3	–0.5	–1.4*
90	13.1	14.0	0.9	12.5	–0.6	–1.5*
95	13.2	14.0	0.8	12.5	–0.7	–1.5*
100	13.1	13.9	0.8	12.4	–0.7	–1.5*
105	12.7	13.5	0.8	12.1	–0.6	–1.4*
110	12.1	12.9	0.8	11.6	–0.5	–1.3
115	11.3	12.1	0.8	11.0	–0.3	–1.1
120	10.2	11.1	0.9	10.1	–0.1	–1.0
N[1]	126	130		137		
SE[2]	0.3	0.3		0.3		
CL_{05}[3]	0.6	0.7		0.7		
LSD_{05}[4]			1.3		1.3	1.4

* Significant differences ($P < 0.05$) between treatments. [1]N: number of samples. [2]SE: standard error. [3]CL_{05}: confidence limits at $P = 0.05$. [4]LSD_{05}: least significant differences at $P = 0.05$.

Table 3. Effect of the different pre-planting treatments on mean tuber weight (g). Mean for 2000-2002 results

Days after planting	Untreated (T_o)	Thermal shock (T_S)	Difference	Pre-sprouting (Ps)	Difference	
			T_S-T_o		P_S-T_o	P_S-T_S
45		0.9		3.6		2.7
50	4.6	8.7	4.1	13.1	8.5*	4.4*
55	12.4	16.0	3.6	21.9	9.5*	5.9*
60	19.8	22.8	3.0	30.0	10.2*	7.2*
65	26.7	29.1	2.4	37.5	10.8*	8.4*
70	33.1	34.9	1.8	44.4	11.3*	9.5*
75	39.1	40.2	1.1	50.6	11.5*	10.4*
80	44.6	45.0	0.4	56.2	11.6*	11.2*
85	49.6	49.4	–0.2	61.1	11.5*	11.7*
90	54.2	53.2	–1.0	65.4	11.2*	12.2*
95	58.2	56.5	–1.7	69.0	10.8*	12.5*
100	61.9	59.3	–2.6	72.0	10.1*	12.7*
105	65.0	61.7	–3.3	74.4	9.4*	12.7*
110	67.8	63.5	–4.3	76.1	8.3*	12.6*
115	70.0	64.8	–5.2*	77.2	7.2*	12.4*
120	71.8	65.7	–6.1*	77.6	5.8*	11.9*
N[1]	126	130		137		
SE[2]	1.1	0.9		1.1		
CL_{05}[3]	2.5	1.9		2.4		
LSD_{05}[4]			4.4		4.9	4.3

* Significant differences ($P < 0.05$) between treatments. [1]N: number of samples. [2]SE: standard error. [3]CL_{05}: confidence limits at $P = 0.05$. [4]LSD_{05}: least significant differences at $P = 0.05$.

Table 4. Effect of the different pre-planting treatments on potato yield (Mg ha^{-1}). Mean for 2000-2002 results

Days after planting	Untreated (T_o)	Thermal shock (T_S)	Difference	Pre-sprouting (Ps)	Difference	
			T_S-T_o		P_S-T_o	P_S-T_S
45				0.7		
50		4.9		6.9		2.0
55	6.0	10.4	4.4*	12.8	6.8*	2.4
60	11.9	15.5	3.6*	18.2	6.3*	2.7
65	17.2	20.2	3.0	23.2	6.0*	3.0
70	22.1	24.5	2.4	27.7	5.6*	3.2
75	26.6	28.5	1.9	31.9	5.3*	3.4
80	30.6	32.0	1.4	35.5	4.9*	3.5*
85	34.1	35.2	1.1	38.8	4.7*	3.6*
90	37.2	37.9	0.7	41.6	4.4*	3.7*
95	39.8	40.3	0.5	44.0	4.2*	3.7*
100	42.0	42.3	0.3	46.0	4.0*	3.7*
105	43.7	43.9	0.2	47.5	3.8*	3.6*
110	45.0	45.1	0.1	48.7	3.7*	3.6*
115	45.8	45.9	0.1	49.3	3.5	3.4
120	46.1	46.4	0.3	49.6	3.5	3.2
N[1]	126	130		137		
SE[2]	0.9	0.8		0.8		
CL_{05}[3]	1.9	1.7		1.8		
LSD_{05}[4]			3.6		3.7	3.5

* Significant differences ($P < 0.05$) between treatments. [1]N: number of samples. [2]SE: standard error. [3]CL_{05}: confidence limits at $P = 0.05$. [4]LSD_{05}: least significant differences at $P = 0.05$.

Results

Influence of pre-planting treatment on the number of tubers

The number of tubers produced per plant in the T_S treatment significantly exceeded that obtain in the untreated control (T_o) until 60 DAP (Table 2). The number of P_S treated tubers exceeded the 50-60 DAP number of tubers for the untreated plants (T_o). Significant differences between the P_S and T_o treatments were seen between 50 DAP (LSD_{05} 2.2) and 55 DAP (LSD_{05} 1.6). In the period 85-105 DAP, fewer tubers were counted in the T_S treatment (LSD_{05} 1.4) than in the P_S treatment. Based on the three year means, the T_S treatment increased the number of tubers per plant from the start of tuber formation until harvest (significantly so until 60 DAP) compared to the T_o treatment, while P_S significantly increased the number of tubers per plant until 55 DAP. The greatest mean number of tubers per plant was recorded at 94 DAP; in the P_S treatment the greatest numbers occurred at 93 DAP (12.6 tubers), in the T_S programme it occurred at 94 DAP (14.0 tubers), and in the T_o treatment it was recorded at 95 DAP (13.2 tubers).

Influence of pre-planting treatment on the weight and growth rate of tubers

In terms of the mean for the three potato varieties, the P_S treatment increased the mean tuber weight (LSD_{05} 4.9) (Table 3). The T_S significantly reduced mean tuber weight from 115 DAP to harvest (Table 3). Over the entire growth period the weight of the tubers in the P_S treatment exceeded the weight of those in the T_o control programme by 5.8 g to 11.6 g ($LSD_{0.5}$ 4.9), and of those in the T_S treatment by 4.4 g to 12.7 g ($LSD_{0.5}$ 4.3).

The increment in mean tuber weight (i.e., the three year mean) in the P_S treatment exceeded that obtained in the T_o treatment by 0.21 g d^{-1} (Fig. 1). The increase in mean single tuber weight obtained in the P_S treatment was greater than that seen in the T_o treatment by 0.21 g d^{-1} on 55 DAP, while that obtained in the T_S treatment exceeded that in the T_o treatment by 0.31 g d^{-1} from 50 DAP. From 50 DAP to 120 DAP, the increase in mean single tuber weight in the T_S treatment exceeded that obtained in the T_o treatment by 0.10-0.19 g d^{-1}. The smallest increment rate during the 50-100 DAP interval was observed in the T_S treatment tubers.

Influence of pre-planting treatment on yield

Tuber formation had started by 45 DAP (0.7 Mg ha^{-1}) in the P_S treatment; in the T_S treatment this occurred at 50 DAP (4.9 Mg ha^{-1}), and in the T_o treatment at 55 DAP (6.0 Mg ha^{-1}) (Table 4). Both the pre-planting treatments brought forward the start of tuber formation and accelerated it until 60 DAP in the T_S treatment and 110 DAP in the P_S treatment.

From 50-120 DAP, the mean daily weight increment of the T_S tubers exceeded that seen in the T_o treatment by 0.10-0.19 g d^{-1}. From 50-100 DAP, however, it was lower than that recorded in the P_S treatment by 0.02-0.31 g d^{-1}. While both the T_S and P_S treatments led to earlier tuber formation, the tuber weight growth rate in the T_o treatment was higher, exceeding the T_S treatment by 0.15 Mg d^{-1} and the P_S treatment by 0.08 Mg d^{-1} at 55 DAP (Fig. 2). The growth rates of the different treatments were the same at 95 DAP.

Tuber production by the different varieties

In terms of the number of tubers produced per plant, the 'Piret' and 'Agrie Dzelteni' varieties were quite similar with 9.9 and 10.5 units respectively. 'Ants' and 'Bintje' were also similar with 12.2 and 12.3 units respectively (Table 5). 'Bintje' provided the highest mean tuber weight with a yield of 762.9 g per plant-significantly higher than that of either 'Piret' (515.7 g) or 'Agrie Dzeltenie' (550.1 g) but not higher than that of 'Ants' (574.7 g). No significant differences were observed in the yield range (24.4-32.8 Mg ha^{-1}) of the experimental varieties.

Table 5. Number of tubers per plant, weight of tubers per plant and yield produced by the different potato varieties. Means for 2000-2002 results

Variety	Number of tubers per plant	Weight of tubers per plant (g)	Yield (Mg ha^{-1})
Piret[1]	9.9[a]	515.7[a]	24.4[a]
Agrie Dzeltenie[1]	10.5[ab]	550.1[a]	29.5[a]
Ants[1]	12.2[c]	574.7[ab]	31.4[a]
Bintje[2]	12.3[bc]	762.9[b]	32.8[a]

[1] Mean for the variety derived from 15 untreated plants. [2] Mean for the variety derived from 30 untreated plants. Different letters within a column indicate significant differences ($P < 0.05$).

Discussion

The influence of pre-planting treatment on potato emergence and number of tubers

Physiological ageing advances sprout growth, crop emergence, crop establishment and usually improves tuber yields (Burke and O'Donovan, 1998). However, the onset of the different developmental stages and their duration can be quite different depending on the biological characteristics of the potato variety in question, the quality of the seed tuber, climatic and soil conditions, and the agrotechnical measures employed. Some authors report that physiologically older seed tubers allow for faster emergence than their younger counterparts (Iritani, 1968; O'Brien *et al.,* 1983), while others have found no difference (Bus and Schepers, 1978). The experiments of Van Loon (1987), however, showed that physiologically older seed tubers emerge more slowly.

A potato plant usually takes 20-35 days to emerge under Estonian climatic conditions. The time from planting to emergence depends on the treatment of the seed tubers, i.e., the physiological age with which they are invested (Struik and Wiersema, 1999; Jõudu *et al.,* 2002). In this study the T_S and P_S treatments accelerated the emergence of plants by 2-5 days, and by 7-12 days respectively compared to the T_o treatment.

Intensive tuber growth begins when the above-ground parts of the plant have fully developed (when the LAI is at least 4), although different varieties show significant variations (Putz, 1986). Tuber formation in early varieties usually takes place earlier and growth is much quicker than in late varieties. In addition, plants derived from physiologically older tubers of late varieties begin their tuber formation slightly earlier (Van der Zaag, 1992b). The T_S treatment increased the number of tubers compared to the P_S treatment (see Table 2), therefore, the former might be of interest to seed tuber-growing enterprises, whose main purpose is to obtain the maximum number of tubers from one plant. Similar findings were reported by Van der Zaag and Van Loon (1987) and Moll (1985).

The influence of pre-planting treatment on tuber weight

The tuber weight achieved depends on the weather conditions and the available nutrients during the period of tuber formation. It also depends on the growth and development of the leaves and branches, the formation of assimilation products and their distribution between different parts of the plant, the rate of tuber formation, and the perishing time of the haulms (Panelo and Caldiz, 1989). According to Burke (1997), the average weight of tubers increases with their physiological age, but in the present experiment this effect was made manifest only in the P_S treatment (Table 3). This treatment had the strongest influence on tuber weight, returning the highest value (77.6 g) at 120 DAP. According to Putz (1986), after the death of the haulms the growth of the tubers ceases, and the skin hardens and starts to suberize. Decisions taken while planning the harvesting period should not be based on data for years with optimum weather conditions but on average years. At the end of growth period the increase in mean tuber weight occurred mainly at the expense of mean tuber size (35-55 mm) and the production of large tubers (over 55 mm).

The influence of pre-planting treatment and variety on yield

According to Möller *et al.* (2001), the duration of yield maturation can be shortened by 8-14 days by the pre-sprouting of seed tubers. With this treatment the time of maximum yield is shifted to about two weeks earlier; yield losses due to potato late blight are consequently reduced. The present work established that the T_S treatment had a positive effect until mid-August; therefore if harvesting is planned in September, there is no need to thermally treat the seed tubers and bear the extra costs involved, especially if cultivation starts early in the growing season with medium to early varieties. Under certain conditions the T_S treatment could be less labour and energy-consuming than pre-sprouting, e.g., when using thermoregulated storehouses (Jõudu *et al.,* 2002). The present results show that physiologically older tubers have a higher yield potential, with plants reaching their harvesting point more quickly. With the P_S treatment the tubers accumulated more temperature than with the T_S treatment, therefore the P_S seed tubers can be considered physiologically older. The T_S seed tubers were physiologically older than the T_o tubers, allowing them to show a higher growth rate and earlier yield maturation than those of the latter treatment. The gradual maturation of the potato yield helps to lengthen the harvesting period even when growing just one variety. The average Estonian potato yield has recently been as low as 10-18 Mg ha^{-1} (ESA, 2004). The T_S and P_S treatments in the current experiment, however, produced maximum yields by 120 DAP of about 50 Mg ha^{-1}. Yields per hectare ultimately depend on radiation levels, the agrotechnical measures taken by the grower and the potential of the potato variety. Given favourable conditions and using affordable measures, the estimate is that potential yields in Estonia could reach as high as 67-78 Mg ha^{-1}.

In conclusion, for very early potato yields the P_S treatment should be used. Thermal shock would be more efficient in seed tuber production since, while it produces more tubers than in the P_S treatment, their mean weight is smaller. If the purpose is to grow potatoes for consumption then the T_S treatment is a useful tool for achieving early to mid-period yields. The P_S treatment may consume a lot of time and energy, but a very early yield is obtained and the full yield potential can be realised.

Different seed tuber pre-planting treatments allow variations in potato harvest times. A very early yield is possible with P_S-treated tubers while the harvest period for T_S-treated tubers starts in the second half of July or the beginning of August.

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