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The effect of pre-planting treatment of seed tubers on potato yield formation

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Abstract. In the trials conducted in 2000–2002, we examined possibilities for growing potato using different methods of pre-planting treatment of seed tubers.

The varieties exploited were 'Varajane kollane' (early), 'Piret' (medium early) and 'Ants' (medium late). There were used the following ways of treatment for all varieties: PS – pre-sprouting, TT – thermal treatment and 0 – tubers not treated.

The dynamics of tuber yield formation during the vegetation period was significantly influenced by the weather. In terms of potato growth, weather conditions were the most favourable in 2001. The weather in 2000 and 2002 was not the most suitable for potato growth and development, and the yield in these years proved lower than the three-year average.

The average results from the three years show that potatoes could not realise their full potential to reach maximum yield. Pre-planting germination and thermal treatment had positive effects during the entire vegetation period, the effect being stronger at the beginning and then gradually decreasing.

Pre-planting treatment of seed tubers had a different effect on varieties with different growing times.

A comparison between the varieties showed that 'Piret' and 'Varajane kollane' started to form tubers early and thus exceeded the development of the variety 'Ants' until the 60th day of growth. 'Ants' reached its maximum yield, 47.0 t ha^{-1}, already by the 114th day, followed by the fast-ripening 'Varajane kollane' and the medium-ripening 'Piret'. Thermal treatment did not give any advantage in terms of total yield formation compared to untreated seeds, except for the pre-planting germination variant of the variety 'Varajane kollane', the total yield of which exceeded that of its untreated variant by 7.08 t ha^{-1}.

Key words: storage, variety, thermal treatment, pre-sprouting, dynamics, weather conditions

INTRODUCTION

One of the main components of producing a stable and economically viable yield of potatoes are healthy and biologically active seeds with a high yield potential. The emergence of the potato in the field, development of the leafy tops and speed of covering the field area depend on the quality of the seed (Kuill, 2002). In order to keep a high yield potential, we should take all essential measures to increase the yield while preparing for planting. One of these measures – the pre-planting thermal treatment of the tubers or pre-sprouting – is widely used, for example, in Holland (Struik & Wiersema, 1999), not only for the early potato but also for the late potato. Each seed batch has a storage period history consisting of the treatment, cooling, storing and

preparation period. The parameters of all the aforementioned periods has a direct effect on the overall durability of the potato as well as on the yield potential of the tubers (Allen et al., 1992). The Department of Field Crop Husbandry has studied age differences of seed tubers. This article analyses the growth and yield of potatoes considering different techniques that have been applied to influence tubers when they wake up after the dormant period.

MATERIALS AND METHODS

The experiments that we performed in 2000–2002 established the possibilities for growing potatoes, using different ways of treating tubers before planting. The tubers were treated as follows: pre-sprouting (PS); thermal treatment (TT) and untreated tubers (0) (Lõhmus et al., 1999). The medium late variety 'Ants', the medium early variety 'Piret' of the Jõgeva SAI, and the early variety 'Varajane kollane' of the Latvian Priekuli SAJ were used in the experiments. The dynamics of the tuber yield formation was determined by taking samples of all options of each variety. The purpose was to find out which way of treatment was the best for growing potato varieties with different growth periods in Estonian climatic conditions in order to ensure a higher and better yield during the vegetation period. The experiments were conducted using methods developed by the Department of Field Crop Husbandry of the Estonian Agricultural University (Lauk, 1995, 1996; Lauk et al., 1996).

The experiments were performed in the Eerika experimental field of the Department of Field Crop Husbandry of the EAU Faculty of Agronomy, where the soil was LP pallescent (Kõlli & Lemetti, 1995). Agricultural techniques typical of potato experiments were used. The yield formation dynamics was determined in every 3 to 5 days.

As different tuber treatment methods were used, the first samples were taken at different times (Table 1). The sampling time and number of samples were different for different options. The number of samplings also depended on the duration of the vegetation period. The potato vegetation period was extremely long in 2001, ending on day 126. As varieties in different options started to develop tubers at different times, the number of samplings fluctuated each year +/- 3 samples.

Table 1. Yield formation dynamics and the number of tuber samples over the vegetation period.

Value	2000 year	2001 year	2002 year
Number of samples	11–14	14–16	15–17
Days from planting:			
a) to the first sampling	42–56	49–61	36–41
b) to the last sampling	118	126	111
Days from planting to emergence	18–30	23–39	16–27

The results have been processed using the regression analysis method with the following quadratic equation:

$y = a + bx + cx^2$, where

y – argument function, yield calculated on the basis of the equation, t ha^{-1}

a – constant term of the equation,

b and c – regression coefficients,

x – argument, number of days after planting.

RESULTS AND DISCUSSION

Tuber formation is a complex process including the emergence and growth of stolons and the development, growth and ripening of tubers at their top as a result of the accumulation of nutrients. Stolons are horizontal sprouts that emerge from the basal bud of the stem in the ground. The buds that develop stolons emerge at the second stage of organogenesis. There are two morphostructure types at this stage during the realisation of morphogenetic information: sprouts specialising in vegetative reproduction (stolons) and duplicate structures (shoots above the ground) (Markov & Maslova, 1998). Due to the influence of the mother tuber, the potato plant is relatively autonomous for some time after emergence and depends on external conditions less than many other crops.

The dynamics of potato yield formation is significantly influenced by weather conditions. The first experimental year (2000) was chillier than the other two. The sum of air temperatures during the vegetation period was 1715.5°C (which is more than 200°C lower than in the following experimental years). The sum of active temperatures was 555.6°C. This sum varied greatly during the three experimental years. Thus, in the vegetation period of 2001 it was 186.7°C and in 2002 295.2°C higher than in 2000. While the air temperature sums in 2001 and 2002 were almost equal, the sum of active temperatures was 108.5°C higher in 2002. V. Tamm (1982) believes that potato needs 230.5 mm of precipitation during the vegetation period. This figure was exceeded in 2000 and 2002 (by 116.6 mm and 84.8 mm, respectively). However, during the vegetation period of 2001 there was only 162.4 mm of precipitation. The time distribution of precipitation was different in all the three years. Only 66.9 mm of rain fell down during tuber formation and in the active growth period (July–September) in 2002. A significant part (65.7%) of rain fell down during the respective period in 2001. In 2000 most rain (68.5%) fell down in the period from the last ten days of June to the first ten days of August, i.e. from tuber formation to the beginning of the active growth of tubers.

To sum up the weather conditions, the most favourable year for the growth of potatoes was 2001. It was relatively warm and the plants got enough water during tuber formation and intensive growth, whereas the efficient blight control ensured an actively working leaf surface until harvesting.

The findings above have also been presented in Table 2 comparing the yields in different years. During the early tuber formation period the yield was highest in 2002 (day 50 to day 65 after planting) since the weather was then most favourable for potato growth. From day 80 to harvesting, the yield was highest in 2001. The active growth of the tubers was caused by the above-mentioned weather factors. In 2000 the yield was apparently largely influenced by the relatively chilly vegetation period.

Table 2. Formation of tuber yield depending on the trial year.

Day	3. years average	Difference		
		2000-average	2001-average	2002-average
50	4.94	0.00		5.67*
55	10.47	-0.25	-4.11*	4.36*
60	15.62	-0.53	-2.55	3.08*
65	20.39	-0.84	-0.99	1.84
70	24.79	-1.19	0.57	0.62
75	28.80	-1.57	2.14	-0.58
80	32.44	-1.98	3.71*	-1.74
85	35.70	-2.42	5.29*	-2.87*
90	38.59	-2.89	6.86*	-3.97*
95	41.09	-3.39	8.44*	-5.05*
100	43.22	-3.93	10.02*	-6.10*
105	44.97	-4.49*	11.61*	-7.11*
110	46.34	-5.09*	13.20*	-8.10*
115	47.33	-5.72*	14.79*	-9.06*
120	47.95	-6.39*	16.38*	-9.99*
LSD_{05}		4.20	3.27	2.74

Explanation: * – reliability

The accumulation of the average yield during the three years for all the varieties and options can be described by the formula:

$y = -71.1 + 1.899\ x - 0.00756\ x^2$, where $r = 0.983$ and $s_y = 3.05554$

where r = correlation coefficient,
s_y = regression standard deviation.

Physiological age is very important for the development of tuber yield. A physiologically older seed accelerates the growth rhythm of potatoes, due to which the yield develops earlier, while the yield formation ability decreases (Jõudu, 2002). The results also show that the earlier the variety, the greater the effect of treatment and that the yield develops evenly during the vegetation period in varieties with a longer growth period. Obviously, any thermal treatment of seed tubers increases their physiological age (Jõudu, 2002). Thus, both pre-sprouting and thermal treatment to some extent increase the physiological age of tubers.

The main purpose of pre-sprouting is to obtain an earlier yield. In order to gain the yield as early as possible, the pre-sprouting should also start earlier, and sprouting would still take 4 or 5 weeks (Jõudu, 2002). If it is too late for pre-sprouting, the tubers can be stimulated using thermal treatment making them develop faster.

Table 3 confirms that physiologically older tubers provide yield earlier. The average results of the three years show that the potato did not have enough time to realise its full potential. It did not achieve the maximum yield it could provide. Pre-sprouting and thermal treatment had a positive effect during the whole vegetation period.

Table 3. Effect of the seed tuber pre-planting preparation method and of the variety on the yield (the average of 2000–2002, t ha^{-1}).

Day	0	Difference		'Ants'	Difference	
		TT-0	PS-0		'Piret'-'Ants'	'V.koll.'-'Ants'
50				1.44	4.30*	1.78
55	6.05	4.35*	6.74*	8.28	2.49	0.97
60	11.87	3.63	6.33*	14.56	0.93	0.28
65	17.24	2.97	5.94*	20.28	-0.39	-0.28
70	22.15	2.38	5.59*	25.45	-1.47	-0.73
75	26.60	1.87	5.25*	30.06	-2.31	-1.06
80	30.60	1.41	4.95*	34.12	-2.90	-1.26
85	34.14	1.03	4.67*	37.62	-3.24	-1.35
90	37.22	0.72	4.41*	40.56	-3.35*	-1.31
95	39.85	0.47	4.19*	42.95	-3.20	-1.15
100	42.02	0.29	3.99*	44.78	-2.82	-0.87
105	43.73	0.18	3.81*	46.05	-2.19	-0.48
110	44.99	0.13	3.66	46.77	-1.32	0.04
115	45.79	0.16	3.54	46.94	-0.20	0.68
120	46.13	0.25	3.45	46.55	1.16	1.44
LSD_{05}		3.65	3.67		3.25	3.54

Explanations *– reliability
0 = average of non-treated tubers of different varieties
TT = average of thermal treatment tubers of different varieties
PS = average pre-sprouting tubers of different varieties
'Ants' = average of different treatments variety 'Ants'
'Piret' = average of different treatments variety 'Piret'
'V. koll.' = average of different treatments variety 'Varajane kollane'

The effect was first stronger and then gradually decreasing. The thermal treatment provided reliable extra yield (LSD_{05}) during the first samplings (55–65 days after planting), and pre-sprouting until day 110, accordingly. It was established that thermal treatment had a positive effect until mid-August. If harvesting is planned for September, there is no need to thermally treat tubers and bear extra costs, especially in cultivating early and medium early varieties. The experiments have proven that physiologically older tubers have a higher yield potential, particularly during the early period of tuber formation and growth. When pre-sprouting was used, the tubers received more heat than during thermal treatment, therefore pre-sprouted tubers can be considered as physiologically older. The yield difference compared to the untreated option decreased more slowly in the case of physiologically older tubers.

The tubers that were exposed to thermal treatment did not provide a yield higher than expected compared to pre-sprouting. The thermally treated tubers were physiologically older in relation to the untreated option, which enabled faster initial development resulting in the earlier formation of a harvest ripe yield. The tubers that gradually achieve full ripeness also enable the harvesting period to be extended if one variety is cultivated.

Table 4. Effect of the seed tuber pre-planting preparation method on the yields of different varieties (the average of 2000–2002, t ha^{-1}).

Day	'Ants'			'Piret'			'Varajane kollane'		
	0	Difference		0	Difference		0	Difference	
		TT-0	PS-0		TT-0	PS-0		TT-0	PS-0
55	2.84	1.73	8.63*	5.97	5.24*	7.02*	3.53	2.57	8.30*
60	10.04	1.45	7.94*	11.60	4.41*	6.02*	9.84	2.99	7.86*
65	16.60	1.18	7.27*	16.81	3.64	5.12*	15.62	3.31	7.47*
70	22.52	0.90	6.61*	21.60	2.94	4.33*	20.88	3.53	7.15*
75	27.80	0.62	5.97*	25.98	2.30	3.64	25.62	3.65	6.88*
80	32.44	0.35	5.34*	29.94	1.72	3.05	29.84	3.67	6.67*
85	36.44	0.08	4.73*	33.48	1.21	2.57	33.54	3.59	6.52*
90	39.80	-0.19	4.14*	36.61	0.76	2.19	36.71	3.41	6.43*
95	42.51	-0.46	3.56	39.32	0.38	1.90	39.36	3.13	6.39*
100	44.59	-0.73	3.00	41.62	0.06	1.73	41.49	2.75	6.41*
105	46.03	-1.00	2.45	43.49	-0.19	1.65	43.09	2.28	6.49*
110	46.82	-1.26	1.92	44.96	-0.38	1.67	44.17	1.70	6.63*
115	46.98	-1.53	1.40	46.00	-0.50	1.80	44.73	1.02	6.82*
120	46.49	-1.79	0.90	46.63	-0.56	2.03	44.77	0.24	7.08*
LSD_{05}		3.73	4.03		3.80	4.03		3.80	3.94

Explanation: * – reliability

If we compare the varieties, we can conclude that 'Piret' and 'Varajane kollane' start developing tubers early and are ahead of 'Ants' up to day 60 after planting (Table 3). 'Ants' achieved its maximum yield by day 114: 47.0 t ha^{-1}.

Thermal treatment of tubers before planting has a different effect on varieties with different growth periods. Pre-sprouting had the greatest effect on 'Varajane kollane'. During the early tuber growth period it was similar in the medium late variety 'Ants' (in the first three samplings the extra yield was respectively 8.30–7.47 and 8.63–7.27 t ha^{-1}(Table 4).

Thermal treatment had a positive effect on the yield of the early and medium early varieties during the entire assessment period and on the yield of the medium late variety Ants in the first three samplings. Thermal treatment affected most the tuber yield of 'Piret' in the first samplings where the statistically reliable extra yields were 4.41–5.24 t ha^{-1}. In the medium late variety, tubers develop similarly to the early and medium early varieties. Thermal treatment accelerates the accumulation of extra yield in the early period. The pre-sprouted option of 'Ants' provided reliable extra yield until day 90 of growth (+4.14 t ha^{-1}). The 'Piret' tubers that were thermally treated provided extra yield until day 60 of growth and the pre-sprouted option of the same variety provided extra yield until day 70 (+4.33 t ha^{-1}). The pre-sprouted option of the early variety provided reliable extra yield during the entire vegetation period.

Thermal treatment provided no benefit in terms of the final yield compared to the untreated seed, except for 'Varajane kollane'. The pre-sprouted option gave extra 7.08 t ha^{-1} in the final yield compared with the untreated option. The medium late variety

'Ants' achieved its maximum yield fastest of all options, followed by the early 'Varajane kollane' and medium early 'Piret'.

CONCLUSIONS

The yield formation dynamics during the vegetation period is significantly affected by weather conditions. In this respect, the most favourable year for potato growth was 2001. In 2000 and 2002 the weather was not so good for the growth and development of potatoes, and the yield was lower than the three- year average.

The average results for the three years show that the potato did not have enough time to realise its full potential and did not reach its maximum yield. Pre-sprouting and thermal treatment had a positive effect during the entire vegetation period. This effect was first stronger and then gradually decreased.

Thermal treatment of the tubers before planting has a different effect on varieties with different growth times.

A comparison between the varieties showed that 'Piret' and 'Varajane kollane' started to form tubers early and exceeded the variety 'Ants' until the 60^{th} day of growth. 'Ants' reached its maximum yield, 47.0 t ha^{-1}, already by the 114^{th} day, followed by the fast-ripening 'Varajane kollane' and the medium-ripening 'Piret'. Thermal treatment did not give any advantage in terms of total yield formation compared to untreated seed, except for the pre-planting germination variant of the variety 'Varajane kollane', the total yield of which exceeded that of its untreated variant by 7.08 t ha^{-1}.

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