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Field performance of potato minitubers produced in aeroponic culture

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ABSTRACT

The aeroponic system is a viable technological alternative for potato minituber production within a potato tuber seed system. The aim of the study was to evaluate the productivity of potato minitubers grown in aeroponic culture and collected in 14 successive periods of the growing season. The minitubers of cvs. Ametyst and Tajfun were tested in an experimental field after a storage period. It was found that cv. Ametyst was characterized by higher yield and number of tubers than cv. Tajfun. Yield of cv. Ametyst averaged 42.6 t/ha, and cv. Tajfun 37.3 t/ha. The number of tubers over 3 cm of cv. Ametyst averaged 644.2 per ha, and cv. Tajfun 437.7 per ha. The yield and number of tubers was dependent on the physiological age of minitubers harvested on successive dates. Comparing the productivity of minitubers grown in aeroponics and in the soil, a significant difference was found in the number of tubers with a transversal diameter over 3 cm. There were more daughter tubers from minitubers grown in soil. They are the result of different-size minitubers used for planting, smaller ones from aeroponics and larger from soil.

Keywords: number of tubers per hectare; physiological age of seeds; potato tuber yield; Sielianinov hydrothermic coefficient; *Solanum tuberosum*

The introduction of microtubers and minitubers into seed production has revolutionized potato production, resulting in a shortening of the field cycle to obtain an adequate number of seed potatoes and hence guaranteeing a high level of healthiness of base materials (Wróbel 2014).

Microtubers are the first generation of nuclear seed potato and their weights range from 24 to 273 mg (Ranalli 2007). They are easier to transport and handle than plantlets. Minitubers are the progeny tubers produced on *in vitro* derived plantlets or from microtubers. The size of minitubers may range from 5–25 mm although in current systems larger minitubers have also become common (Struik 2007). Minitubers from *in vitro* seed material are usually obtained from cultures growing on different substrates. However, it is an expensive procedure due to reduced productivity of conventional seed multiplication systems (Tierno et al. 2014).

In order to increase the multiplication rate of seed material *in vitro*, multiple techniques have been assayed in the last decades. Aeroponic systems for potato pre-basic seed production were established following increased demand for more efficient, high quality seed production methods (Ritter et al. 2001, Nickols 2005). In this soilless culture system, roots are kept in a dark environment saturated with an aerosol of nutrient solution. In the study of Rykaczewska (2016) the number of minitubers produced was two to three times greater by aeroponic production than by traditional method. Results of this study showed that the aeroponic system is a viable technological alternative for the potato minituber production within a potato tuber seed system and that the cultivar played a significant role in the number of tubers formed. Certainly a full economic analysis including energy cost, labour costs and amortization of material specific to aeroponics is necessary to prove that this production technique can be put into practice (Mateus-Rodrigues et al. 2013). However, the question arises regarding the seed value of minitubers produced in aeroponics and collected repeatedly during the growing season, therefore different in physiological age.

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The aim of this study was to evaluate the productivity of potato minitubers produced from microtubers in aeroponic culture and collected in subsequent periods of the growing season.

MATERIAL AND METHODS

The study was conducted in the years 2013–2014 at the Plant Breeding and Acclimatization Institute in the Research Division at Jadwisin (52°28'44''N, 21°02'38''E).

Minituber production. Minitubers of medium early cvs. Ametyst and Tajfun were produced from the microtubers in aeroponics and in the soil in the years 2012 and 2013 (Rykaczewska 2016). Harvests in aeroponics were done at weekly intervals starting on July 9–10. The last harvests were just after the first ground frost (October). The total number of harvests was 15 in 2012 and 14 in 2013. All minitubers of a size not smaller than 2 cm in length were collected at each harvest. The harvest of minitubers produced by traditional method, in boxes filled with universal soil substrate, was performed after full maturity of plants; depending on the years of study between August 10 and 12 for cv. Tajfun and between August 25 and 29 for cv. Ametyst. The mean size of minitubers grown in aeroponics was 9–10 g depending on cultivar and that of grown in the soil was 15–22 g (Rykaczewska 2016).

Storage management. Minitubers of cvs. Ametyst and Tajfun produced in aeroponics on successive dates were stored from July to October in a room with a temperature about 12°C and next they were transferred to a storage chamber under conditions optimal for potato seed (3°C). The minitubers produced in the soil were stored under the same conditions but from October. Four weeks before the scheduled date of planting, pre-sprouting of minitubers at a temperature of about 18°C took place.

Agronomic performance. The minitubers of both cultivars collected from aeroponics on the previous 14 dates and from the soil were hand-planted on 25 April in 2013 and 22 April in 2014 in an experimental field, on a poor clayey sand of good agricultural suitability. The field trials were set up in a randomized complete block design with four replicates. The size of the plots was 7.5 m^2, the number of plants per plot was 30 at 75 cm row spacing with plant separation in the same row of 33 cm.

As a natural fertilizer, wheat straw was used first and next white mustard (*Sinapis alba* L.), ploughed under after the first frost in autumn. Mineral fertilization was adjusted to the mineral content of the soil, and was applied in autumn in doses of 18 kg P/ha, 100 kg K/ha plus microelements. In the spring 100 kg N/ha was sown. Crop pests and diseases were controlled as normally done in the area. Weather conditions were monitored using a Campbell Weather Station (Campbell Scientific Inc., Logan, USA). The meteorological factors during the growing seasons are given in Table 1. Harvesting was performed on September 16–17 in both years, when the crop cycle was completed, using a potato elevator digger. 10 kg samples of tubers were taken manually from the middle of each plot and next the yield was weighed. Directly after harvest tuber size was determined. The number of tubers per hectare was calculated.

Data analysis. The results of the experiment were analysed with ANOVA using a model of statistics programme in Statistica 12. Means were separated with the Tukey's test at 5% *P*-value.

Table 1. Precipitation and air temperature on the experimental field in the growing seasons and Sielianinov hydrothermic coefficient

Meteorological factor	Year	Month					Sum/mean
		V	VI	VII	VIII	IX	
Sum of precipitation (mm)	2013	130.0	105.4	17.1	97.7	94.0	444.2[a]
	2014	41.3	69.8	23.5	79.2	11.9	225.7[b]
Mean daily air temperature (°C)	2013	15.7	17.2	18.7	18.2	10.3	16.0[a]
	2014	14.1	15.8	21.5	18.2	14.8	16.9[a]
Sielianinov coefficient*	2013	2.95	2.04	0.29	1.75	2.86	1.98[a]
	2014	0.92	1.47	0.35	1.40	0.26	0.88[b]

*Sielianinov hydrothermic coefficient: > 0.5 – drought; 0.5–1.0 – shortage; 1.1 – 2.0 – wet; > 2.0 – very wet

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Table 2. Yield, number of tubers with a transversal diameter more than 3 cm, size of individual tuber and percentage of two fractions in the yield depending on cultivar and year – mean values for all dates of minitubers harvest

Yield characteristic	2013		2014		Mean		2013	2014
	Ametyst	Tajfun	Ametyst	Tajfun	Ametyst	Tajfun		
Total yield (t/ha)	28.12[a]	26.81[a]	57.9[a]	47.71[b]	42.61[a]	37.26[b]	27.47[b]	52.40[a]
Number of tubers (thousnd/ha)	604.4[a]	415.3[b]	683.9[a]	458.0[b]	644.2[a]	437.7[b]	509.9[a]	571.0[a]
Size of individual tuber (g)	36[a]	53[b]	69[a]	98[b]	52[b]	76[a]	45[b]	84[a]
Fraction of tubers 3–6 cm (%)	92[a]	89[a]	65[a]	54[b]	78[a]	72[a]	90[a]	60[b]
Fraction of tubers > 6 cm (%)	1[a]	7[a]	32[b]	45[a]	17[b]	26[a]	4[b]	39[a]

RESULTS AND DISCUSSION

The impact of meteorological conditions on minituber productivity. The meteorological conditions during the growing seasons were significantly different (Table 1). In 2013, excessive rain in May, June, August and September had a restrictive impact on the productivity of minitubers of the tested cultivars produced by both methods (Tables 2 and 3). This is confirmed by high correlation coefficients between the mean values of Sielianinov hydrothermic coefficient during the growing season in the years of study and yield and the size of individual tubers (Table 4).

Productivity of minitubers grown in aeroponics. In the present study mean values for all dates of mnitubers harvested in aeroponics indicate that there was a significant differentiation between the tested cultivars in terms of yield, number of tubers with a transversal diameter more than 3 cm, mass of individual tuber and percentage of fractions of tubers over 6 cm (Table 2). Cv. Ametyst was characterized by higher yield and number of tubers but lower value of individual tuber size and fraction of the biggest tubers than cv. Tajfun. There were no significant differences in the fraction of tubers of 3–6 cm. The overall level of yield of the tested cultivars was typical for using the conventional seeds and conditions of the described experimental field. This is confirmed by the results obtained by Rykaczewska (2013) where the yield of 14 tested cultivars ranged from 25.00 to 66.22 t/ha depending on cultivar and year.

The number of tubers per hectare was similar to the number of tubers obtained from small minitubers in the studies of Radouani and Lauer (2015) and was from 603 125 per hectare in cv. Nicola to 409 375 per hectare in cv. Russet Burbank. According to these authors a higher number of tubers is usually beneficial to seed production, nevertheless it appears that each cultivar needs further investigation.

Table 3. Yield, number of tubers with a transversal diameter more than 3 cm and size of individual tuber depending on cultivar and year – mean values for minitubers grown in the soil

Yield characteristic	Cultivar		2013	2014
	Ametyst	Tajfun		
Total yield (t/ha)	44.86[a]	38.19[b]	29.57[b]	53.48[a]
Number of tubers (thousnd/ha)	835.1[a]	556.3[b]	684.3[a]	707.2[a]
Size of individual tuber (g)	45[b]	64[a]	41[b]	67[a]

Table 4. Correlation coefficient between the mean values of Sielianinov hydrothermic coefficient during the growing season in the years of study and yield, number of tubers with a transversal diameter more than 3 cm and size of individual tuber – from minitubers grown in aeroponics and in the soil (n = 8)

Tested factor	Sielianinov hydrothermic coefficient
Yield of MTs grown in aeroponics	–0.9613**
Number of tubers from MTs grown in aeroponics	–0.2815
Size of individual tubers from MTs grown in aeroponics	–0.8539**
Yield from MTs grown in the soil	–0.9599**
Number of tubers from MTs grown in the soil	–0.0819
Size of individual tuber from MTs grown in the soil	–0.7319**

**$P \leq 0.01$; MT – minituber

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In our study the yield and number of tubers was dependent on the physiological age of minitubers harvested on successive fourteen dates from July to October and on cultivar (Figure 1). The yield of cv. Ametyst was highly dependent on the harvest date of minitubers while in the yield of cv. Tajfun there were no significant differences. This is also indicated by the regression equations as shown in Figure 1. Such a varied reaction of cultivars is associated with different physiological vigour of mother tubers and the rate of their physiological ageing (Rykaczewska 2013). This was earlier demonstrated by van der Zaag and van Loon (1987) and Caldiz (2010). In the presented study the number of tubers of the tested cultivars was also significantly dependent on the minituber harvest date (Figure 1). However, regardless of the date of the minituber harvest, it was higher in cv. Ametyst than in cv. Tajfun. Minitubers from earlier harvest dates were physiologically older at the time of planting than those which came from the later harvests. In previous works it was widely shown that using physiologically older tubers for planting may result in a smaller number of daughter tubers (van der Zaag and van Loon 1987, Caldiz 2010). This is related to the smaller number of emerging eyes on physiologically older mother tubers (Rykaczewska 2013).

Comparison of productivity of minitubers grown in aeroponics and in the soil. Comparing the most important elements of minituber productivity of the tested cultivars, yield and number of tubers with transversal diameter more than 3 cm, it was found that the differences in yield between the two systems of production were not statistically significant (Figure 2). However, highly significant differences in the number of tubers with a diameter over than 3 cm were found. They are the result of different-size minitubers used for planting; smaller from aeroponics (9–10 g) and larger from the soil (15–22 g) (Rykaczewska 2016). The importance of the size of minitubers in their productivity was also pointed out by other authors (Ranalli et al. 1994, Struik 2007, Radouani and Lauer 2015). However, the larger number of minitubers produced in aeroponic than in soil, allows for better economic effect with the use of this innovative production system. This would require a precise calculation, similar to those done by Mateus-Rodrigues et al. (2013). It should

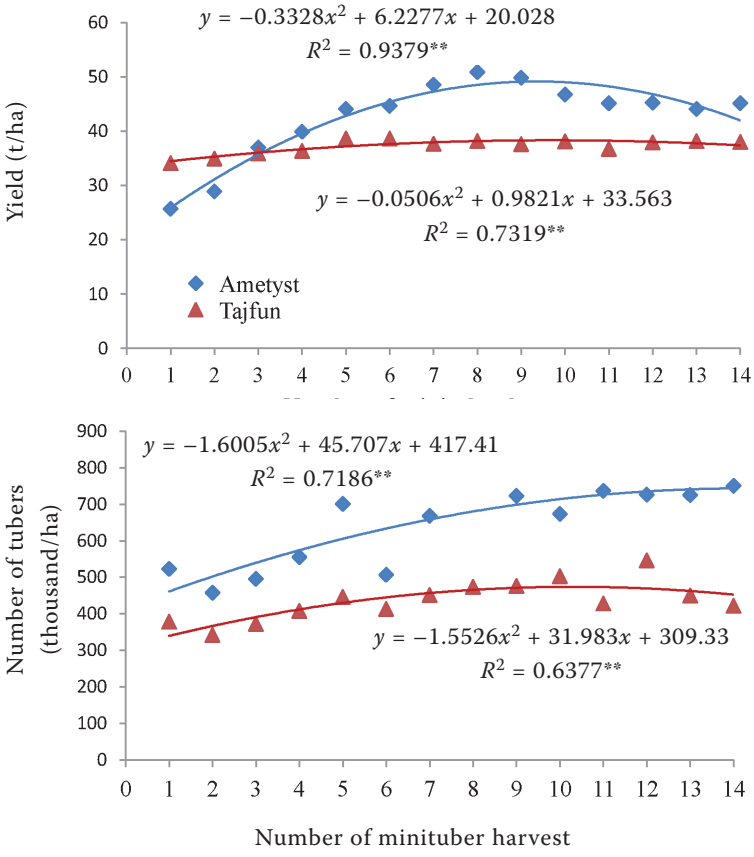

Figure 1. Yield and number of tubers with a transversal diameter more than 3 cm per hectare depending on number of minitubers harvest and cultivar – mean values for the years of study. $^{**}P \leq 0.01$; $^{*}P \leq 0.05$; number of minitubers' harvest corresponds to the date of the successive harvests from July to October at weekly intervals

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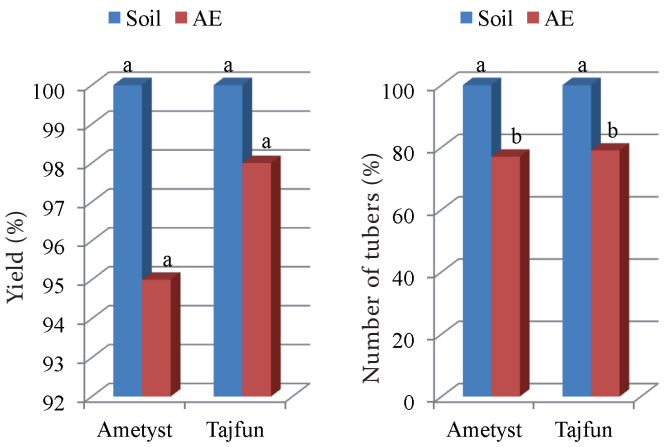

Figure 2. Comparison of the yield and number of tubers with transversal diameter more than 3 cm from hectare obtained by using minitubers grown in aeroponics and in the soil. a, b – mean values followed by the same letters are not significantly different at the 0.05 level according to the Tukey's test

be noted, however, that the size of the minitubers harvested from an aeroponic system may be different, higher or lower, depending on the production target.

In conclusion, results of the presented study show that the aeroponic system can be a suitable system of producing potato pre-basic seed under temperate conditions, and its optimization may be considered as a strategic investment with the aim of promoting a more efficient and sustainable production of high quality potato minitubers.

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